International Earth Science Colloquium on the Aegean Region
IESCA 2012

ABSTRACTS BOOK

October 1, 2012 – October 5, 2012
Dokuz Eylül University, Izmir, TURKEY

WELCOME

Dear colleagues,

It is a great honour for us to welcome you to the International Earth Sciences Colloquium on the Aegean Region, IESCA-2012.

The Aegean Region has been home to a variety of races and peoples over the centuries. With its matchless beauty, which came about via the operation of various geological processes through the ages, from ancient times this region has hosted population, cultural and commercial centres for a plethora of different civilizations; Pergamum, Smyrna, Sardis, Ephesus and Miletus are but a few examples. From the days of the ancient Aegean civilizations, people with various cultures and beliefs, hailing from the Mediterranean Region, from Anatolia, from Mesopotamia and beyond, have lived on this soil in peace.

Since the times of Thales and Anaximander, geological studies have been carried out in this region. Many scientists have engaged in research and mineral exploration, and all have contributed to the understanding of the geology and natural resources of the Aegean Region. And many earth scientists are still at work here, including institutes and individuals from around the globe, insofar as this region presents so many key geological problems and provides an exceptional laboratory in which we may come to further understand the ever-developing earth sciences.

The Aegean Region plays a key role in our understanding of geological problems of the eastern Mediterranean region and preserves important records of geological processes which have operated in a zone of convergence. Many examples of metamorphic, magmatic and sedimentary processes, and the related economic mineral deposits and energy resources of the region, have already been extensively studied by earth scientists from around the world. This geological wealth is a consequence of a regional tectonic setting in which several continental blocks were amalgamated via Tethyan subduction events, giving rise to the present configuration of the region.

The colloquium has been organized broadly along the lines of several regional geological topics, including tectonics, metamorphism, magmatism, sedimentation, geophysical research, mining and mineral deposits, energy resources and engineering geology. We believe that new advances in our knowledge of the geology of the Aegean Region will be discussed extensively and that the colloquium will encourage the collaboration of scientists from different countries in the international scientific endeavour. This international meeting has been designed as a forum to bring together geoscientists from around the world so that they might discuss the regional geology and processes at work in this extraordinary region—so active that it is one of the world's great natural geological laboratories. Conference participants and guests will also examine the geology and regional culture via an array of field trips.

In recent years, global climate changes have profoundly demonstrated the magnitude of the environmental threats to our world. One of the main reasons that 2008 was designated "Year of the Earth" by UNESCO was -through resources provided by the earth sciences- to focus on what might be done to create a cleaner, healthier, and more productive world. Accordingly, the maximum reduction of risks associated with natural events such as earthquakes, landslides, floods and erosion; the protection of subsurface and surface waters; the prioritization of new, clean energy sources; the most productive and effective utilization of underground resources; and, most importantly, the creation of a sustainable environment, are among the fundamental issues upon which earth scientists must train their attention.

The main goals of this colloquium are to provide 1) a platform for the communication of new ideas and 2) a setting for the possible obtainment of interdisciplinary solutions pertaining to the natural resources and geological problems of the Aegean Region by eminent scientists from all over the world. Hosting this distinguished group of scientists is a great privilege for me, and the calibre of these researchers makes me confident about the success of this meeting. I greatly appreciate and thank you all for your efforts and contributions. I extend my heartfelt thanks to all of the prominent earth scientists from many different countries who have given of their valuable time to contribute to the success of this gathering, who have given encouragement and practical and financial support, and who will share with us here their accumulated knowledge. Even though this meeting has become a tradition, it also provides a choice venue and important opportunity for our younger colleagues -who have newly begun (or will soon begin) scientific research- to become familiar with our profession and to gain knowledge and experience on a variety of subjects.

I sincerely believe that, beyond the goals of emphasizing the importance and quality of international-level earth science investigations being carried out in Turkey, of creating a setting for scientific discussion, and of providing a context for exchange of knowledge, the meeting will be productive and successful as it draws the attention of all segments of our populace, and also national and international organizations, to subjects which concern them; namely, subsurface mineral, water and energy resources, earthquakes and other natural disasters.

Once again, I wish to thank you profusely and wish you all fruitful and pleasant scientific sessions, workshops and field trips. I offer sincere affection and kind regards to each of you, thanking you - personally and in the name of the organizing and planning committees- for your significant contributions, with the desire that the colloquium will bear much fruit for the sake of our country and the earth sciences community.

Prof. Dr. Cahit HELVACI
On behalf of the Organizing Committee of IESCA-2012
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SCIENTIFIC SESSIONS

ISC – 1

MELT EVOLUTION OF OPHIOLITIC MAGMAS: CRUSTAL AND UPPER MANTLE PERPECTIVES

Conveners:
Yıldırım Dilek and Ercan Aldanmaz

Cr-PGE mineralization of the Turkish ophiolites: The state of the art

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Ophiolitic chromitites have become a potential target for the recovery of platinum-group elements (PGE) although so-far reported concentrations are usually sub-economic with prevalence of the low-priced IPGE (Os, Ir, Ru) compared to the high-priced PPGE (Rh, Pt, Pd). Turkey is one of the major chromite producing country, and most of the economically important Turkish chromitites are associated with the mantle section of supra-subduction zone ophiolites. In this contribution we present an overview of mineralogical and geochemical investigation of several Turkish ophiolitic podiform chromitites. Most of the chromites located in the deeper mantle are represented by the Cr-rich compositon whereas some of those located close to the MOHO or in crustal section of the ophiolite are found to be enriched in Al. About 400 PGE analyses are available for the investigated chromitites from the main chromite production areas of the Turkey. The total PGE (Os, Ir, Ru, Rh, Pt, Pd) concentrations range between 28 and 1305 ppb, with an average value of 265 ppb. The Cr-rich chromitites have slightly elevated total PGE contents, and the majority of the mantle-hosted ophiolitic chromitites, display enrichment in Os+Ir+Ru (IPGE) relatively to Rh+Pd+Pt (PPGE), with an overall negative slope on the C1-chondrite normalized PGE patterns. Small grains (<10 μm) of about 700 platinum group mineral (PGM) grains have been encountered in all the investigated chromitites. The most abundant PGM are Ru-Ir-Os sulfides, sulfarsenides and alloys. They occur in fresh and altered chromite crystals, along cracks and fissures of the chromite and, rarely, in the silicate matrix. The PGM form single phase crystals or are part of polyphasic grains composed of other PGM, base metals sulfides and silicates. However, recent investigations on SE Turkish chromitites have shown that Cr-rich podiform chromitities from few localities were characterized by extremely enriched total PGE (up to 13 ppm), showing extreme IPGE/PPGE fractionation ratio of up to 72. Consistently, these chromitites contain great number of PGM, reaching up to 100 microns in size and mostly characterized by Ru-rich laurite grains associated in most cases by NiS phases. Mineralogical and geochemical investigations on different Turkish chromitites show that both Cr-rich and Al-rich chromitites are represented by less priced IPGE over the more high-priced PPGE. Consistent with these geochemical data, the most common PGM are IPGE phases. Owing to the low PGE concentration and small size of the PGM, the investigated Turkish chromitites, although economically important for chromium recovery, represent only a future potential target for PGE exploration.

Keywords: Ophiolitic chromitites; Platinum group elements; Platinum group minerals; Mineralogy

Chromite geochemistry of Elekdağ Meta-ophiolite: Implications for deep magma processes, melt–rock reaction and/or melt-melt interaction in a suprasubduction-zone setting

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Chromium-spinel geochemistry provided valuable information for geotectonic emplacement of ophiolitic complexes and dominant mantle conditions during these tectonic processes. Main subject of this manuscript is to consider the mineral chemistry data of podiform chromitites of Elekdağ meta-ophiolites (n=31 and 160 point analysis) according to the magmatic processes in the mantle. Elekdağ metaophiolites are located at the Sakarya Zone of Central Pontides and are one of the most important metaophiolites of Turkey. Chromitite occurrences within the study area are mostly represented by small bodies of massive, nodular and disseminate-banded ores with chromite contents ranging from >75% to 25-40% (by vol.) in massive chromitites, and nodular/disseminate-banded types, respectively. Elekdağ chromitites can be divided into 2 types, such as High-Cr [% 5.1 – 18.2 Al_2O_3; % 0.1 – 0.3 TiO_2 Cr#: 0.65 – 0.89 ve Mg#: 0.39 – 0.73] and High-Al [% 23.7 – 34.9 Al_2O_3; % 0.08 – 0.3 TiO_2; Cr#: 0.39 – 0.55 ve Mg#: 0.61 – 0.95] chromitites according to core analysis of chromites. The Al_2O_3 content (%wt) and FeO/MgO ratio of parental melts determined from the mineral compositions are quite variable. The Al_2O_3 (%wt) contents and FeO/MgO ratio of High-Cr chromitites vary from 7.4 to 13.9 and 0.4 to 1.9, respectively. In contrast, The Al_2O_3 (%wt) contents (15.3-16.9) and FeO/MgO ratios (0.3-0.8) for High-Al chromitites are considerably different from high Cr chromitites. According to above data, it can be concluded that parental melt composition of High-Cr and high-Al chromitites are derived from boninitic and MORB-like source regions, respectively.
High-Mg tholeitic or boninitic type melts refer to in a supra-subduction zone (SSZ) setting. Boninitic composition of parental melt of High-Cr chromitites imply high partial melting degree in the mantle source. However, MORB-like composition of parental melts of High-Al chromitites may exhibit low degree of partial melting in the source region. The relation between Cr# and TiO_2 (wt%) indicate a melt – rock reaction for High-Cr chromitites, and melt-melt interaction and/or melt/rock reaction for High-Al chromitites. The co-existence of High-Cr and High-Al chromitites in the same peridotitic sequence is still debated. The similar TiO_2 contents of High-Cr and High-Al chromitites of Elekdağ metaophiolites indicate a same tectono-magmatic setting for both types of chromitites. But, as high-Cr chromitites were derived from deep-mantle conditions, High-Al chromitites were from shallow mantle conditions. Concisely, the similar TiO_2 values of both type of chromitites indicated that they are generated in fore-arc tectono-magmatic conditions.
As a result, the chromitites in Elekdağ meta-ophiolites consist mainly of deep mante derived high-Cr chromitites, and high-Al chromitites produced by evolved melts at shallower levels. It is also concluded that Elekdağ meta-ophiolites are generated in a supra-subduction zone (SSZ) settings.

Keywords: spinel geochemistry; meta-ophiolite; magmatic processes; parental melts

Dating the geological history of the northwestern North American plate: Re-Os isotopic analyses of sulfides from western Yukon ultramafic complexes

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The Western Yukon contains an assemblage of schists, basalts and ultramafic rocks. The basalts were recently dated (U-Pb zircon) as Lower Permian (282 Ma, Escayola et al, in prep). The ultramafic massifs are composed of dunite, harzburgite and cpx harzburgite, with replacive dunite layers and orthopyroxenite veins. Dunites host irregular veins of chromitite and disseminated Cr-spinel. The peridotites are refractory in terms of whole rock Al_2O_3 content (ca 1%), olivine Mg# (up to 0.91) and Spinel Cr# (~0.5), suggesting initial high degrees of partial melting. Microstructures show that they have reacted with intergranular melts prior to cooling in the lithosphere, leading to crystallization of olivine, cpx and spinel at the expense of opx. Coarse and intergranular cpx show re-fertilization by reaction with melts representing 8-9% melting in the garnet stability field. A two-stage partial melting/melt-rock reaction history is suggested. In situ Re-Os isotopic analyses on primary sulfides show peaks of T_{RD} model ages at 2.5-2.0 Ga, 1.2-1.0 Ga and 650-700 Ma. We propose that these ages record the main events of the western North American plate's history from an Archean origin, supercontinent breakup, accretion of Rodinia (~1.2-1.0 Ga) and the break-up of Rodinia to form the Panthalasa Ocean (Neoproterozoic). The main peak at ~700 Ma may represent the evolution from sub-continental mantle to a passive margin - ocean transition environment.

Keywords: Re-Os, Permian; passive margin ultramafics

Mineralogy and geochemistry of platinum group elements (PGE) in ophiolitic chromitites (Kahramanmaraş−Malatya−Gaziantep), Southeast Turkey: implications for primitive melts

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Ophiolitic chromitites of southeastern Turkey associated with depleted mantle peridotites (mainly harzburgite and dunite) are geochemically divided into two groups as high−Cr (Cr#>70) and high−Al (Cr#<70) in composition. Although, total contents of platinum group elements (PGE) in all chromitites are generally low (42–348 ppb, 135 ppb average), two samples of high Cr composition show a significant enrichment in PGE up to 1.2 and 2.8 ppm, respectively. These samples are characterized by richer total contents of PGE than ophiolitic chromitites of all over the world. The distribution of platinum group elements (PGE) display the high IPGE (Os+Ir+Ru)/PPGE (Rh+Pt+Pd) ratio (3−14) typical of ophiolitic chromitites.
Chromitites contain primary inclusions of platinum group minerals (PGM). Laurite is the most abundant PGM, especially in the PGE rich samples, accompanied by few irarsite, Os-Ir alloys and probably Ru oxides phases. These minerals are very small, generally less than 10 microns in size, and mostly occur in fresh chromite. Laurites occur as single phase or multi phases together with hydrous silicates such as amphibole and chlorite, are rich in Ru [Ru#; Ru/(Ru+Os) = 0.61–0.80]. Amphibole, clinopyroxene, orthopyroxene have been identified as primary silicate inclusions in chromites. These inclusions are bigger (10−70 μm) than PGM inclusions.
The chemical and calculated composition of the parental melts from the southeastern chromitites crystallized indicate that the high−Cr chromitites are crystallized out of boninitic melt in deeper mantle sequence and high−Al chromitites are thought to crystallized from the MORB type melt in shallow mantle sequence near the MOHO transition zone.

Key words: Platinum group element (PGE), platinum group mineral, Southeast Turkey, ophiolitic chromitites.

Geochemistry and Tectonic Significance of the Latest Cretaceous-early Cenozoic Syeno-dioritic Plutons, Lamprophyric Dykes, and Alkaline Volcanic Rocks in the Ankara Mélange, Turkey

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We report here on the age and geochemistry of alkaline intrusive rocks in the Ankara Mélange in North-central Turkey, and discuss their significance for the tectonic evolution of northern Anatolia. The Ankara Mélange occurs within the Izmir-Ankara-Erzincan Suture Zone (IAESZ) between the Sakarya Continent and the Anatolian Crystalline Complex, and represents a subduction-accretion system containing thrust sheets and megablocks of Mesozoic oceanic rocks with diverse geochemical affinites. Blocks of volcanic rocks display geochemical characteristics of N-MORB oceanic crust, E-MORB oceanic plateau and OIB seamount affinities The SSZ-type, 180 Ma-old Eldivan Ophiolite is thrust over the Ankara Mélange, providing important age constraints for the mélange.

Lamprophyric dykes, syeno-dioritic plutons, and alkaline volcanic rocks crosscut and cover the blocks of volcanic and volcano-sedimantary rocks, serpentinite, radiolarian chert and shale in the Ankara Mélange. These alkaline rocks collectively reveal an igneous age of 64.9±1.3 Ma. The lamprophyric dykes display tephrite, phonotephrite, picrobasalt, trachybasalt and trachyandesite compositions with alkaline characteristics. They have the high K_2O+Na_2O (5.36-9.88wt%) ratios with generally ultrapotasic compositions, variable SiO_2 (39.81-58.15wt%) contents, high Mg number (Mg# 38-62), Al_2O (11.2-17.47wt%), Ba (739-3229ppm), Rb (21-184ppm), Sr (679-1432ppm) and Pb (8.8-32.3ppm) values, reminiscent of shoshonitic rocks. Alkaline volcanic rocks are associated with flyschoidal rocks composed of carbonaceous and sandy limestone, pebblestone, sandstone and shale, and consist of basanite, foidite, trachybasalt, basaltic trachyandesite, and trachyandesite. These volcanic rocks are locally intercalated with volcaniclastic rocks of similar compositions, and are covered by an Upper Cretaceous reefal limestone. The shoshonitic volcanic rocks have the high K_2O+Na_2O (4.71-6,69wt%) and variable SiO_2 (42.69-51.33wt%) values, and high Al_2O (12.84-18.47wt%), Mg number (Mg# 48-71), high Ba (1051-1883ppm), Rb (29-129pm), Sr (743-780ppm) and Pb (3.9-13.4ppm) values. A syeno-diorite stock (~ 1km in diameter) has an intermediate composition with SiO_2 = 49.1-50.3wt%, and contains high K_2O+Na_2O (7.64-8.03wt%), Al_2O (18-19wt%), Ba (1520-1685ppm), Rb (130-148ppm), Sr (759-915ppm) and Pb (22-25ppm) values. It also displays a shoshonitic composition as its volcanic counterparts.

High Ba/Th (58-179), Rb/Nb (4-20), $^{87}Sr/^{86}Sr$ (0.704697-0.704892) ratios and low $^{143}Nd/^{144}Nd$ ratios (0.512674-0.512690) of the alkaline rock suites indicate that their magma source was derived from partial melting of a lithospheric mantle metasomatized by previous intra-oceanic subduction events. However, high $^{206}Pb/^{204}Pb$ (19.332-19.939), $^{207}Pb/^{204}Pb$ (15.655-15.691) and $^{208}Pb/^{204}Pb$ (39.192-39.612) ratios, high Ce (38-159ppm) and Sm (3.2-11.6ppm) contents also suggest strong crustal contamination prior to their emplacement and eruption. We interpret these alkaline rock units as the products of the latest stages of arc magmatism above the North-dipping Neotethyan subduction zone, prior to the collision of the Sakarya Continent with the Central Anatolian Crystalline Complex.

Keywords: IAESZ, Ankara Mélange, syeno-diorite, alkaline volcanics, lamprophyre, Turkey

The use of trace elements and Os isotopes in chromite deposits to understand the origin and evolution of old upper mantle fragments within young ophiolites

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In ophiolites, sizeable chromite deposits are usually found hosted in upper mantle peridotites. These deposits are characterized by wide ranges of compositional variations in terms of the geochemistry of the chromites and the associated platinum-group-minerals (between two end-members: high-Al and PGE-poor, high-Cr and PGE-rich). These variations are thought to reflect the difference in the nature of their parental melts, as they have been produced in different tectonic settings of lithosphere generation. It is thought that in mid-ocean ridge (MOR) spreading centers, dry melting of lherzolite or fertile harzburgite at relatively low degrees produces MORB-type melts that precipitate PGE-poor aluminous chromitite. In contrast, hydrous melting of variably depleted harzburgites at relatively greater degrees in supra-subduction zone (SSZ) mantle beneath different portions of island arcs produces a range of more siliceous, magnesium- and chromium-rich melts (e.g., IAT, Boninite, BABB) which tend to precipitate chromitites richer in Cr and PGEs. Using major element concentrations of chromites (Al_2O_3, FeO, MgO and TiO_2) one can estimate the composition of the melt in equilibrium with chromite, which allows a rough approach to estimate the composition of original parental melt that produced the chromitites. However, in many cases, this simple method can provide inconclusive or contradictory results. In contrast, the application of the novel techniques with laser ablation may permit a better definition of the geochemical fingerprint of the parental melt of chromitites by measuring a suite of minor and trace elements (Ga, Ni, Zn, Co, Mn, V, Sc), most of which are non-detectable in chromite by conventional electron-microprobe analysis. Some of these elements have been demonstrated to be very useful in determining the geochemical and thermodynamic parameters for the formation of mantle silicates, and could help in deciphering the origin of chromite deposits and their mantle host-rocks. In this work, we report and compare distributions of major, minor and trace elements in spinels of chromitites (high-Al and high-Cr) from different tectonic settings and well-known ophiolite complexes. We demonstrate the usefulness of trace elements as potential petrogenetic indicators of geodynamic setting for the ophiolite formation. This information is complemented with Re-Os isotope data obtained *in situ* on chromite-hosted platinum-group minerals (PGM). We show that, because of the sampling old domains preserved in the ophiolitic mantle, PGM found as inclusions in chromite deposits can display highly heterogeneous distribution of Os isotopes. Some of the chromite deposits formed during the Mesozoic or Cenozoic preserve records of melting events that took place during the Precambrian or even the Archean times. This implies the recycling of older pieces of sub-continental or oceanic mantle during the formation of young oceanic basins, or intra-oceanic plate subduction. Our results provide a new tool for better understanding of the origin and evolution of old upper mantle fragments in recently formed ophiolites.

Keywords: ophiolites; chromitites; Os-isotopes; in-situ trace elements

Ophiolitic peridotites from the Western Khoy ophiolitic complex, NW Iran; Petrological and geochemical characteristics and application for connecting the Baft-Khoy and Izmir-Ankara-Erzincan Sutures

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The western Khoy ophiolitic complex in NW Iran is consisted of serpentinitezed peridotites, matabasic rocks, marbles and limestone. Peridotites show different degrees of serpentinisation. The peridotites are mainly clinopyroxene-bearing harzburgites with a mantle origin. Calculated partial melting rate for the peridotites is 5-18%, indicating a depleted type. Mineral chemistry and trace element contents of clinopyroxenes, indicate that the rocks are affected by refertilization process by fluids derived from the subducting slab. Whole rock and mineral chemistry of the studied peridotites indicate that they are formed in an oceanic environment, in a supra subduction zone and at fore-arc tectonic setting. Considering the similarities in age and tectonic setting, it is possible to connect the Baft-Khoy suture in Iran with a SE-NW trend with Izmir-Ankara-Erzincan suture from east to the west of Turkey. Comparison of characteristics of ophiolites from Nain, Baft and Khoy with those along the Izmir-Ankara-Erzincan suture, especially Refahiye ophiolite supports the continuation of the long Neotethys suture from west Turkey to SE Iran.

Keywords: Khoy Ophiolite; refertilization, SSZ, Neotethys suture

Origin of the Quaternary alkaline volcanic rocks in Ahar, NW Iran

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Quaternary alkaline volcanic rocks are widely developed in NW of Ahar, NW Iran. The volcanic sequences in the Ahar area are correlatable with the eastern part of Turkey. The volcanic rocks in this area are characterized by the LILE and LREE enrichments and negative HFSE anomalies. The Sr and Nd isotopic ratios vary from 0.704463 to 0.704921and from 0.512649 to 0.512774, respectively. CaO/Al_2O_3 ratios versus MgO, La/Sm ratios versus Rb and Ba and Zr versus Th suggest that fractional crystallization was a major process during the evolution of magmas. AFC modeling and isotopic data as well as microscopic evidence, clearly indicate that crustal contamination accompanied by the fractional crystallization played an important role in petrogenesis of the trachyandesites. Also, geochemical and isotopic compositions indicate that magma mixing was not essential process in the evolution of Ahar magmas. Alkali basalts with high $^{143}Nd/^{144}Nd$ ratio, low 87Sr/86Sr ratio and high MgO, Ni and Cr contents indicate that they crystallized from relatively primitive magmas. REE modelling and Trace element ratios indicate that the alkali baslats were derived by small degrees (~2-5%) of partial melting from the spinel lherzolite. We suggest that late Miocene to Quaternary post-collisional volcanism occurred by slab breakoff and rollback processes after Neo-Tethys subduction. Slab breakoff after subduction lock-up caused mantle upwelling that provided the necessary heat and melt to produce the first phases of post-collisional magmatism in these young orogenic belts.

Keywords: alkaline volcanism, partial melting, AFC modeling, slab breakoff, Quaternary

Mineral chemistry of ultramafic rocks from the Piranshahr ophiolites, NW Iran

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The late-Cretaceous Piranshahr ophiolithic melange sequence is occurred in northern part of Zagros suture zone, which extends to Rayat ophiolites in the Iraqi part of Zagros. They consist of tectonized harzburgites, gabbros, dibasic dikes, rare pillowed basalts, radiolarites and pelagic limestones. Mantle peridotites are the volumetrically most abundant variety in this sequence. They are including prevailing harzburgites and minor lherzolites. The primary minerals of tectonite have been altered to varying degrees of secondary minerals assemblage and converted to sheared serpentinite. Dunites with cumulithic texture, wherlite and troctolite are the cumulus phases. Cr-spinel is a ubiquitous accessory mineral in all peridotites. The Cr number Cr# = 100*Cr/(Cr + Al) of the Cr-spinels in harzburgites varies from 33-50. The Fo content of olivine from harzburgites varies from 84 to 90. The mineral chemistry indicates that harzburgites experienced previously partial melting and indicate similarity with residual peridotite from the fast spreading mid-ocean ridges.

Keywords: Ophiolite, Piranshahr, spinel, Cr Number, harzburgite

ISC – 2

ISC02-ROLE OF OPHIOLITES AND RELATED UNITS IN TETHYAN OROGENIC ASSEMBLY

Conveners:
Osman Parlak, Alastair Robertson and Aral İ. Okay

Ancient mantle domains stranded in ocean lithosphere add complexity to understanding Tethyan ophiolites

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Ophiolites are important components of the Tethyan orogen and an understanding of their origin and evolution is critical to understanding the nature and timing of collision processes. Recent studies highlight the contribution of intra-oceanic subuction zones, as well as mid-ocean ridges, to ophiolite formation. However, a third possibility should be considered that adds new complexity.

Recent high-resolution tomographic models and the 2007 world magnetic-anomaly map show that significant high-velocity, magnetically distinct domains occur in the Atlantic Ocean basin. They are not confined to the basin margins as predicted for normal oceanic-mantle extensional cooling, but are scattered randomly through the Basin, some significantly distant from the continental margins of South America and Africa. These are interpreted as remnant fragments of ancient continental lithosphere, based on comparison of their geophysical properties with deep-lithosphere domains beneath cratonic regions, mapped from mantle xenoliths brought to the surface in kimberlitic magmas (O'Reilly et al., Lithos 2010). Basaltic magmas erupted near such domains carry the geochemical signatures of interaction with refertilised cratonic mantle.

These high-velocity volumes in the present-day Atlantic Basin are considered to represent remnants of depleted (buoyant) ancient continental lithosphere, fragmented and stranded during the rifting process at the opening of the ocean basin. The high-velocity domains extending out from the coastlines are not uniformly distributed along the basin edge. The new global magnetic-anomaly map shows that these regions have a complex magnetic signature that is consistent with extended continental crust, and distinct from that of oceanic lithosphere. The seismic data suggest that this thinned continental crust is underlain by Archean to Proterozoic subcontinental lithospheric mantle (SCLM) that has been mechanically disrupted and thinned during the formation of the ocean basins, accompanied by listric detachment of continental crust from the underlying continental SCLM. Re-Os isotopic data on sulfides in mantle xenoliths from Cape Verde support this concept. Their depleted mantle model ages, extending back to 2.7 – 3.5 Ga (Coltorti et al., Lithos 2010) suggest that these xenoliths are disrupted fragments of the West African cratonic SCLM. Closure of the Atlantic would result in these ancient mantle domains being obducted due to their buoyancy.

The Atlantic Basin is not an isolated example of stranded ancient high-velocity mantle blobs. Recent integrated geochemical, geochronological and geophysical studies on mantle xenoliths from NW Svalbard (Norwegian Arctic) indicate that eastward rifting of Svalbard from Greenland at 50 Ma resulted in detachment of the lower lithosphere of the rifted segment, with the stranded mantle relics now lying beneath the Yermak Plateau and the Gakkel Ridge, providing buoyancy for the Plateau and the Dupal-like geochemistry of the ridge basalts (Griffin et al., Lithos 2012).

Closure of the Tethyan Ocean would be likely to capture and obduct analogous ancient lithospheric mantle relics to form ophiolitic terrains. Careful geochemical and geochronology (especially Re-Os data for sulfides in the ultramafic rocks) could reconstruct a long tectonic history and enrich our understanding of the lithosphere beneath the Tethys ocean.

Keywords: ancient mantle lithosphere; Re-Os ages of ophiolite ultramafics; listric rift faults; seismic tomography; oceanic lithosphere

Demir Kapija (Macedonia-FYROM) ophiolite: a snapshot of subduction initiation within a back-arc

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Demir Kapija ophiolitic complex consists of a mafic volcanic sequence (pillow lava rocks, sheeted dyke diabases and gabbros) that was intruded by island arc rocks with and without adakitic affinity. Minor harzburgite occurrences are present as well. The mafic volcanic sequence of the ophiolite complex formed in a short-lived intra-oceanic back-arc setting in the Mid-Jurassic by slab roll-back of the Western Vardar Ocean (?). The mafic sequence is characterized by slightly increased LILE/HFSE, flat REE patterns, and radiogenic $^{143}Nd/^{144}Nd$ (up to 0.51272) and high TiO_2 contents, which reflects Pl+Ol+Cpx fractionation. The fractionation pattern between TiO_2 and MgO indicates that Ti saturation was reached and Ti-magnetite fractionated.
The rocks with and without adakitic affinity are spatially and temporally closely related. The rocks with adakitic affinity show most of the features of typical adakites, i.e., low HREE, elevated Sr/Y, high LILE, and LREE. The trace element composition of clinopyroxene is typical for adakite. The very high Th/La, Th/Yb and Ba/Yb ratios and the reduced $^{143}Nd/^{144}Nd$ values (around 0.51245) of the rocks with adakitic affinity reflect contributions of sedimentary material to their mantle source. The rocks without adakitic affinity show a broad range of SiO_2 content (51-75%) and more radiogenic Nd isotopic compositions than the rocks with adakitic affinity. Composition of their clinopyroxene resembles one from common arc magmas.
The arc intrusions with and without adakitic affinity are related to the switch from an extensional to a compressional regime. Our expanded dataset together with age data suggest unusually high amount of melts derived from the subducting sediments to play a role in the origin of arc rocks, making Demir Kapija ophiolite a unique Tethyan ophiolitic assemblage. We offer a new model for the formation and the closure of the Demir Kapija basin, connecting ophiolite origin with a back-arc ridge collapse and subduction initiation within a relatively narrow continent-surrounded oceanic basin. It is this special geotectonic environment and the subduction initiation that allowed prograde melting of garnet amphibolite from an exceptionally young slab.

Key words: ophiolite, back-arc MORB, intra-oceanic subduction, adakite-like rock, ridge collapse.

Intrusive products of H_2O and CO_2 rich alkaline magma: The Karakoç Magmatic Association and its significance in Tethyan Realm, Turkey

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The Karakoç Magmatic Association (KMA) within the Central Anatolian Crystalline Complex (CACC) consists of ultramafic cumulates, layered gabbros and diorite. The KMA intruded the carbonate dominated upper part of the CACC as a network and includes host rock xenoliths.
The KMA is characterized by abundance of Ca-rich phases (green diopside (Mg#=57-93), pargasite (Mg#=41-86), plagioclase (An=91-95), scapolite (Me=42-92), calcite) and Ca-free minerals (phlogopite (Mg#=71-76), alkali-feldspar). The accessories are apatite, sphene, rutile, zircon, and Fe-oxides. Scapolite and calcite are in textural equilibrium with surrounding silicates, inferring magmatic origin. The KMA, with low SiO_2 and high CaO, Na_2O, K_2O, H_2O, CO_2 contents, has high-K alkaline nature. The rocks display positive Th, U, K, Pb, P and negative Nb, Ta, Ti, Zr anomalies on the primitive mantle normalized spider diagrams. The rocks enriched in REE (∑REE=179-673) show sloped pattern from LREE to HREE. The KMA is characterized by low $\varepsilon Nd_{(T)}$ values [(-2.2) – (-6.2)] and moderate to high initial $^{87}Sr/^{86}Sr$ isotope ratios (0.707262 – 0.707864).
Geochemically, the KMA is strongly comparable with the Late Cretaceous monzonitic I- and A-type granitoids, and also shows similarities to the Late Cretaceous to Lower Tertiary alkaline and ultrapotassic volcanic rocks within the CACC. The KMA is assumed to be product of a hydrous mafic magma generated in a post-collisional extensional setting during the Late Cretaceous. Release of CO_2 in an extensional setting is likely to cause extensive assimilation of crustal carbonate in liquid state and increase in alkalinity and desilicification of the host magma.

Keywords: Karakoç; hydrous alkaline magma; carbonate assimilation

The Kermanshah ophiolite: a SSZ type ophiolite from Outer Zagros Iranian Ophiolites

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Many studies dealing with the tectonic history of SW Eurasia deal with the geological evolution of the Neo-Tethyan Ocean and with discrete continental blocks of the region. Late Cretaceous ophiolites in the Mediterranean eastwards through Iran, Oman and into Pakistan preserve fossil slices of Neo-Tethyan lithosphere. The Outer Zagros ophiolite belt, of central interest to this study, lies along the NE flank of the Zagros fold-thrust belt and preserves a remarkable example of Late Cretaceous subduction initiation on the north side of Neo-Tethys. Zagros ophiolites can be subdivided into "inner belt" and "outer belt" ophiolites respectively for those south of the Main Zagros Thrust Fault (MZT) and along the SW periphery of the Central Iranian block. The Kermanshah ophiolite in westernmost Iran is a part of the Outer Zagros Iranian Ophiolites consists of mantle harzburgite with pegmatite gabbros pockets, pillow lavas, sheeted dike complex (SDC) and late Cretaceous overlying pelagic sediments.
Kermanshah peridotites have high Cr# spinel compositions that mostly plot in the fore-arc field. Al_2O_3 vs. TiO_2 and Cr_2O_3 compositions of basalt clinopyroxenes mostly show affinities to both boninite and island-arc tholeiites, less commonly MORB.
The ophiolitic lavas have nearly flat to LREE-enriched patterns similar to IAT and calc-alkaline rocks. Extended trace element (spider) diagrams show typical supra-subduction geochemical signatures: enrichments in large ion lithophile and fluid mobile incompatible trace elements and depletions in high field strength elements. Basaltic lavas and early mafic dikes (in SDC) have $\varepsilon Nd_{(100\ Ma)}$ ranging from 4.6 to 8.6 as expected from mantle-derived melts, while andesites and felsic dikes havee negative values of $\varepsilon Nd_{(100\ Ma)}$; -3.6—5.1 with relatively higher $^{87}Sr/^{86}Sr$, indicating involvement of older continental crust.
Nearly all of the Zagros Iranian ophiolite lavas, including the Kermanshah lavas, fall into both island-arc tholeiitic and boninite fields on a Ti-V diagram, similar to depleted Lasail lavas (V_2 unit) of Oman. In summary, all rock units of Inner and Outer Zagros ophiolitic belts, from harzburgitic mantle to lavas, are characterized by strong supra-subduction zone compositional features. The similarity of ages for igneous rocks (U-Pb dating of 100-101 Ma) at nearby Dehshir and Nain ophiolites and overlying sediments and of geochemical compositions for both inner and outer belt Zagros ophiolites, along with similarity to other Late Cretaceous Ophiolite Belt of SW Asia (in Cyprus, Syria, Turkey and Oman) and position between the Urumieh-Dokhtar magmatic arc and Zagros accretionary prism suggest that the entire ophiolite belt formed as a ~3000 km long tract of fore-arc oceanic lithosphere fringing southern Eurasia, during a ~100-90 Ma subduction initiation event, which established the subduction system that continues to operate to this day.

Keywords: Iranian Zagros Ophiolite, Late Cretaceous, Fore-arc Oceanic Lithosphere, Subduction Initiation.

Diversity of ophiolites from the Southeast Anatolia: implications for the late Cretaceous tectonics of the Southern Neotethys

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The ophiolites of southeastern Turkey occur in two belts, namely the Peri-Arabic belt and the Southeast Anatolian belt. The Peri-Arabic belt ophiolites including the Kızıldağ and Koçali were emplaced directly onto the Arabian platform to the south of the Bitlis-Pütürge metamorphic massif. The ophiolites of this belt are genetically linked with the Troodos ophiolite and the Baer-Bassit ophiolite. In contrast, to the north of Bitlis-Pütürge metamorphic massif the SE Anatolian ophiolites, including the Göksun, Doğanşehir, İspendere, Kömürhan and Guleman ophiolites were tectonically emplaced beneath the Tauride platform and cut by I-type calc-alkaline volcanic arc granitoid rocks mainly during the Late Cretaceous. The ophiolites in two belts exhibit a complete ophiolite pseudostratigraphy and are geochemically of supra-subduction zone (SSZ) type.
A detailed comparison of the ophiolites of the two belts suggests that there are number of differences between the Southeast Anatolian and Peri-Arabic belt ophiolites based on the petrology, geochronology and related units. The Southeast Anatolian ophiolites (a) are in general more magmatically evolved, from basic to silicic rocks, (b) pelagic carbonates are commonly interbedded with the lavas, (c) most of the ophiolites and the Malatya-Keban platforms were intruded by Late Cretaceous granitoid rocks, (d) the ophiolites are tectonically overlain by the Tauride platform and in turn tectonically overlie the Middle Eocene Maden Group, suggesting late Cretaceous and post-Middle Eocene tectonic emplacement, and (e) available radiometric dating of plagiogranites from the Göksun, İspendere and Kömürhan ophiolites has yielded ages from 84 to 88 Ma. In contrast, the peri-Arabic belt ophiolites are (a) represented by basic to highly depleted boninite-type plutonics and extrusives, suggesting a forearc setting, (b) the volcanics are locally interbedded with or overlain by metalliferous oxide sediments, (c) these ophiolites were emplaced southwards onto the Arabian continental margin during Campanian-Maastrichtian time, (d) granite intrusion is absent, (e) Eocene contractional tectonics does not affect the Arabian platform, (f) the age of the Hatay and the Trodoos ophiolites is ~92 Ma. In addition, the the Bitlis and Pütürge metamorphic units of southern Turkey were affected by HP/LT and LP/LT metamorphism both during the latest Cretaceous. This suggests that rifted continental blocks from the Arabian platform subducted and then exhumed at ~74 Ma during closure of the southern Neotethys.
All the evidence suggest the existence of two separate SSZ-spreading centres in the southern Neotethys, one to the north and one to the south of the Bitlis-Pütürge massif.

Keywords: ophiolite; peri-Arabic belt; southeast Anatolian belt; SSZ-spreading; island arc tholeiites; boninites

Geochemistry and Paleotectonic Setting of the Southern Sanandaj-Sirjan Zone, SE Iran

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The volcanic-sedimentary sequence at the West of Sabzevaran occupies an important area for testing the paleotectonic setting of the southern Sanandaj-Sirjan zone in SE part of the Zagros orogenic belt (SE Iran). Stratigraphically, the Early-Middle Mesozoic volcanic-sedimentary sequence regionally overlies Paleozoic metamorphic basement rocks and in turns overlain by flysch type sedimentary rocks and Upper Jurassic to lower Cretaceous Calpionella bearing limestone. This complex records magmatic evolution of an early period of bimodal mafic and felsic (dominantly tholeiitic) volcanism with geochemical signatures indicating formation in an incipient ensialic back-arc setting.

The REE profiles of the tholeiitic basalts are MORB-like with only a slight enrichment of the LREE, a feature typical of basalts generated during the early stages of intra-arc rifting and/or back arc basin. The basalt REE profiles suggest that residual garnet was not involved in their genesis, indicating derivation from a shallow mantle source. Characteristic moderate Y values are consistent with derivation through approximately 15-25% partial melting of a spinel lherzolite source, followed by crystal fractionation, as is indicated by the variable trace elements (e.g., Ni, Cr) and the Mg numbers.

Elevated Th/Ta, La/Yb, and Th/Yb elemental ratios result from crustal assimilation and/or a subducted slab component in their mantle source. Although the latter process appears to be of only minor significance for the most of basaltic volcanics, alternatively Zr/Y ratios of the basalts may suggest emplacement on thinner continental crust.

Keywords: Volcanism; Paleotectonic; Basalt; Sabzevaran; Iran

ISC - 03

POST-COLLISIONAL CENOZOIC EXTENSIONAL TECTONICS IN THE AEGEAN REGION

Conveners:
İbrahim Çemen, Cahit Helvacı, Yalçın Ersoy,
Özgür Karaoğlu and Zeynep Öner

IN MEMORY OF ORHAN KAYA

Post-Collisional Large Scale Extensional Tectonics: A Review

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It is commonly observed in the geologic record that a continent-continent collision is followed by an extensional tectonics. However, there are still many fundamental questions regarding the nature of post-collisional extensional processes. The Aegean region of the Eastern Europe and Asia Minor and the Basin and Range region of western North America are two well-developed examples of post-collisional extensional tectonics.
Western North America experienced arc-continent collisions during the middle to Late Jurassic Nevadan Orogeny. When these arcs were accreted to the continent, the subduction stepped westward and produced many of the accreated terrains. The Sierra Nevada batholith was produced by a continental arc system, and a wide fold-thrust belt developed in the continent behind the arc during the Late Cretaceous Sevier Orogeny. The Basin and Range extension was initiated in an Eocene back-arc setting in the Northwest US and spread southward. It was probably triggered by slab collapse following the low-angle Laramide subduction. Continental extension in the southern Basin and Range began in Early to Mid-Miocene and propagated northwest. This caused the westward movement of the Sierra Nevada batholiths away from the Colorado Plateau. The propagation evolved in response to slab rollback and a northwestward migrating slab window created by the movement along the San Andreas fault zone. Brittle extension in the southern Basin and Range initiated ~15 Ma ago, apparently because the North American Plate cooled sufficiently enough to deform brittly with normal faulting which also coincides with volcanic activity changing from calc-alkaline to basaltic.
Since the 1970s, geological research in the Basin and Range contributed significantly to our understanding of the processes of large-scale continental extensional such as recognition of lowangle normal faults; mapping of the metamorphic core complexes and detachment surfaces structurally separating highly deformed metamorphic rocks from the brittly deformed sedimentary rocks. These recognitions led to development of large-scale displacements hypotheses in response to extreme crustal thinning and extension. Examination of Cenozoic sedimentary rocks and radiometric age determinations of volcanic rocks provided data supporting the importance of detachment surfaces during the initiation and consequent development of extensional basins. Recently, thermochronology has been used to determine the slip-rates along the detachment surfaces.
The Aegean region is a part of the Alpine-Himalayan belt and has experienced a series of continental collisions from the Late Cretaceous to the Eocene that led to the formation of the Izmir-Ankara-Erzincan and Tauride suture zones. In recent years, it has been widely accepted that the post-collisional extension of the Aegean Region was accomplished as continuous extension since its initiation in Late Oligocene due to orogenic collapse. The cause, rate and processes of the extension however changed at least twice since the Late Oligocene. Continued extension produced a secondary breakaway in the Early Miocene along the Alaşehir Detachment surface. The original dip angle of the Alaşehir Detachment surface is controversial. The detachment surfaces may have formed with a steep dip in the Early Miocene but rotated to its present low angle as the extension continued. The third stage of extension in Western Anatolia and probably in the whole Aegean region is started in Late Miocene about 5 Ma ago and influenced by the formation of the North Anatolian fault zone which caused lateral extrusion of the Turkish Plate westward.

Keywords: Post-collisional extensional tectonics; detachment surfaces, Basin and Range, Aegean region, Western Turkey

Tectonic change from compression to extension at ±30 Ma in the Thraki basin (Greece-Turkey)

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The stratigraphy of the Thraki basin comprises several formations dated from middle Eocene to Pliocene. A basic change can be observed between the lower part of the sedimentary sequences, which is intensively deformed with folding, thrusting and strike-slip faulting and the upper part where deformation is very weak with only some normal faulting. Sampling from several sections of the basin has enabled us to determine the transition from compression to extension at ±30 Ma, applying calcareous nannofossil biostratigraphy. Characteristic examples can be referred from the Mezardere Fm in eastern Thraki near Tekirdag (definition of Oligocene nannoplankton bioznone NP24) and in Pythion south of Orestias in western Thraki (definition of Oligocene nannoplankton biozone NP23). A significant change of facies is also evident at the basal horizon of the upper molassic type sequences with characteristic cross-bedded sands and lignite intercalations. The overall contemporaneous changes in the tectonic and paleogeographic regime indicate a change of mechanism in the entire Thraki basin and not local tectonic conditions.

Keywords: compression; extension; Thraki basin; nannofossils; Oligocene

Late Eocene – Late Miocene geodynamic evolution of the central Hellenides: from compression to extension

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The deposition of flysch in the Parnassos - Ghiona unit (PGU), Central Greece, ended in the late Eocene when ongoing compressive deformation, including thrusting and folding, led to the tectonic emplacement of the unit over more external ones (e.g. Vardoussia, Penteoria and Pindos units). From early Oligocene to middle Miocene (Langhian), the sedimentation of an exotic coarse-grained material produced an extensive and diachronous unconformity, which covered the previously tectonised areas. The thickness of these molassic-type clastics varies within several hundred meters and includes compressive structures, such as folds, reverse and strike-slip faults. From Langhian to ?Tortonian, low-angle to moderate extensional faults affected the molassic polymictic sequences, controlled the sedimentation patterns and led to the unconformable deposition of late Miocene monomictic conglomerates. In conclusion, in the central Hellenides we can identify four (4) main deformational events from Late Eocene to present: (i) two compressional episodes, with structures of NW-SE to N-S direction, that affect the PGU and the foreland basin sediments on top of it, the first one post-dating the flysch and the second post-dating the early molassic sediments and (ii) two extensional; one during Langhian – Serravallian – (?Tortonian) with NW-SE to N-S normal faults, affecting the last molassic sediments and a second one during late Pliocene – Quaternary with E-W normal faults, which controls the present day Corinth rift.

Keywords: Corinth; molasse; compression; extension; foreland basin; Parnassos – Ghiona

Petrology of the Miocene volcanism at around the Karaburun Peninsula and Çubukludağ graben (Western Anatolia, Turkey): Geochemical and radiochronological data for its regional implications

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The Karaburun peninsula (Karaburun volcanics; KV) and Çubukludağ graben (Cumaovası volcanics; CV) are the key regions to understanding volcanic evolution of the Miocene magmatism of the western Anatolia. The alkaline basalt lavas (the Ovacık basalt; 20 Ma) are the earliest products of Neogene volcanism in the region. This is followed by widespread calc-alkaline (CA) basaltic andesite, andesite, dacite and latites in the Karaburun peninsula (20-16 Ma). These intermediate volcanic products are accompanied by the large volume felsic volcanics (17 Ma) in the Çubukludağ graben. The Urla trachyte and trachydacites (13 Ma) is the final product of volcanism in the Karaburun peninsula.

The Cumaovası volcanics consist of dacitic and high-silica rhyolitic lavas, which are calc alkaline, peralumious and enriched in LILE. Extremely low Sr, Ba contents, strong Eu depletions and very low La_N/Yb_N ratios are typical for the rhyolites. The Karaburun volcanics with the exception of the minor alkaline basaltic and trachytic lavas are mainly calc alkaline and metaluminous intermediate lavas. $^{87}Sr/^{86}Sr$ ratios of the KV and dacitic samples of CV are close to each other and range from 0.708 to 0.709; while Sr isotopic composition of the rhyolites are absolutely high and variable (0.724-0.786). $^{143}Nd/^{144}Nd$ ratios for CV and KV, except for the alkaline samples, are similar for both sequences vary from 0.51230 to 0.51242. Nd and Sr isotopic ratios for the Urla trachyte ($^{143}Nd/^{144}Nd$: 0. 51252-0. 51253, $^{87}Sr/^{86}Sr$: 0.707-0.724) and Ovacık basalt ($^{143}Nd/^{144}Nd$: 0.51257 and 87Sr/86Sr: 0.706) are distictly different from the other volcanic members

All the geochemical, isotopic and radiochronologic data indicate that the KV and CV were formed in similar tectonic setting, but evolved by different petrological processes in different magma chambers. Our data reveal that extension related mafic inputs caused crustal melting and formed felsic melts that rapidly ascended into the upper crust.

Key Words: Western Anatolia; Neogene; Mafic and silicic volcanism; Geochemistry; Isotope; Radiochronology

Çamyayla pluton; A caldera type intrusion in Çan region, NW Anatolia

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An extensive magmatic activity developed in NW Anatolia during the Eocene-Miocene period. During this activity some granitic plutons formed and reached shallow levels in the continental crust, and above which were developed felsic-andesitic volcanic associations. The Camyayla pluton of the Can region is one of the representatives of this activity. The pluton is temporarily and spatially closely associated with the Dededağ volcanic suit, and is dated to be 28 my old. Their close genetical relations are revealed by the lateral transitions of some members as well as intricately developed cross cutting relationships. With all the field relationships the pluton and its volcanic associates collectively represent a caldera collapse environment. The pluton is mainly granodioritic and dioritic composition, and when emplaced into the regionally metamorphic country rocks were generated a thin metamorhic aureole reaching to the Actinolite hornfels facies along the immediate contact. The major and trace elements of this plutonic-volcanic association display calcalkaline characteristics and affinity to subduction zone magmatic associations. Such subduction related nature may be regarded as the earlier product of the ongoing subduction along the Hellenic trench of the Eastern Meditterranean oceanic lithosphere.
In this presentation the geological and petrological data derived from these rocks will be outlined and then an attempt will be made to their possible mechanism of generation.

Key Words: Northwest Anatolia, Çamyayla Pluton, Caldera, Petrology.

Post-collisional Tertiary extensional tectonics in Central Anatolia

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Previous studies suggested compressional tectonics in Central Anatolia. Recent field work based on kinematic data collected from the basement and Tertiary cover in the region reveals that the basic tectonic regime is extensional, since possibly the Late Cretaceous time. We have detected several major detachment fault zones in basement and cover rocks that are, from north to south, the Sorgun, Karanlıkdere, Savcılı-Himmetdede and Tuzgölü fault zones. The footwall of the Sorgun fault zone comprises the Upper Cretaceous ophiolitic and sedimentary rocks, with Eocene sedimentary units in the hanging-wall. The Karanlıkdere fault zone has its footwall consisting of Upper Cretaceous-Paleocene granitoids with a hanging-wall composed of the same plutonic unit with its Tertiary cover. The footwall of the Savcılı-Kırşehir-Himmetdede fault zone is made up of metamorphic and granitic rocks with a hanging-wall comprising again these crystalline units with their Tertiary cover. The southernmost detachment fault zone in our study area is the Tuzgölü fault zone, with a footwall composed of metamorphic, granitic and Mesozoic-Tertiary rocks, whereas the hanging-wall comprises Tertiary and Recent sediments of the Tuzgölü Basin. Between these fault zones, we have observed contractional structures, namely from north to south, the Sorgun, Mahmutlu, Savcılı-Mucur-Himmetdede and Özkonak-Avanos Zones. We interpret these narrow fold-and-thrust zones as gravity-driven structures associated to regional thin-skin extensional tectonics and not as contractional structures of regional crustal shortening as previously suggested.

Keywords: thin-skin tectonics; crustal stretching; exhumation; detachment faulting; Kırşehir Massif

Post-Miocene extension in Central Anatolia; It's linkage to Aegean extension

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Anatolian Plate -where Central Anatolia situated on- escapes westward onto African plate along Eastern Mediterrenean to Cyprus subduction zones, sliding by North and East Anatolian faults. Central Anatolia is bounded by North Anatolian Fault from north, Taurides from south and it is fragmented by strike slip faults evolving under N-S compression in east and by Aegean horst and grabens evolving under N-S extension in west.
In deformation analysis, the fault slip data collected from unconformity bounded faults were analyzed by using of Angelier Direct Inversion method. The relationship between principle stress ($\sigma 1$) and minimum stress ($\sigma 3$) orientations and ratios are analyzed and interpreted.
Miocene sequences were folded-thrusted-strike slip faulted under almost N-S compression during post-uppermost Late Miocene to pre-Pliocene period. This period was followed by NW-SE to almost N-S orientated progressive extension during Plio-Quaternary. This period is characterized by normal faults and gentle folds except a short-lived strike-slip deformational period during Early Pliocene. The overprinted normal faulting on strike-slip deformation pointed out that the extension is the latest deformation in the Ankara region.
There is a clear time correlation between the order of deformational events in Aegean extensional terrain and Ankara region for Miocene to Quaternary period.

Key words: normal fault, extension, Miocene, Aegean extension, Ankara terrain, Central Anatolia.

Geotectonic development of Southwestern Turkey and its role on the hydrocarbon exploration of the region

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Menderes Massif is a well-known and well-defined metamorphic massif of Turkey. It consists of an old gneissic core at the base, which is covered by schist and marble envelopes. Another word, it has a gneissic core which is covered by schists and meta carbonates. Metamorphic and or non-metamorphic allochthonous units tectonically overly the Menderes Massif .

The Eocene and younger sediments, mainly clastic rocks, deposited above the Menderes Massif. Some of these rocks display significant hydrocarbon potential. Field data supported by the data derived from the laboratory studies indicate collectively that even the core rocks of the Menderes Massif are not really allochthonous in nature, they have been transported together with the various overlying rocks as a giant tectonic entity from the north to the south directions together with the overlying tectonic series and the syntectonic sediments on itself as a giant complex. As a consequence, the Massif were tectonically imbricated, structurally rearranged and the metamorphic rocks were partly or totally recrystallized.

The three essential prerequisites of hydrocarbon occurrences in a region are source, reservoir and seal rocks. In addition to these an evolutionary path of the rocks and the region in a favorable direction for the petroleum generation are also needed. Thus, any hydrocarbon exploration work should take into account all these available and unforeseen parameters for a successful exploration. Therefore, geology of the region must be evaluated in terms presence of these three elements. Geological and geophysical exploration tools must be used to evaluate presence of likely areas for exploration.

Keywords: Menderes Massif, geotectonic development, hydrocarbone exploration, southwestern Turkey

Determination of the basement topography of Büyük Menderes Graben systems by using microgravity data

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Büyük Menderes Graben is one of the most important neotectonic structures in western Anatolia. Büyük Menderes Graben bounded by normal faults extending E-W direction has a thick sedimentary cover. Therefore, many researchers who study for the geothermal and oil purposes were interested in this area. In this study, Microgravity data were measured along the three profiles selected in the graben area. These data were evaluated by using 2-D inversion and the power spectrum methods and, the thickness of the sedimentary fill of the B.Menderes graben tried to determine subsurface basement topography. Inverse theory is concerned with the problem of making inferences about physical systems from geophysical data. The depth of the top of the rectangular prismatic models can be calculated from microgravity data for a density difference by inversion to define the subsurface basement topography in a 2-D cross-section. Inversion method optimizes the solution of by utilizing the initial parameters with maximum and minimum depth values. The method was utilized to estimate the basement geometry and the thickness of the sedimentary cover of the Büyük Menderes Graben systems for various density differences. The thickness of the sedimentary cover was determined between 1,8-2.0 km in the Büyük .Menderes Graben. According to model geometry, thickness of the sedimentary cover decreases to the south of the graben. Also, the power spectrum method was applied to microgravity data and similar depths were achieved.

Keywords: Büyük Menderes Graben; Sedimentary thickness; Microgravity; Inversion; Power Spectrum

Fold Geometry in Karadut Fault, Alaşehir Graben, Western Anatolia

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Alaşehir Graben is one of the E-W trending graben systems in Western Anatolia. Approximately 200 km^2 area between Salihli and Alaşehir in the southern edge of the Alaşehir Graben has been mapped on 1/25.000 scale during this study (Öner, 2004; Şen, 2004; Metin, 2004, O.I; Ağırbaş, 2006). The southern edge of the Alaşehir Graben is bordered by the Karadut Fault. This is the fault surface which is exposed from Turgutlu to Alaşehir along approximately 150 km.
Karadut Fault dips to the north with a low-angle (2^0-20^0) and is represented by a 60-150 meters thick mylonitic zone. Collected kinematic data from the fault zone indicate that the hanging-wall of this fault moved to the north along a low-angle normal fault (Emre, 1996; Hetzel et al, 1995b; Işık et al., 2003). In the study area, there are two different rock associations, which are separated by the Karadut detachment fault. The basement is presented with the Menderes Massif rocks (mica-schist and gneiss) which are cut, under the Karadut Fault, by Midddle Miocene aged intrusive rocks, composed of granodiorite. The Cenozoic aged sedimentary rocks are structurally and tectonically on top of the Menderes Massif rocks (Emre, 1996; Koçyiğit et al, 1999a; Yılmaz et al., 2000; Sözbilir, 2001).
The Karadut detachment fault is forming the scope of this study; it has been studied in detail between Gökçealan-Kara Kirse (Alaşehir) and Karadut-Değirmendere (Salihli). Slickensides plunge to northwest in Kayraklıkayalığı, Oyukkıran, Güzelcik, Haramlıtarla and in its vicinity, to northeast in the western and eastern side of Karadudun Hill and in the Tombulca area, on footwall of the detachment fault. These measurements indicate that the fold axis is N20^0E trending and 20^0 NE plunging, with stretching lineations plunging to the northeast. On the other hand, structural data obtained from footwall of detachment fault, on the bottom of the Bağırsak Valley in the south of Gökçealan and Şahyar Valley south of Kara Kirse, are shown that the fold axis is N80^0E trending 30^0 SW plunging, with stretching lineations plunging to the south west. This difference of the fold axis is explained by tilting of the detachment fault along younger high-angle normal faults, which are cutting all the rock unites in the study area.

Key Words: Alaşehir Graben, Karadut Detachment Fault, folds, slickensides, tilting.

Geotectonic significance of dykes in the İstanbul Paleozoic sequence, western pontides: preliminary results

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Paleozoic rocks underlying Istanbul and its surroundings are called the Istanbul Paleozoic sequence. The units of Istanbul Paleozoic sequence are intruded in various orientations by volcanic dykes and intrusions called previously as diabases. These volcanic intrusions were considered to be linked to a single magmatic phase and were not adequately investigated with respect to their structural features, geochemistry and geochronology.
Dykes and other volcanic intrusions are determined to have different lithology and preferential strikes in N-S, E-W, and N70-80^{0}E orientations. Those in N-S orientation are determined as diabase and lamprophyre, those in E-W orientations as basalt and basaltic andesite porphyre, and those in N70-80^{0}E orientations as dacite porphyre.
Of the dykes and magmatic intrusions with N-S strike, a diabase has collisional character, whereas lamprophyres exhibit within plate character. Basalt/basaltic andesitic porphyres with E-W strike have within plate character. The 'Gülsuyu Dacite Porphyre' intrusion and dykes with N70-80^{0}E strike have within plate character. Radiometric ^{40}K/^{40}Ar age of five selected samples of basic dykes yield ages ranging from the Middle Jurassic to the Lower Eocene; these are the first ages obtained from dykes in the İstanbul Paleozoic fragment.
Considering these dykes indicate directions of regional extension, the Istanbul Paleozoic units underwent different episodes of extension at different times. These units are affected by E-W extension during the Middle Jurassic- Lower Cretaceous and by N-S extension during the Lower Cretaceous - Lower Eocene within plate tectonic settings. Structural, geochemical and geochronological data on dykes and intrusions suggest more than one geotectonic environment, including that caused the formation of the Modern Black Sea basin.

Key Words: Gülsuyu Dacite Porphyre, dykes, lamprophyre, Modern Black Sea, K/Ar.

Volcaniclastic deposits in the Afyon-Sinanpaşa Neogene Basin, Central-Western Anatolia Turkey

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Afyon-Sinanpaşa Neogene basin is situated in the eastern part of the western Anatolia, where the stratovolcanoes developed during Middle-Late Miocene period (14,8-8 Ma) in association with lacustrine sedimentation. The potassic and ultrapotassic volcanic activity created topographic irregularity and/or caldera formation in which local lakes were filled by volcanic and non-volcanic sediments. The volcanic-fill materials were generally derived from trachybasalt, trachyandesite, trachytic lavas and their volcanic grains. They were transported either airfall material or pyroclastic flow into the lakes. Caldera lake consists of diatomaceous mud, airfall tephras, kaolinized tuffaceous rocks and channel-fill deposits composed of lava fragments. Morphology of the caldera lake reflects complex origin that occurred after large eruption of acid rhyolithic volcanism involved deposition of airfall tephras (lapilli and lapilli tuffs) in the caldera lake where diatomes accumulated as deeper part sediments. Channel-fills on the top of the section indicate that drowned river system carried out inflowing water into the lake basin.
Younger lakes, which are considered as post-caldera formations in this study, were generally initiated bu calishe or lensoidal limestone layers characterized by desiccation cracks suggesting shallow lake deposition. They are upward followed by tuffite beds mixed with various amount of mollusc shells. Peat bearing intervals are also formed within the tuffeous units. Block and ash flows with radial cracks were deposited on the top of the section that characterized by reverse grading and poorly sorted volcanic clasts in matrix supported diamictite having clasts in a range of meter size blocks. Soft deformation structures, especially syn-depositional faultings are a typical feature for the coarse-grained volcaniclastic deposits in which volcanic blocks exhibit a hanging wall setting. The blocks were transported by high dense grain-mass flows (Lahar) or debris avalanches moved from slopes or fault-scarp into the local lake.
Petrogragraphic studies revealed that non-welded tuff consists of plagioclase, biotite, pumice, lithic/glass shards, opaque minerals with vitrophyric and eutaxitic textures, and it is formed as vitric tuff. Feldspar fenocrystals are also determined within these units. Aphyric lava flows predominantly consist of glass. Whereas fenocrystals were produced during final stage of the volcanic activity**.**
Volcaniclastic lake deposits in the Afyon-Sinanpaşa subbasins were result of a combination of volcanic and tectonic activities (Volcanism-induced eartquake) that caused very rapid and thick deposition. Where outstanding rate of sedimentation was balanced by rapid subsidence of the lake.

Keywords: Volcaniclastic deposits; lacustrine facial models; Sinanpaşa-Turkey.

Miocene volcano-stratigraphy of the Simav-Gediz-Şaphane region (Kütahya - Western Anatolia) based on new ^{40}Ar-^{39}Ar Geochronology

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The study area is located at the intersection of E–W-trending Plio-Quaternary Simav Graben and NE–SW-trending Neogene Selendi and Güre basins in the western Anatolia. According to previous studies, it is argued, based on the stratigraphic position and the radiometric age of volcanic rocks dated at 16.8±0.7 to 20.3±0.6 Ma (K-Ar), that the calk-alkaline volcanic rocks of the study area are interrelated with sedimentary deposits of the Hacıbekir Group. Therefore volcano-sedimentary sequence related to Middle Miocene calk-alkaline volcanism is not observed. In this respect, Neogene stratigraphy of the study area has not yet been well-established up to now and its regional correlation is still controversial. In order to establish the stratigraphy of the study area, we mapped 1/25.000 scale and revised the stratigraphy of the Miocene volcano-sedimentary units on the basis of field expeditions, as well as petrographic studies on volcanic rock samples and with new nine ^{40}Ar-^{39}Ar geochronologic data. Four distinct volcanic successions occur in the study area: (1) Akdağ volcanics with felsic compositions (consist of trachyandesite, andesite, dacite and rhyolite rocks), (2) Güzüngülü volcanics with mafic composition, (3) Lamproitic rocks and, (4) Basaltic rocks. Akdağ volcanics consist of rhyolitic-dacitic intrusions with pink-purple color sanidine crystal, lavas and pyroclastic rocks. Güzüngülü volcanics composed high-K, lava flows with andesitic compositions, rarely basaltic dykes and in addition to them white color tuffs and agglomerate. According to petrographical features, lamproitic rocks are divided into two units. These are Şaphanedağı and Ilıcaksu lamproite. Basaltic rocks, according to observed basins, were renamed with a different name. These are, from south to north, Dereköy Basalt, Naşa Basalt, Eskigediz Basalt, İnceğiz Basalt. The İnceğiz basaltic lavas show peperitic textures displaying interfingering relations with Ulubey carbonate rocks. The new ages obtained from the Akdağ volcanics (rhyolites) are 18.07±0.14 and 19.86±0.08 (sanidine) Ma and indicate volcanism during the Burdagalien (early Miocene). The radiometric age obtained from the Güzüngülü volcanics is 14.26+0.34 (plagioclase) Ma. The Ar-Ar analysis of the Şaphanedağı lamproites yielded ages between 15.56±0.06 and 15.74±0.06 (phlogopite) Ma. In light of these data, we assessed that volcanism in the region started to accumulating from the end of late early Miocene and continued until the end of middle Miocene (Burdagalien−Serravalien).

Keywords: Ar-Ar geochronology; Şaphane; Gediz; volcano-stratigraphy

The role of episodic basaltic input in the generation of Early Miocene volcanic suites of NW Anatolia: evidence from petrography and mineral chemistry of Kepsut-Dursunbey volcanites

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Located in NW Turkey, the Kepsut_Dursunbey volcanic field comprises lavas represented by various compositions ranging from basaltic andesite to rhyolite and associated pyroclastic rocks. Andesite to basaltic andesitic lavas and associated pyroclastic rocks were formed during the early stage of volcanism in the region. Partly contemporaneously, they followed by an extensive felsic volcanism producing mainly dacitic domes-lavas and felsic pyroclastic rocks. The relationships between these two volcanic suites and their areal distributions in the study area indicate that the first volcanic episode were produced by plinian-sub-plinian eruptions of a major stratovolcano in the Kepsut area while the felsic volcanic rocks produced by fissure eruptions of small vents aligned along NW-SE and NE-SW in and around the stratovolcano(es). Both groups show petrographical and chemical evidence suggesting interaction between mafic and silicic magmas for their formation. Petrographically, early stage volcanic products display disequilibrium textures such as existence of rounded plagioclase phenocrysts with reaction rims (regrowth textures), hornblend-mantled clinopyroxenes (corona texture), synneusis, sieve textured plagioclase, patchy zones and oscillatory zoning in plagioclase phenocrysts. Basaltic andesitic lavas also contain xenocrysts represented by biotite mantled quartz and asidic plagioclase ovoids and glomerocrysts entrained from melt zones near base of the crust. These observed disequilibrium textures shown by both suites provide evidence for magma mixing/mingling or AFC. The amphibole-plagioclase geothermometer and Al-in-hornblend geobarometer calculations give values of 5.7–7.0 kbar and 927–982 °C for the intermediate to mafic lavas and 3.7–5.3 kbar and 783-787°C for the felsic lavas, indicating crystallization in magma chambers at deep and mid crustal levels; 21 km and 12 km, respectively. Therefore, a deep main magma reservoir served as a source for the intermediate to mafic lavas. The existence of similar mixing-compatible textures in both volcanic suites with contrasting compositions support the establishment and evolution of magma reservoir(s) producing basaltic andesite to rhyolitic lavas and associated rocks promoted by episodic basaltic inputs which may generate and mix/mingle with crustal melts at different depths.

Keywords: NW Anatolia; Kepsut; Dursunbey; petrography; mineral chemistry

The crust stucture modelling of western part of Aegean region, Western Anatolia

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Western Anatolia is one of the conspicuous areas in the world with its active and rapidly deforming tectonical structure. The most important tectonic features of the region is Büyük Menderes, Gediz, Küçük Menderes and Denizli graben systems. The study area covers the western part of Büyük Menderes, Küçük Menderes and Gediz grabens. To investigate the deep and shallow crust structure of Western Turkey, we use Bouguer gravity anomaly data of the region. With this aim we selected two horizontal and two vertical profiles on Bouguer gravity anomaly map of region to make 2D model of crust. We defined from the models the crust get thinner from east to west and from north to south. The Moho depth is defined as 27-28 km at the east and 23-24 km in the western part of study area. The Moho discounity level gets higher from E to W. The average depth of basement is defined 12 km in the area. The highest level of basement is under the grabens, where the extentional regime shown well. Sediment thickness is defined as 2.5-3 km between Ortaklar-Aydın and 2 km between Aydın-Köşk-Yenipazar in Büyük Menderes graben and 4-5 km between Menderes-Torbalı-Bayındır, 3 km in between Bayındır-Tire, 5 km in Ödemiş and 2 km at Kiraz in Küçük Menderes graben. To determine the linear features of the region we applied horizontal gradient method to Bouguer gravity anomaly map we defined the boundary faults of northern and southern sides of both Küçük Menderes and Büyük Menderes grabens. And also the location of faults their position contact points and buried faults in grabens.

Keywords: Western Anatolia; gravity; crust structure; 2D model; horizontal gradient

Neogene-Quaternary Stratigraphy and Tectonics of Alaşehir Graben, Western Anatolia

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Western Anatolia is one of the fastest extending regions in the world. In Lower-Middle Miocene as a result of starting the lithospheric extension, NE-SW and E-W trending horst and grabens were developed in the Western Anatolia. The Alaşehir Graben is an asymmetric graben, trending E-W from Ahmetli to Turgutlu and NW-SE in near Alaşehir.

The study area is between Salihli and Alaşehir, located in the southern part of the Alaşehir Graben. The stratigraphy of the region is mainly represented by metamorphic rocks of the Menderes Massif and the synextensional Salihli Granitoid as basement rocks, which are tectonically overlain by Neogene-Quaternary aged sedimentary rocks. These rocks are cut by two detachment faults, which are also cut by younger various high-angle normal faults.

The Neogene-Quaternary aged cover rocks have been divided into seven formations. The cover rocks begin on the bottom with Early-Middle Miocene aged shale-sandstone intercalations, deposited in a lacustrine environment (Gerentaş Formation) and are followed be limestone-claystone intercalations (Kaypak Tepe Formation). Upper Miocene units were developed in two phases. While the first phase is represented by fluvial controlled to alluvial-fan sedimentary rocks - coarse clastics (Acıdere Formation), the second phase consists of fine grained clastics of fluvial controlled flat plains (Göbekli Formation). These units are followed by fine clastics of fluvial controlled lacustrine rocks interbedded with peat laminations (Yenipazar Formation) that unconformably overlie the Miocene sequences. These fine clastic rocks are conformably overlain by coarse clastics of fluvial controlled alluvial-fan deposits (Asartepe Formation). The youngest rock unit consists of fluvial fine-coarse clastics (Erendalı Formation) that unconformably overlie the coarse clastics.

Paleo-current measurements derived from rocks of the Neogene-Quaternary aged cover rocks show that the source was located to the south of study area throughout the period of developing this stratigraphy.

Keywords: Alaşehir Graben, Neogene-Quaternary, stratigraphy, controlled, paleo-current measurements.

ISC - 04

ELECTROMAGNETIC TOMOGRAPHY IN SUBSURFACE INVESTIGATIONS

Conveners:
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Deep magnetotelluric soundings in the Aliağa region, Western Turkey

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Two deep magnetotellurics (MT) sounding data were acquired in Aliağa region by the collaboration of Ankara University and Hungarian Academy of Sciences in the time range of 10 seconds to 10.000 seconds. The total measurement duration for each station was about one week. The data was interpreted by using 1D inversion software.
The deep MT stations were over a remote-reference MT profile consisting of 21 stations and measured by MTA in the framework of joint geothermal project with Ankara University. The distance between the stations was approximately 250 m constructing a profile of 5 kms in length. The seven-channel equipment was used for the measurements of two orthogonal electric and three orthogonal magnetic (*H*) field components. The high- and low-frequency bands included frequency ranges of 320-7.5 and 6-0.00055 Hz, respectively. We acquired the MT data in the lower band for longer than 24 hours. This profile was interpreted by using two-dimensional modelling and published recently.
The deep MT stations share the same location of two stations of conventional MT line. This permits to combine the field data corresponding to relatively high and low frequency bands and to validate the shallow part by comparison with the 2D model derived from the MT line. The interpretation of deep MT data reveals that the depth of interface between the upper and lower crusts is about 12 km. The thickness of upper crust was estimated from the 2D inversion. A prediction for the total thickness of lower crust and asthenosphere was made by the use of 1D inversion of deep magnetotelluric sounding curves.

Keywords: Deep magnetotellurics; crust thickness

1-D Inversion of VLF-R data, case study: Magnesia archaeological site

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Very Low Frequency wave-Resistivity (VLF-R) method has been widely used for near surface and archaeological prospection for the last two decades. Shallow buried structures that show resistivity variation with respect to surrounding medium could be determined with VLF-R. It is also a particularly rapid and cost-effective technique for collecting data on large scale exploration. VLF-R studies were carried out in Agora of Magnesia archaeological site (Aydın/Turkey) in order to determine the location and depth of ruins of Temple of Zeus. After performing theoretical studies to test the inversion algorithm, apparent resistivity and phase data were collected with 3 different frequencies and laterally constrained two-layer inversion process was applied to each station. In addition to the inversion of all profiles for each frequency, all lines were stacked within a precise resistivity interval to obtain a 3-D view of the structure. An excavation site is recommended after achieving the location of the temple.

Keywords: Archaeology; Electromagnetics; Inversion; Magnesia; VLF-R

ISC - 05

REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS

Conveners:
Vahap Tecim and Güven Koçak

AppLication of Landsat 7ETM+ in Investigation of Alteration Zones in Varzeghan Area

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Remote sensing is the field of study associated with extracting information about an object without coming into physical contact with it. Therefore; the collected information is obtained by emission issue and the radiation of the electromagnetic waves of the observed objects. This technique allows observing most possible surface, while having a big spatial precision. Nowadayes, the Landsat image interpretation as the most powerful tool in lithologic discrimination and geological mapping and investigation of alteration is proved by several works especially in dry and semi-arid zones.
Varzeghan area is situated in Northwest part of Iran on Alp - Himalayan Metallogenic Belt. Wide range of this magmatic belt consists of volcanic and intrusive series. It has a mining high potential, because of abundant ore evidences in this area. Hydrothermal alteration zones in the area have been studied in this research. Satellite images processing have been used for clarifying porphyry and epithermal systems in this area. Volcano-plutonic activities caused a wide range of alteration zones and related ore forming. Study of Alteration zones in the area was useful to find ore zones on Landsat ETM+ images. Processing on satellite images has clarified as: Porpylitic; Argillic; Advance Argillic and Phyllic alteration zones. Different image processing techniques such as band ratios, colour composite, principal component analysis, crosta technique, and lineament factor analysis are used to identification of the alteration zones associated with copper and gold mineralization. Finally, all alteration and mineralization zones have been tested by Chemical Diffraction Analysis (XRD) of related minerals.
This study lead us to test the satellite processes and specific treatment application on Landsat 7ETM+ images in alteration and mineralization discriminations and also obtaining a structural mapping of the region. Color composition (742), band Ratio (2/1- 4/3- 7/5) and the selective principal component analysis provide an excellent distinction between alteration zones.
Finally this factors caused the research to identity alteration zones such as Sungun, Kighal and Haftcheshmeh porphyries and some alterd area based on the finding criteria.

Keywords: Iran, Varzeghan; Band ratio; principal component analysis; Satellite image processing, Landsat

The application of GIS-based processing & modeling techniques to reconnoiter the mineralization of porphyry copper in the southwest of Yazd province

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The successful exploration of the ore deposits, especially in the areas which are not easily accessible, requires the best use of the spatial data of an (EGIS) and also the application of GIS and RS technologies. In this research we investigated a sheet of aqda-abarkouh zone in southwest of Yazd providence.the1:100000 sheet of khezr Abad with geographical coordinates of 53°,30´to 54°, eastern longitude and 31°,30´to 32° northern latitude located in south of Yazd province, was investigated in order to identify the promising areas of porphyry copper mineralization .in this research, these areas were identified by recognizing the metallogenic nature of the region and the related generative model as well as changing geology, remote sensing, airborne geophysics and geochemistry data to such beneficial information as source rock, host rock, structure, alteration and interpreting it. Following this goal, at first all data layers were correct and processed and then analyzed based on the intended exploratory model,metallogenic nature of the region and modeling method,(index overlay),finally the related mineral potential map predicting areas having the probability of porphyry copper mineralization was made through integrating the produced binary maps. These areas are of the most spatial relation with this mineralization since they have the most confirmation and correlation of data layers. This map represents 30 prioritized regions being proposed for exploratory surveys. The proposed area is currently being studied in field and effects of a range of copper mineralization have been observed and 20 samples have been taken and sent for analysis.

Keywords: GIS technologies, Index overlay, method, Geochemistry data, related mineral potential map

Using remote sensing multispectral data and GIS techniques for the geological mapping of Rhodes and Halki Islands

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The major geological cartographic scale of the Institute of Geological and Mineral exploration of Greece (IGME) is the 1/50.000. The whole country is covered by 325 map sheets. The geological mapping was done during the last six decades by Greek and foreigners geologists. As a result there are still some serious problems about the homogeneity of the formations, the boundaries of the formations, the geological zones that cover the Greek territory et.c.
It was marked that in many regions of Greece there are abutter geological map sheets that present serious unconformities. Those unconformities are possibly due to the fact that different geologists at different periods have based their mapping onto different geological and geotectonical theories. Additionally, the currently used theory about the geotectonical zones of Greece has been developed after 1970.
The Institute of Geological and Mineral Exploration of Greece (I.G.M.E), in the framework of CSF 2000 – 2006 (Community Support Framework 2000-2006, Operational Program Competitiveness, Priority axis 7: Energy and Sustainable Development, Measure 7.3: Exploitation of natural recourses and support in meeting environmental commitments, Action 7.3.1) has been implementing the project called “Collection, Codification and documentation of geothematic information for urban and suburban areas in Greece - pilot applications”. The sixth sub-project has to do with the updating of fifty geological map sheets using GIS and Remote Sensing techniques. The five 1/50.000 geological map sheets of Rhodes Island and the one geological map sheet of Halki were included in the updating project.
In this paper we present the combined use of remote sensing and GIS techniques for the geological mapping of Rhodes and Halki Islands at a 1/50.000 scale. The geological formations, geotectonic units and the tectonic structure were recognized in situ and mapped. Interpretation of multispectral satellite images (Landsat 7 ETM and Terra ASTER) has been carried out in order to detect the linear or not structures of the study area. The in situ mapping was enhanced with data from the digital processing of the satellite data. All the analogical and digital data were imported in a geodata base specially designed for geological data. After the necessary topological control and corrections the data were unified and processed in order to create the final layout at 1/50.000 scale.

Keywords: Remote sensing; GIS; geological mapping

Remote sensing data and gis techniques for quarry monitoring. Three case studies from Greece

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Active quarries near to urban centers are at the same time a necessity but also a source of pollution. Necessity as they supply to the construction companies the necessary aggregates and source of pollution as they affect biodiversity, vegetation cover and threaten water resources. The objective of this work is to indicate a monitoring methodology in order to survey the present state of the quarry sites and their evolution in time, which are the basic data needed to implement an adequate land reclamation project.
Three different case studies are presented. The first one demonstrates how we can use Digital Elevation Models and high resolution orthophotos in order to remodel the planes of an ancient quarry. Based on the same data and taking into account the tectonism and geomorphology of the study area, the average visual thickness and the volume of the excavated marbles as well as the volume of the derived debris deposits are estimated. The second case study deals with the use of satellite remote sensing data and GIS in order to quantify the excavation volumes in an active quarry within a year of activity. The third case study presents the use of airphotos, GIS and geological mapping in order to estimate the possible volumes of marbles into a quarry before the beginning of the excavations.

Keywords: Quarry; monitoring; gis; remote sensing

ISC - 06

TECTONIC ASSEMBLY OF THE TETHYAN OROGEN IN THE EASTERN MEDITERRANEAN REGION

Conveners:
Alastair Robertson, Dimitrios Papanikolaou, Aral İ. Okay,
Timur Ustaömer and Osman Parlak

Tectonostratigraphy of the Tethyan continental terranes drifting from Godwana towards Eurasia: The example of the Hellenides

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The tectonostratigraphy of the continetntal terranes within Tethys is related to their paleogeodynamic and paleogeographic evolution, which comprises three major stages: (i) Continental rifting in the northern margin of Gondwana, characterised by volcanosedimentary complexes (of Late Paleozoic – Triassic age in the Hellenides). (ii) Continental drifting and contemporaneous oceanic opening of Tethyan basins in between the continental terranes (during Triassic – Paleogene in the Hellenides) with shallow-water carbonate platforms on the continental terranes and ophiolite suites interlayered with pelagic sediments within the Tethyan basins. (iii) Accretion of the tectonostratigraphic terranes with docking along the active European margin, characterised by flysch/melange sedimentation along the trenches (from ?early Jurassic to Neogene in the Hellenides). Two tectonostratigraphic models can be distinguished: one for the continental terranes/carbonate platforms and another for the oceanic basins. The duration of each geodynamic stage for each terrane is obtained from the chronology of the tectonostratigraphic facies change. The general trend is younger ages observed in the southern terranes and older ages towards the northern terranes. The two alternative tectonostratigraphic models are applied in the two groups of terranes and the chronology of the geodynamic-paleogeographic stages is estimated. A palinspastic model of the Hellenides is presented taking into account the chronology of each stage for every terrane. Obduction of ophiolites over the southern platforms is observed in all four oceanic basins. Blueschists exhumation, formation of core complexes and tectonic windows through extensional detachments occur after micro-collision of continental terranes/platforms and their isostatic uplift within the upper plate after their detachment from the subducting slab.

Keywords: continental terranes; Tethys; paleogeodynamic evolution; Hellenides

Overview: Inter-relations of continental and carbonate platform units in the Mesozoic-Early Cenozoic construction of the Anatolian continent

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Reconstructions of the Anatolian continent for Mesozoic-Early Cenozoic time generally assume the existence of one or more continental units that rifted from North Africa (Gondwana) during Triassic time and drifted across the Mesozoic Tethyan ocean to amalgamate with Eurasia, mainly during latest Cretaceous-Palaeogene time. Current end-member solutions range from one in which the present Tauride-Anatolide area restores as one large continental unit, to another in which a variable number of rifted fragments were surrounded by Mesozoic oceanic crust. Here, the available field-based evidence for the mutual relationships of the different continental blocks and carbonate platforms is evaluated.

Category 1 (very well established): The Southern Neotethys is the best established ocean because it still remains partially non-emplaced beneath the deep Mediterranean Sea adjacent to N Africa (e.g. Herodotus basin). Its existence is supported by the presence of ophiolites (e.g. Troodos, Cyprus), ocean-derived melange (Mamonia complex, Cyprus) and U. Cretaceous arc-type volcanism (Kyrenia Range, N Cyprus; Kannaviou Formation, W Cyprus). The Izmir-Ankara-Erzincan-Sevan-Akera ocean is also very well established in view of its expected features including ophiolites, accretionary melange and related magmatic arc units (e.g. E Pontide arc).

Category 2 (well established). The Berit ocean (new name) between the Malatya-Keban platform and the Bitlis and Pütürge massifs is considered to be well established in view of its associated ophiolites, U. Cretaceous and Eocene arc-type magmatism and U. Cretaceous HP/LT metamorphism. In addition, the Alanya ocean (new name) is also considered to be well established because of the presence of associated rifted margin units, ophiolitic melange and HP/LT metamorphism. The Inner Tauride ocean between the Tauride carbonate platform and the Kırşehir Massif is also well established, based on the presence of ophiolitic rocks (e.g. Pozantı and Mersin ophiolites), magmatic arc rocks (Kırşehir massif) and HP/LT metamorphism of its subducted southern margin (i.e. Afyon zone). The existence of oceanic crust (e.g. Gödene zone) separating continental fragment(s) (e.g. Kemer unit) from the Tauride carbonate platform in the Isparta Angle (Antalya area) is also well supported by several lines of evidence.

Category 3 (unlikely). Potential 'Ayfon', 'Menderes' and 'Munzur' oceans have been suggested in the light of the age relations of associated HP/LT metamorphic rocks, but at present lack much supporting field evidence (e.g. preserved rift/ passive margin units, related arc magmatism, or ophiolitic rocks).

The majority of the continental/platform units can, therefore, be restored as different parts of one large Tauride-Anatolide continent. Several smaller crustal units (e.g. Kırşehir, Pütürge and Bitlis massifs; Alanya crystalline basement-Kyrenia platform) are restored as continental fragments surrounded by oceanic crust. Our interpretations of the various inter-platform relationships form the basis of outline palaeotectonic maps, which in turn, have interesting implications for continental rift and passive margin units, ophiolite genesis and emplacement, and collisional processes (e.g. roles of intra-continental thrusting/subduction).

Keywords: continents; oceans; Mesozoic; Anatolia; reconstructions; Tethys

Timing of subduction processes in Anatolia

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Deciphering the palaeogeography of the complex tectonic mosaic, such a the Alpine-Himalayan orogenic belt, classically relied on the study of ophiolites and continental passive margin sediments. In order to unravel the closure history of the Neotethys Ocean in Anatolia, we investigate metamorphic rocks from high-pressure (HP), low-temperature (LT) belts occurring throughout this microplate.
The continuous occurrence of HP-LT metasediments and metavolcanics, mainly distributed into two units - the Tavşanlı Zone and the Ören-Afyon-Bolkardağ Zone - can be followed from the Aegean Coast to southern Central Anatolia. They are evidence for the suture of a northern branch of the Neotethys Ocean running along the southern border of the Central Anatolian Crystalline Complex. The eastward continuation of these belts points towards the Amassia belt in Armenia, and first findings of blueschist-facies mineral relics near Erzincan by G. Topuz confirm such a hypothesis. From HP metasediments from the Ören-Afyon-Bolkardağ Zone, we obtained phengite Ar-Ar ages around 66-59 Ma, which clearly contrast with the overlying Tavşanlı Zone where HP metamorphism was dated to 88-78 Ma (Sherlock et al., 1999). P-T conditions of the high-pressure metamorphism also differ between Tavşanlı eclogites (2.4 GPa/500 °C; Okay & Kelly 1994; Okay, 2002; Davis & Withney, 2006, 2008, Çetinkaplan, 2008) to blueschists and Ören-Afyon-Bolkardağ Zone Blueschists (1.0 GPa/330 °C; Candan et al., 2005; Rimmele et al., 2003, 2005, Pourteau, 2011) . The implications of this duality are crucial for geodynamic interpretation. Assuming a common basin for both, Tavşanlı and Ören-Afyon-Bolkardağ Zone, the different P-T conditions and ages allow to pinpoint the dynamic of exhumation.
In addition, we document new HP relics from the Bistun Block that may outline an additional, more southerly, subduction zone, and thus oceanic branch. Possible lateral continuations of this southern HP belt are found: (a) to the west, in the Alanya Nappes, where eclogites and blueschists yielded us metamorphic ages around 80 Ma (zircon U-Pb and phengite Ar-Ar), and (b) further east, in the Bitlis Complex, where phengite Ar-Ar geochronology yielded 79-74 Ma ages for HP peak assemblages (carpholite-chlorite-phengite) and 74-71 Ma ages for retrograde assembles (chloritoid-chlorite-phengite-kyanite). This leaves a short time span for the exhumation from ca. 35 to 20 km depth that can be interpreted to exhumation rates of 2-3 mm/a. A new occurrence of eclogites within the Bitlis basement rocks from the Kesandere Valley documents subduction of the complete Bitlis Complex prior to its collision with the northerly Tauride Block. These new findings complement eclogites from the western part of the Bitlis Complex (Okay et al., 1985), although the newly- and previously-reported eclogues differ in their lithologic association, protoliths and P-T metamorphism. While the westerly kyanite eclogites occur within garnet mica schists and gneisses, and experienced P-T conditions of 1.9-2.0 GPa and 600-650°C, we calculated that those from Kesandere experienced 1.9-2.4 GPa and 480-540°C. The latter metamorphic conditions therefore are somewhat colder that those estimated by Okay et al. (1985) further to the west of the Bitlis complex. Zircon U-Pb geochronology in these Kesandere eclogites yielded ca. 85 Ma ages. Based on their common eclogitic ages and regional structural position, the Kesandere and Alanya eclogites stemmed most probably from the same subducted continental margin, distinct from the Taurides. Comparing the Kesandere eclogite ages (ca. 85 Ma) with the ages from the Bitlis blueschists (79-74 Ma) leaves a time span of ca. 10 Ma, which seems shorter than that for northerly HP belts (Tavşanlı and Ören-Afyon-Bolkardağ Zone) (ca. 20 Ma). We assess this difference to point two distinct subduction zones and contrasting exhumation rates. Our investigations throughout Anatolia lead us to envisage that, in the Late Cretaceous, continuous convergence between Africa and Eurasia engendered the simultaneous consumption of several, separated branches of the Neotethys Ocean.

Keywords: subduction processes, high-pressure rocks, dating

Role of Middle Eocene sedimentary melange (olistostromes) and thrusting in the tectonic development of the northern, active continental margin of the S. Neotethys (Kyrenia) Range), N Cyprus

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The Girne (Kyrenia) Range provides a unique insight into the Late Cretaceous-Recent tectonic development of the northern continental margin of the S Neotethys. The Range developed in main four structural stages: 1. Late Cretaceous: burial, metamorphism and rapid exhumation; 2. Middle Eocene: emplacement of turbidites, mass-flows and debris flows (olistostromes), followed by southward thrusting; 3. Late Miocene southward thrusting; 4. Plio-Quaternary uplift.

Here we focus on the Mid-Eocene stage, utilising new N-S cross-sections. Paleogene deep-sea pelagic carbonates and alkaline volcanics pass upwards into redeposited neritic limestones and then into a thick succession of redeposited sedimentary material (Bahçeli-Ardahan (Kalograi-Ardana) Formation)) that is exposed in three main E-W trending thrust sheets. The most southerly unit, exposed in the eastern Range, is dominated by siliciclastic turbidites, mass flows and debris flows. The sand matrix contain abundant ophiolite-related material (e.g. (basalt; radiolarite) together with well-rounded clasts of lithologies (e.g. pelagic limestone; marble; dolomite; basalt) that are similar to the rock types exposed in the underlying Paleogene and Mesozoic successions. The overlying thrust sheet is dominated by debris-flows with exotic blocks (up to 100s of m in size), notably the Permian neritic Kantara Limestones, together with dismembered thrust sheets of ophiolitic rock (mainly serpentinised harzburgite). The uppermost tectonic unit is exposed along the western flank of the central Range and is dominated by debris-flows that were derived locally from the Paleogene and Mesozoic successions beneath. The planktic foraminiferal assemblage is dominated by *Acarinina bullbrooki*, *A. praetopilensis*, *Morozovella aragonensis* of Lutetian age. Whole rock major and trace element analysis indicates that the igneous clasts in the gravity flows are largely alkaline within-plate basalt, similar to the composition of the lavas interbedded with the Maastrichtian-L. Eocene succession beneath (Lapta (Lapithos) Group). The emplacement of the debris flows and the high-density turbidites of the Bahçeli-Ardahan (Kalograi-Ardana) Formation during the Lutetian was followed by southward thrusting to produce the stack of thrust sheets. Following subaerial erosion, marine deposition resumed during the Late Eocene with the accumulation of non-marine to shallow-water conglomerates (Beylerbeyi (Bellepais) Formation) marking the base of the Değirmenlik (Kythrea) Group. Palaeocurrent data (e.g. clast imbrication) indicate mainly southward transport of these basal conglomerates, which were potentially derived from within and/or to the north of the present Girne (Kyrenia) Range. Basaltic clasts are locally abundant in the basal conglomerates together with other ophiolite-related material (e.g. serpentinite; radiolarian chert). Whole rock major and trace element analysis of the basaltic clasts indicates a predominance of high-magnesian andesite (boninite-type) volcanism. The probable source of the ophiolite-related material was ophiolitic rocks/melange located to the north of the Girne (Kyrenia) Range in an area that has since collapsed to form the deep-water Cilicia basin between Cyprus and S Turkey.

The Mid-Eocene thrusting can be seen as a consequence of the regional closure of the İzmir-Ankara and/or Inner Tauride oceans to the north during Early Eocene time. After collision, convergence jumped southwards, accelerating northward subduction of remaining S Neotethys beneath the Tauride continental margin to the north.

Keywords: N Cyprus; debris flows; olistostromes; Eocene; thrusting; S Neotethys

Eclogites in the Berit area (Kahramanmaraş, Turkey) and their tectonic implications

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Metamorphic rocks are exposed over large areas in SE Anatolia. The main bodies are represented by Bitlis, Pötürge, Keban, Malatya, Engizek, Berit and Binboğa massifs. The Berit area (N Kahraman Maraş, SE Anatolia) is characterized by late Eocene nappe stacking. The nappe sheets are made up non-metamorphic and metamorphic rocks ranging from very low- to very high-grade. Here we report our preliminary results on eclogites and garnet pyroxenites in one thrust sheet, so-called lower amphibolite - metagabbo unit.
The metagabbro - amphibolite unit consists of weakly foliated medium to coarse grained rocks. Plagioclases are mostly replaced by epidote and zoisite. Eclogites – garnet pyroxenites occur as numerous boudinaged lenses and veins. These lenses, a few centimeters to 25 meters in size, are massive, fine to medium-grained rocks. Primary texture and mineralogy of the protoliths were obliterated by complete recrystallization. Partial to complete retrogression to garnet amphibolites due to the medium-pressure overprint is common. Eclogites – garnet pyroxenites comprise clinopyroxene + garnet + quartz + rutile/sphene and ± epidote/clinozoisite ± hornblende. Omphacite in eclogites has a maximum of 23 mole % jadeite. The garnets show the compositional range of Alm_{50-53} Prp_{18-21} Grs_{27-30} Sps_1-And_{0-1}, and are slightly zoned. Calcic amphiboles are pargasite in composition.
PT conditions of high-pressure metamorphism can be estimated as 600 - 800 ^{o}C temperatures and 10-25 kbar pressure, based on the garnet-clinopyroxene Fe-Mg partitioning, the jadeite content of omphacite and Domino. The host rock of eclogites, metagabbro-amphibolite unit, is free of effects of high-pressure metamorphism representing tectonic juxtaposition during the exhumation. Considering the late Cretaceous – Eocene geodynamic evolution of this region, this high-pressure event can be attributed to the closure of the southern branch of Neotethys.

Key words: Eclogite, Neotethys, SE Anatolia

Upper Cretaceous volcaniclastic Kannaviou Formation, W Cyprus: evidence of arc volcanism along the northern, active continental margin of the S Neotethys

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The Kannaviou Formation, up to 750 m thick, was deposited in a deep-sea setting above the Troodos ophiolite in W Cyprus during Campanian-Early(?) Maastrichtian time. The sediments are dominantly redeposited volcaniclastic sandstones, interbedded with smectite-rich clays and radiolarian mudstones. We focus on the volcaniclastic sediments associated with arcuate serpentinite-hosted lineaments that swing NW-SE across W Cyprus. A study of the field relations confirms that the Kannaviou Formation depositionally overlies Upper Cretaceous ophiolitic lavas, including outcrops within the arcuate lineaments (e.g. S of Marathounda; N of Ayia Varvara; W of Mamonia). In some parts of the arcuate tectonic lineaments the Kannaviou Formation directly overlies serpentinite, indicating that mantle rocks were exposed on the seafloor prior to the deposition of these sediments. The presence of locally imbricated lavas and deep-sea sediments (Fe-Mn mudstones, normal mudstones and radiolarites) within the arcuate lineaments (e.g. S of Marathounda) indicates compression or transpression which is likely to have taken place after the deposition of the Kannaviou Formation, prior to the deposition of Maastrichtian-aged subaqueous debris flows (Kathikas Formation) which overlie or border the arcuate lineaments in some areas. Geochemical analysis of the basaltic pillow lavas, which depositionally underlie the Kannaviou Formation within the arcuate lineaments show close similarities with the high-magnesian andesite (boninite) lavas of the Upper Cretaceous South Troodos Transform Fault Zone, as exposed further east in southern Cyprus. Petrographical studies indicate derivation of the Kannaviou sandstones mainly from an intermediate-silicic volcanic source, rich in unrecrystallised silicic volcanic glass, rhyodacite, basaltic andesite, clinopyroxene and plagioclase. Clastic debris (e.g. basalt, minor epidote) was supplied to the base of the succession from the underlying Troodos ophiolitic extrusives, as seen in the type section (Palaeomylon stream). In addition, terrigenous material (metamorphic quartz; muscovite) and pelagic sedimentary rock material (e.g. radiolarian chert) are variably present in the mid to upper levels of the succession. Kaolinite is locally abundant within interbedded red clays. Abundant fragile, vesicular glass shards were derived from a contemporaneous volcanic source. Whole-rock geochemical analysis of the volcaniclastic sandstones (by X-ray fluorescence) indicates that they are mainly of intermediate-silicic composition, comparable with modern and ancient volcanic arc products. Electron microprobe analysis of the fresh glass indicates a silicic composition that is comparable with some early stage volcanic arc or back-arc eruptives. The microproble analysis also confirms that the clinopyroxene and plagioclase compositions are typical of volcanic arc lithologies.
The Upper Cretaceous Kannaviou Formation was therefore derived from volcanic arc, continental margin and oceanicl material. Suitable source lithologies are present in the tectonically juxtaposed continental margin/deep sea rocks of the Mamonia Complex (Ayios Photios Gp.). Similar silicic volcanics, mainly subaqueous tuffs and rhyodacites, of Late Cretaceous age are exposed in a thrust sheet at a low structural level in the western part of the Kyrenia (Girne) Range, N Cyprus (Robertson et al. 2011). Comparable U. Cretaceous volcaniclastic sediments including reworked tuffs are also present in the Misis Complex of adjacent mainland Turkey.

Keywords: W Cyprus; U. Cretaceous; volcaniclastic; volcanic glass; volcanic arc; subduction

Relationship between paleostress partitioning on the cover sediments and the presence of basement transverse faults in the basement of the Zagros Orogen

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Paleostress analysis of the Zagros fold-thrust belt (ZF-TB) including the High zagros, Izeh and Dezful Embayment zones showed paleostress partitioning in the selected area. The Paleostress partitioning map showed the presence of five major restraining step-over zones in trend of 165 in Azimuth. Geometry and kinematics analysis of structures developed on the cover sediments has been showed the effect of a deep-seated strike-slip fault zone on the belt structures. Surface deformations of this fault zone are including changes on the trend of the belt major structures and development of minor folds and faults that are overprinted on the major structures. Detailed structural mapping support the presence of the five major restraining step-over zones along the fault that are marked by paleostress analysis. Interpretation of isopach maps of various formations and seismic reflection profiles showed that these surface structures are related to the reactivation of the basement Izeh fault zone with 165 trend in Azimuth and right-lateral strike-slip movement that cross cut the High Zagros and the Folded Belt zones of ZF-TB in the selected area. Oblique convergence of the Arabian Plate with the Central Iran is in favor for the reactivation of the fault zone and formation of surface deformations and paleostress partitioning. The result of this study can be used for interpretation of deformation partitioning on the cover sediments along the similar transverse fault zone in the ZF-TB.

Key Word: Paleostress partitioning; Cover sediments; Basement faults; Zagros Orogen

Age and provenance of detrital zircons from a sandstone turbidite of the Late Triassic-Early Jurassic Küre Complex, Central Pontides, N Turkey

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The Küre Complex is a structurally thickened wedge of siliciclastic sandstone turbidites, shales and minor carbonate sediments *(~Akgöl Flysch)* that are interleaved with tectonic slices and blocks of a dismembered ophiolite. Rare palaeontological data (e.g. pelagic bivalves and ammonoids) suggest a Late Triassic-Early Jurassic age for the Küre basin sediments, coeval with the better dated Tauric Complex in the Crimea. The Küre Complex is interpreted as a marginal basin that formed adjacent to the southern margin of Eurasia. The Küre basin was bounded to the south by a thick pile of mainly basic-intermediate composition meta-volcanics and volcanogenic sediments (Çangaldağ Complex) that is interpreted as a Late Palaeozoic-Early Mesozoic magmatic arc founded on oceanic crust and Devrekani Metamorphics (a continental fragment of presumably Precambrian age) to the S.

In this study we report the preliminary results of LA-ICP-MS U-Pb dating of detrital zircons from one sample of siliciclastic sedimentary rock of the Küre Complex. These were collected from the inferred southern margin of the Küre basin, close to the Çangaldağ Complex. The separated zircons are dominantly pink, although brown and colourless varieties also occur. CL images and Th/U ratios indicate that igneous zircons predominate. A total of 154 spot analyses were carried out on 90 zircon separates, of which 104 are 90-110% concordant. The source ages range from 178 Ma to 2543 Ma. The most prominent zircon population (40% of whole data) is dated at 270 Ma (Late Permian) to 202 Ma (latest Triassic). Less pronounced populations occur at 275-285 Ma, 300-307 Ma, 380-395 Ma and 440-430 Ma. Notably, Cadomian-aged zircons (550-600 Ma) which form the most prominent zircon population in Palaeozoic and older sediments/meta-sediments of many of the Turkish crustal blocks (i.e. İstanbul terrane, Central Sakarya Basement, Pulur Metamorphics, E Taurides) is completely absent from the sample studied, as are Mesoproterozoic-aged zircons. However, a few Palaeoproterozoic- and Neoarchean-aged zircons are present. The zircon populations dated at 275-285 Ma and 300-307 Ma overlap with the reported crystallisation ages of the Deliktaş and Sivrikaya granitoids that intrude the Devrekani Metamorphics. Four zircon grains dated at ~500 Ma could also correspond to the reported intrusion age of the Büyükçay metabasics. However, there is no obvious source for the 380-395 Ma (Givetian-Frasnian) and 440-430 Ma (Llandovery) zircon populations in the nearby crustal blocks. Meta-granitic intrusions of 395-401 Ma are, however, known from the Sakarya Zone in the Biga Peninsula and from 430 Ma-aged metagabbroic intrusions in the N Caucasus.

Zircons dated as Late Permian-Late Triassic cluster into four time intervals separated by short time intervals that could record hiatuses in magmatism. The oldest interval is dated at 270-255 Ma (Late Permian). No igneous activity is recorded during 251-245 Ma (Scythian). Magmatism is recorded during 242-239 Ma (Anisian), 234-225 Ma (Ladinian-Carnian) and 218-205 Ma (Carnian-Norian).

We envisage the Çangaldağ magmatic arc as the most likely source for the Late Permian-Late Triassic zircon population in the sample studied. Our ongoing dating program in the region will test this hypothesis.

Keywords: Küre Complex; Sandstone; U-Pb dating; Central Pontides

Geochemical features of metabasic rocks from the Jurassic metamorphosed accretionary complexes from the Eastern Pontides (Refahiye and Kurtlutepe metamorphics, NE, Turkey): Implications for the nature of accreated materials

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The Refahiye and Kurtlutepe metamorphics (Erzincan, Eastern Pontides) occur as tectonic slices within the Jurassic peridotites of the Refahiye ophiolite immediately to the north of the Izmir-Ankara-Erzincan suture. The Refahiye metamorphics are made up of greenschist-facies metabasite, marble, serpentine, phyllite and minor garnet amphibolite, garnet mica schist, eclogite and metachert. All the Refahiye metamorphics are well-recrystallized, and are devoid of any obvious relic structures. The Kurtlutepe metamorphics are made up of subgreenschist-facies basic to intermediate metavolcanics, metavolcanoclastics, marble, calc-phyllite and minor carbonized serpentine and metachert. In clear distinction of the Refahiye metamorphics, primary fabrics are well-preserved in the Kurtlutepe metamorphics. Both metamorphic associates are interpreted as metamorphosed accretionary complexes. Timing of the metamorphism in the Refahiye metamorphics are constrained as Early to Middle Jurassic, while that of Kurtlutepe is totally unconstrained. Here we present whole-rock geochemical data on the metabasic rocks from both metamorphic areas, and discuss these data in terms of the accreted materials during the Early to Middle Jurassic subduction.
Metabasic rocks are are variably hydrated (LOI ~ 1.3-5.1 wt %). Geochemically four distinct groups are distinguished: *Group I* display clearly cumulate nature, with anormalously high CaO and Al_2O_3 contents (13-21 and 17- 20.8 wt%, respectively). Group II is similar to ocean island basalt with their moderately to strongly fractionated REE patterns [$(La/Yb)c_n$~8-18] and absence of any Nb-Ta anomaly in normalized multielement variation diagrams. *Group III* is characterized by nearly unfractionated REE ratios [$(La/Yb)c_n$~0.56-1.13] and absence of any Nb-Ta anomaly, thereby resembling unorogenic tholeiitic basalts (N-MORB). *Group IV,* on the other hand, displays nearly flat REE patterns [$(La/Yb)c_n$~0.6] and negative Nb-Ta anomaly (orogenic tholeiitic basalts). The metavolcanics from the Kurtlutepe metamorphics are geochemically clustered in two groups in terms of silica contents (49-52 and 57-62 wt %). However both groups show obvious negative Nb-Ta anomaly and moderately fractionated REE ratios [$(La/Yb)c_n$~0.8-4], thereby resembling island arc tholeeitic basaltic andesites to andesites.
All these data indicate that the Refahiye metabasics were derived from a substantial amount of accreted seamounts, and minor MORB and IABs. However, the Kurtlutepe metamorphics were derived from basaltic andesite to andesite with suprasubduction signature. The main question to be posed is how the magmatic rocks with suprasubduction zone signature were transported into a trench.

Keywords: Accretionary Complexes; Geochemistry; Geodynamic Evolution; Eastern Pontides

Petrochemistry, ^{40}Ar-^{39}Ar geochronology and Sr-Nd isotopic characteristics of the Eocene post-collisional volcanic rocks from Borçka (Artvin) area: Implication for genesis of Eocene Magmatism in the Eastern Pontides (NE Turkey)

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Major, trace element, Ar-Ar age and Sr-Nd isotopic data are presented for the Eocene Borçka volcanics in the eastern edge of the eastern Pontide orogenic belt (NE Turkey). Borçka (Artvin) volcanics are divided into three suites; basic dyke, Borçka Basalt and Civanköy member. These rocks contain plagioclase (An_{11-93}), clinopyroxene ($Wo_{38-49}En_{38-54}Fs_{8-25}$), hornblende ($Mg^{\#}$=0.57-0.74) phenocrysts and magnetit/titanomagnetite and apatite microphenocrysts. ^{40}Ar-^{39}Ar ages on hornblendes range from 46.9±0.1 to 39.9±0.5 Ma, within the Middle Eocene. The volcanic rocks show calc-alkaline affinities and have low to medium K contents. They are enriched in large ion lithophile (LILE) and light rare earth elements (LREE), with pronounced depleted of high field strength elements (HFSE). The chondrite-normalized REE patterns (La_{cn}/Lu_{cn}=1-19) show low to medium enrichment, indicating similar sources for the rock suite. Initial $^{87}Sr/^{86}Sr$ values vary between 0.70423 and 0.70495, while initial $^{143}Nd/^{144}Nd$ values change between 0.51263 and 0.51285. The main solidification processes involved in the evolution of the volcanics consist of fractional crystallization with minor amounts of crustal contamination±magma mixing. All evidence supports the conclusion that the parental magma(s) of the rocks probably derived from an enriched mantle, previously metasomatized by fluids derived from subducted slab in a post-collisional extension-related geodynamic setting.

Keywords: Eastern Pontides; Sr-Nd isotopes; post-collisional magmatism; Borçka (Artvin) volcanic; Turkey

Deformation and Structural framework of the Tarom (Tarim) Basin, Western Elburz

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The Tarom depression is one of the lowest part of northern Iran located in trans-Caspian Sea region. This morphologic feature is the biggest and lower most inter-mountain basin which is located in the Elburz Range of northern Iran. Geometrically, Elburz mountains are interconnected with Talesh mountains in the form of an extensive arcuate shaped pattern. This is a Neogene sedimentary basin developed at the northern margin of Karaj Paleogene basin that extends laterally for about 90 km and having width of more than 10 km. Seismically active part of the basin comprises the lowest part of the basin situated at about 200m above the sea level. Morphologically, this basin is surrounded by about 3000m high peaks of mountains with marvelous geometries. However, in the tectonic domain of Elburz range no detailed studies have been conducted earlier/ or available in published form which may show the development of this particular basin. However, in the some published literature and geological maps Tarom and other Neogene depressions of the surrounding areas have been interpreted as foreland basins and the Neogene sedimentary succession as piggy back basin deposits. The present studies have been conducted through field observations of the morphological and geological structures of the area which provided informations to construct basin architecture and development. Tarom basin is situated to the northwest and may show continuity of Talegan and Alamut Neogene basins. Based on geological and morpho-tectonic data these basins also show resemblance with each other. According to the staratigraphic correlation of Neogene units these basins seems to show single depositional basin up to the late Miocene. Based on the morpho-tectonic informations this basin segregated into three different Plio-Quaternary basins as a result of post Miocene east-west trending left lateral strike slip fault system development. According to the morphological features and geological markers a sum of 54 km offset towards left has occurred/ happened over Talgan, Alamut, Loshan and Rudbar Faults. The earthquake of June 20, 1990 occurred over Rudbar fault, indicates that this system still active. The Middle –Late Miocene aged Red Formation is covered by Plio-Quaternary fluvial sediments. Generally the sediments deposited within the fault scarp are comprised of coarse grained, poorly sorted and excessive block components. As a result of detailed studies conducted in Tarom basin it is assumed that during the same time and space this depression was controlled by different fault systems towards west. The western margin of this depression was controlled by a fault system with N-S trending normal faults while that of southern margin was controlled by NW-SE trending right lateral strike slip fault with normal component. According to the geometry and position of right lateral and normal fault segments, the general mechanism of the western part of Tarom depression is an extensional releasing bend.

Keywords: Strike-slip deformation, Elburz, Tarom Basin, Releasing bend

Extensional Tectonics and Style of Basin Formation in Northwest Central Iran

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In the central Iran a well defined angular unconformity has developed in between Cenozoic and Mesozoic period. The collision between Arabian and Eurasian plates and consequently following deformation due to convergent tectonics in different areas, the Paleogene sedimentary rock units of northwestern part of central Iran also exhibits the affects of this geological activity. The Paleogene sediments have been exposed over wide areas from Sanandaj-Sirjan zone to Talesh montains and according to the literature their thickness is more than 4 kms. These sediments trending in NW-SE direction and their outcrops laterally extends for about 200 kms. The studies conducted in different areas at the surroundings of Zanjan give informations about deposition, sedimentary environments and structural features of Paleogene sediments. During studies special emphasis was given on the basement related conglomerates forming unconformity and overlying facies variation and their thicknesses in the sub-basin sedimentary succession. The field studies show that Paleogene aged vocano-sedimentary rock units deposited coevally and moreover exhibit the affect of calc-alkaline volcanic activity on broader scale from the middle Eocene. In the previous studies sandstones, shale, tuff and volcanic units has been identified as the Middle-Late Lutesian Karaj Formation which make sharp contact with the basement rocks due to normal fault and at various places completely overlap the basement. The depositional basins developed due to NW-SE trending growth faults along the same strike may be clearly identified on the geological cross-section. The lithofacies of shallow depositional environments typically show more than normal thickness and have alligned along the NW-SE trending growth faults. The deepening trends have also been found in the Zanjan and Tarom sub-basins. The sequence stratigraphy of Tarom area shows the lateral change in lithofacies within the basin in the NE-SW direction. The facies changes and deepening may be directly linked to the extension of Paleogene basin in NE-SW direction. The similar kind of interpretations have been made from the measured sections of basement rocks. In general, the structural and sedimentary relationships of early Tertiary aged units of Zanjan and Tarom sedimentary basins show extensional tectonic regime. The distribution of Paleogene aged sedimentary rock units is directlly related to the block faulting of basement which deposited in a number of basins in NW-SE direction. Moreover, the surrounding transfer zones and faulted blocks show overlapping from Sanandaj-Sirjan Range to southern Caspian Basin. Such structural identifications and interpretations at the surroundings of Zanjan and Tarim areas shows the post Cretaceous extensional tectonics in these areas.

Keywords: Extensional tectonics, Central Iran, Zanjan, Karaj Formation, Growth faults

ISC - 07

PALAEOMAGNETISM OF THE AEGEAN AND ANATOLIAN REGIONS

Conveners:
Orhan Tatar and John Piper

Revised Magnetostratigraphy of the Cappadocian Ignimbrite Succession, Central Turkey, and Neogene Tectonics of the Anatolian Collage

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The Central Anatolian Volcanic Province in Cappadocia includes 13 high volume calc-alkaline ignimbrite sheets emplaced by Plinian eruptions within a succession (the Ürgüp Formation) dated ~11-2 Ma and recording the last phase of Neotethyan subduction accompanying emplacement of the Tauride orogen in southern Turkey. To integrate magnetostratigraphy with recent revisions to the chronostratigraphy we have extended palaeomagnetic investigation to 32 new sites yielding significant ChRM directions. Integrated rock magnetic and palaeomagnetic investigations identify magnetic remanence residing predominantly in Ti-poor titanomagnetites although secondary processes within the ignimbrite sheets, notably post-emplacement oxidation, have locally produced hematisation yielding composite IRM spectra and variable reduction in intensity of magnetisation. The ignimbrite sheets possess weak anisotropies of magnetic susceptibility (AMS, mostly <5%) which describe tensors with an axial distribution close to bedding and minimum axes predominantly perpendicular to this plane; collectively the directions show weak imbrication which correlates with palaeoflow to indicate a dominant emplacement towards the north and east away from an inferred topographic high at the southern margin of the basin. Older ignimbrites (Eneski, Lower and Upper Göreme, Zelve) erupted from the Çardak Centre are all of normal polarity whilst ignimbrites erupted from the younger Derinkuyu Centre (Sarımaden, Cemilköy, Gelveri, Gordeles, and Kızılkaya) are of reversed polarity. These concentrations of uniform polarity may be fortuitous; alternatively they could record magmatic concentrations within limited time intervals (compatible with age evidence from the lower Çardak Centre) or limited remagnetisation of underlying units. The younger Incesu ignimbrite (2.8 Ma) sourced in a centre to the east is of normal polarity. The overall (reversed) group mean direction is D/I = 170.8/-52.4° (N = 9, R = 8.91, α_{95} = 5.4°, k = 91). All pre-Incesu ignimbrites are rotated systematically anticlockwise and show that tectonic rotation in this sector of central Anatolia (16 ± 4° anticlockwise relative to Eurasia) is young and postdates the Derinkuyu Centre (<4.1-6.9 Ma). This is consistent with wider evidence indicating that rotational deformation across Anatolia and the Aegean is distributed and has been confined largely to mid Pliocene and later times.

Palaeomagnetism of the Karacadağ Volcanic Complex of Southern Turkey and Neogene Rotation of the Arabian Plate

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The Karacadağ Volcanic Centre of south east Turkey is a major basaltic complex sited at the northern margin of the Arabian Plate and emplaced in several pulses between ~11 Ma and Late Quaternary times. We have sampled 71 sites in lavas of this complex and undertaken age dating to constrain the timing of the magmatism. Sixty two sites yield significant component definition with mixed normal and reversed polarities. From age dating and morphologic analysis we identify four episodes of lava emplacement and group site mean directions into these divisions to resolve migration of the palaeofield direction with time. Preliminary group mean directions are: D/I = 182°/-47° (N=25, R=23.9, α_{95}=6.3°) for the 11.1 Ma group, D/I = 169°/-45° (N=13, R=12.7, α_{95}=6.6°) for the 7.4 Ma group, D/I = 174°/-45° (N=15, R=14.7, α_{95}=5.9°) for the 2.3 Ma group and D/I = 168°/-49° (N=7, R=6.9, α_{95}=6.7°) for the 0.29 Ma group. Thus from ~7 Ma consistent anticlockwise rotation is recognised through to the late Quaternary. This finding conforms with our results from Neogene igneous complexes further to the west along the northern perimeter of the Arabian Plate. It demonstrates that rotation of Arabia occurred long after collision with Eurasia/Anatolides and closure of the Bitlis suture; it appears to correlate with opening of the Red Sea and instigation of young rotations in the Anatolides and Aegean.

Reconstructing the geometry of central Anatolia during the late Cretaceous: Large-scale Cenozoic rotations and deformation between the Pontides and Taurides

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The Central Anatolian Crystalline Complex (CACC) exposes metamorphic, ophiolitic and igneous rocks that were formed and deformed during closure of the Neotethyan ocean. The CACC is located in central Turkey, between the Pontides in the north and the Taurides in the south, separated by major fault zones. The composite plutons were emplaced between ~95 and 75 Ma, and form linear magmatic belts (~100km long) along the western and northern margins of the CACC. Exhumation of the metamorphic and igneous complex was finalized by Paleocene time.
In this study, we paleomagnetically study fifteen plutons spanning the entire non-deformed upper Cretaceous granitoid belt to test whether the initial configuration of the CACC was modified by vertical axis rotations after its exhumation. Our results show three internally coherent domains with significantly different vertical-axis rotations: (1) in the north-east, the Yerköy-Yozgat block (YYB) records 14.5 ± 6.2° clockwise rotation, (2) in the north-west, the Kırıkkale-Kaman block (KKB) shows a small 6.1 ± 3.6° counterclockwise rotation and (3) in the south-west, the Ağaçören-Aksaray block (AAB) 25.2 ± 4.2° counterclockwise rotation.
We propose that these rotations were accommodated by two transpressional faults: the sinistral Hirfanlar-Hacıbektaş Fault Zone between the YYB and KKB and the dextral Delice-Kozaklı Fault Zone between the KKB and AAB. The restored configuration of the CACC suggests that the three blocks were largely aligned in a ~NNE orientation at an early stage of their history. Consequently, since the late Cretaceous the shape of the CACC was affected by large scale deformation, resulting in its modern triangular geometry. This deformation phase is best explained as a result of collision of the CACC with the Pontides.

Keywords: Central Anatolia; tectonics; paleomagnetism

Paleomagnetic, geochronologic and tectonic constraints on the late Cenozoic evolution of western Anatolia

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The late Cenozoic evolution and related basin formation of western Anatolia in the active Africa-Europe convergence zone is one of the hot topics in geoscience research today. This is mainly due to the complex extensional deformation history of the region where metamorphism, basin formation and volcanism took place coevally. Despite the large number of studies in the region that include many aspects of tectonics, only few appreciated the importance of strike-slip deformation in western Anatolia.
In this context, the study area, which is the topic of this presentation, is located at the western part of Gediz graben in the Aegean Extensional System. It is formed in a seismically (still) active zone of weakness, the İzmir-Balıkesir Transfer Zone. Our field observations and structural evidence obtained from 1:25.000 scale geological mapping of late Cenozoic units exposed Aegean onshore of western Anatolia, show the validity and importance of strike-slip faulting in the Aegean extensional system. Recently, a paleomagnetic and geochronological study have been initiated. To this end, 97 sites have been sampled for paleomagnetism, and 37 sites for geochronologic ($^{40}Ar/^{39}Ar$) purposes. Our structural methods and the sampling sites mainly concentrated on the late Cenozoic units including Miocene lavas and sedimentary rocks.
In this presentation, the late Cenozoic structural evolution and rotation history of the western Anatolia will be discussed in the light of the new paleomagnetic and kinematic data, and new geochronologic data as far as they will be available. This study is supported by the foundation of a Tübitak Project (TUB/109Y044).

Keywords: paleomagnetism, block rotation, $^{40}Ar/^{39}Ar$ ages, İzmir-Balıkesir Transfer Zone, late Cenozoic, W Turkey.

ISC - 08

TERTIARY GEODYNAMIC DEVELOPMENT OF THE AEGEAN REGION: MAGMATIC PERSPECTIVE

Conveners:
Dejan Prelevic and Ioan Seghedi

IN MEMORY OF NEZİH TUZCU

A review of the Eocene to Quaternary volcanic evolution of Western Anatolia: implications for potassic magma generation in collisional regions

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The western Anatolian volcanic province formed during Eocene to Recent times and is one of the major volcanic belts in the Aegean–western Anatolian region. The region has a complex geodynamic evolution during which different tectonic activities occurred. The most prominent events, shaping the region, are (1) northward subduction and consumption of the northern branch of the Neo-Tethys existed between Sakarya Continent to the north and the Anatolide-Tauride block to the south, and formation of the İzmir-Ankara Suture Zone along which the continental blocks collided, (2) post-orogenic extension during which core complexes and Neogene basins with volcano-sedimentary successions formed, (3) northward subduction of the African Plate beneath the Aegean-Anatolian, which rolled-back with time assisting the extensional tectonics in the upper plate, and causing the formation of the South Aegean Volcanic Arc (SAVA).
Taking into consideration the geochemical features, tectonic settings, ages and locations of the Eocene to Recent volcanic rocks in the western Anatolia and Aegean region, they may be grouped as; (1) Eocene volcanic rocks emplaced in a narrow E–W trend along the south of the Marmara Sea, (2) Oligocene to Miocene volcanic rocks emplaced in a roughly NW-SE-trending ellipsoidal belt lying from Rhodope in the NW, to the Menderes Core Complex in SE, (3) local extrusions of late Miocene Ezine and Quaternary Kula volcanics.
The Eocene volcanic episode is represented by low- to high-K calc-alkaline series including basaltic to rhyolitic volcanic rocks. They show arc-like trace element compositions and $^{87}Sr/^{86}Sr$-$^{143}Nd/^{144}Nd$ isotopic ratios. Their geochemical features are comparable with those of the SAVA that also have depleted mantle sources.
Oligocene to Miocene volcanism is characterized by coeval occurrences of (a) high-K calcalkaline series (HKCA) and, (b) K-alkaline series including shoshonitic, ultrapotassic rocks (SHO-UK). Their geochemical features clearly indicate that SHO-UK was derived from mantle-lithosphere and HKCA was from lower crust. The less evolved rocks of SHO-UK indicate that they are commonly enriched in $^{87}Sr/^{86}Sr$, LILE and LREE with respect to the Eocene volcanic rocks. This indicates that their mantle sources were intensely metasomatised by crustal materials, to an even greater degree than those of the Eocene volcanics and SAVA. The geochemical features of the most primitive HKCA are indicative of the dominance of lower crustal melts in their genesis. Primitive andesites then underwent to extensive fractional crystallization processes with or without crustal contamination processes to produce dacites and rhyolites.
The late Miocene Ezine and Quaternary Kula volcanics are characterized by Na-alkaline basaltic rocks with OIB-type geochemical characteristics. The locations of the Ezine and Kula volcanics are also unique sites where tectonic uplift and core complex formations occurred in the region.

Keywords: Western Anatolia; Neogene volcanism; potassic volcanism; post-collisional magmatism

Time and compositional evolution of the Late Cretaceous to Miocene magmatism in South Bulgaria, North Greece and Thrace: Implications for the Late Alpine geodynamic evolution of the Balkan Peninsula

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Based on P-wave tomographic images and modeling for the Eastern Mediterranean region, recent papers propose that a single, long-lived north-directed subduction zone operated from the Cretaceous to Recent. We test this hypothesis by studying the time evolution of Late Cretaceous-Miocene magmatism in South Bulgaria and North Greece.
The abundant Late Cretaceous magmatism in the Srednogorie zone and the northernmost Rhodopes shows a southward or centroclinal shifting from 92 to 67 Ma. Magmatic products are represented by subduction-related extrusive and intrusive rocks of variable composition and unradiogenic initial Sr and radiogenic Nd isotopes. This magmatism is related to the N-NE-ward subduction of the Vardar ocean under the Rhodope Massif. The models of slab retreat and rifting are consistent with the observed increasing mantle input with time. After a break of ~11 Ma, related to continental collision, magmatic activity resumed in the Early-Middle Eocene (56-40 Ma). This magmatism is represented by scattered felsic plutons in the Rhodopes and dacitic and rhyodacitic dike swarms in the Kraishte zone. The rocks have subduction-related signature and isotopic compositions, suggesting significant mantle component and uniform crustal thickness throughout the Rhodopes. The missing mafic magmas most probably were underplated to the crustal base, adding material to the previously collision-induced thickening. Contemporaneity and isotopic similarity of this magmatism to the nearby OIB-like basalts in Eastern Serbia implies a common origin from an astenospheric source that was weekly influenced by intracrustal contamination and fractionation. The magmatism was followed by 5-7 Ma regional uplift and exhumation of Late Cretaceous and Early-Middle Eocene granitoids, and core-complex formation. From 35 to 26 Ma the Rhodope massif and the Pirin-Osogovo zone were affected by new episode of magmatism, directly overlying in places the Middle Eocene granitoids. Volcanic, plutonic rocks and dykes of this phase have variable compositions, strongly controlled by crustal thickness. The rocks in Osogovo-Pirin have felsic composition. The Central Rhodope magmatism is represented by felsic ignimbrites, followed by dykes and intrusions of high-K intermediate compositions. The Eastern Rhodope magmas show the most complex variations from basic to acid and calc-alkaline, shoshonitic to rare ultra-K lithologies. This magmatism ended with OIB alkaline basalts. The geochemistry, isotopic compositions and zircon populations suggest a strong crustal influence on the magmatism, decreasing from west to east and north to south and with time. We suggest that this magmatism is the result of major orogenic extension, caused by asthenospheric uplift and asymmetric crustal thinning. The youngest Early-Middle Miocene (22-15 Ma) orogenic magmatism occupies the southernmost part of the Rhodope Massif. Felsic intrusives dominate its western part, whereas the eastern sector contains intermediate to acid volcano-plutonic associations. This magmatism was synchronous with OIB volcanism in Central and North Bulgaria and older than OIB basalts in the neighbor Trace basin (11-7 Ma). The Early-Late Miocene magmatic evolution mimics the Late Eocene-Early Oligocene magmatism and, most probably, results from similar geodynamic processes.
In conclusion, the Late Cretaceous-Miocene magmatism in the South Bulgaria and North Greece cannot be explained by a long-lived north-directed subduction. A more elaborate model is needed.

Keywords: Late Alpine magmatism, Rhodopes, Srednogorie, geodynamic evolution.

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Extension-related magmatism in Pannonian Basin and Menderes Massif-Comparative remarks

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Major and trace element geochemistry reveal similarities between the magmatism developed from 22 to recent times in the Pannonian Basin (PB) and Menderes Massif (MM) closely related to post-collisional extensional tectonics.

In PB an initial generation at ~22 Ma of rhyolites attests a crustal source; it was followed dominantly by andesite generation through a mixed crustal/lithospheric mantle sources, to a lithospheric mantle source with decreasing subduction component through time up to 11 Ma. Diminution of subduction components in the lithospheric mantle with time favor the further magma mixing with asthenospheric mantle components and then the eruption of asthenospheric magmas. Mixing of magmas derived from the lithosphere and asthenosphere probably caused the sudden increase of Nb/Y that allowed generation of transitional rocks at 10 Ma, dominated by basalts, basaltic andesites. Intermittent, but continuous generation of small volume Na-alkalic basalts between 8 and 0.13 Ma in the central part of the basin suggests a long period of small volume asthenospheric melt production via decompression melting.

In the northern part of MM between 22-13 Ma the volcanic rocks were generated in several NE–SW trending basins that were emplaced during episodic exhumation of the MM as a core complex. Calc-alkaline high-K volcanic rocks were generated associated and followed by K-alkalic and ultra-K volcanics, suggesting both a crustal and an enriched lithospheric mantle sources contribution. Rhyolites dominated during the early Miocene, followed by andesites, trachytes and lamproites during the middle Miocene. At ~ 8 Ma more primitive rocks were generated suggesting that their formation by mixing of lithospheric with asthenospheric mantle-derived magmas. The generation of Na-alkalic basalts from ~ 1.9 Ma up to recent times, in the central area of MM, reflects the presence of asthenospheric upwelling from the late Miocene onwards.

In both regions the subduction fluids created the metasomatized mantle geochemical signature during different subduction events in the course of the geodynamic evolution of each region; beneath MM the lithospheric mantle source was much more metasomatized. Heat from the asthenosphere enabled melting in the hydrated part of lithosphere implicating either underplating or delamination and favored crustal melting. In both cases extension caused heating of the crust and allowed generation of crustal partial melts which, in association and/or mixing with subduction-related lithospheric mantle magmas, made the crust more ductile. The addition of both volume and heat from crustal and lithospheric magmas led to melt-induced weakening at the crust-mantle boundary that initiated the contemporaneous extensional tectonic processes, detachments and block rotations.

Keywords: Pannonian Basin; Western Anatolia; Miocene to Quaternary; Extension-related volcanism; Core complex

Age and isotope-geochemical characteristics of the Tertiary magmatism in Kraishte region, W Bulgaria

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Tectonic reconstruction of the Balkan-Aegean region infer northward subduction and slab retreat from the Jurassic, or at least Cretaceous time to present. Compression and extension during this time leaded to extensive magmatism with specific geochemical characteristics and to the formation of world class ore deposits. Distinctive features reveal the Paleogene magmatic rocks in Kraishte region, Western Bulgaria. They crop out as sill-like subvolcanic bodies and dykes forming a NNW (150-160º) trending strip between the Penkyovtsi trust and the Trun-Kosharevo fault zone. Their morphology is controlled by the Lower-Mid-Cretaceous Penkyovtsi trust and parallel shear zones. Compositionally the rocks are plagio-rhyolites to plagio-rhyodacites with normal calc-alkaline seriality.
For present study we sampled and studied dykes and sills that cross-cut the Carboniferous Ruy granitoids in Trun region, and some subvolcanic bodies that follow the contact between the Carboniferous granites and the Lower Paleozoic basement close to the villages of Erul, Jarlovtsi, Leshnikovtsi and Gorna Glogovitsa. The rhyolites and rhyodacites are fine-porphyric to almost aphiric. They consist of irregularly hydrothermally altered plagioclase (An_{26-29} to An_{38-42}), biotite, needle amphibole and quartz, whereas K-feldspar is only present in the groundmass. Accessory minerals are apatite, zircon and monazite. The major element chemistry is in agreement with published data for normal calc-alkaline seriality. Trace element geochemistry defines mainly VAG-affinity. The rocks are enriched in LREE, with negative Ta-Nb anomaly and reveal adakite-like characteristics with Sr/Y ratio >45 (48-71), low Y content <18 (5.9 to 8.3) and La/Yb>20 (30-40).
Sr-Nd isotope data define a mantle dominated source for the plagio-rhyolites with initial strontium ratios $(^{87}Sr/^{86}Sr)_i$ around 0.7047, and epsilon Nd in a narrow range between -0.2 and +2.4. The Hf-isotope system in the zircons is also clearly mantle-influenced with epsilon Hf mainly between +4 and +6.
The subvolcanic rocks are dated precisely using U-Pb method on zircons and monazite and two techniques - LA-ICP-MS and ID-TIMS. Leshnikovtsi plagio-rhyolite is dated at 43.58±0.56 Ma (LA-ICP-MS data on zircons). ID-TIMS of chemically abraded zircons of the Erul body yield an age of 45.71±0.08 Ma – this is the youngest of four concordant zircons, whereas the other three spread between 47.99±0.03 Ma and 46.61±0.04 Ma. In the Gorna Glogovitsa body the majority of Paleogene zircons concentrate around 44 Ma, and monazites are slightly younger – 42-43 Ma. Considerable amount of inherited zircons and cores are present in the zircon population of all dated samples, ranging from 330 to more than 1000 Ma. The epsilon Hf of these zircons define crustal source for their protoliths.
The new data for the Paleogenic subvolcanic rocks confirm their formation in Pre-Priabonian time in the interval 43.5-45.8 Ma. The older concordant zircon ages are possibly related to negligible lead inheritance from xeno- and antecrysts, whereas slightly younger monazite ages of 42 Ma might be reset by hydrothermal fluids. The mantle Sr-Nd-Hf isotope and trace-element characteristics infer subduction or post-collisional tectonic setting. Adakite-like characteristics are described in many tonalitic (TTG) rocks. They do not necessarily infer slab melting and could be explained by high-pressure amphibole fractionation in the lower crust.

Key words: plagio-rhyolites, Western Bulgaria, U-Pb zircon-monazite dating, Nd-Sr-Hf isotopes

The East Serbian Paleocene alkaline rocks revisited: Evidence of decoupling of Sr-Nd and Pb isotopes in anorogenic setting

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The East Serbian Paleocene mafic alkaline rocks (hereafter ESPMAR) are both in time and space sandwiched between two igneous provinces of a clear orogenic affinity. In the East there are Late Cretaceous calc-alkaline rocks of the Banatitic Timok Srednjegorje Magmatic and Metallogenetic Belt whereas in the West occur Oligocene to Pliocene medium-K calc-alkaline to ultrapotassic rocks. The ESPMAR are predominantly alkali basalts and basanites with La/Nb<0.9, U/Nb<0.07, Ce/Pb>20, $^{87}Sr/^{86}Sr$~0.703, and □Nd>+2, and are very similar to the rocks of other anorogenic provinces in the Circum-Mediterranean area. This geochemical signature generally supports a view that the ESPMAR originated from asthenospheric melts *sensu lato*, again similarly to the petrogenetic explanation of other Circum-Mediterranean anorogenic provinces. Previous trace element inversion modelling slightly refined this interpretation suggesting that small scale asthenospheric melts first metasomatized the lithospheric bottom underneath present day East Serbia and were subsequently melted giving rise to small volume magmas having a strong asthenospheric geochemical signature. On the other hand, some ESPMAR geochemical characteristics transitional to those shown by typical orogenic magmas suggest that there occurred (source?) mixing between melts having asthenospheric and lithospheric geochemical characteristics. However, along with the above mentioned typically anorogenic geochemistry, the ESPMAR display distinctively unradiogenic lead isotopes ($^{206}Pb/^{204}Pb$ mostly <18.6, $^{207}Pb/^{204}Pb$<15.63, $^{208}Pb/^{204}Pb$<38.4) differing from most Circum-Mediterranean provinces except to the unradiogenic group of the alkaline rocks of Sardinia. This suggests that the petrogenetic model explaining the origin of ESPMAR cannot simple involve a predominant asthenospheric source variably mixed with the enriched lithosphere but must account for the unradiogenic Pb signature, as well. Any mixing between the asthenospheric and lithospheric sources (or their magmas) cannot produce the low $^{206}Pb/^{204}Pb$ values observed in ESPMAR because the Serbian Cenozoic ultrapotassic rocks, which can be used as the proxy for the local lithospheric mantle, are more radiogenic in Pb isotopes than the ESPMAR themselves. Therefore, we propose here a possible two-step model based on Sr-Nd-Pb variations. The first step is modelled using a primary alkaline basaltic melt ($^{87}Sr/^{86}Sr$=0.7026, $^{143}Nd/^{144}Nd$=0.51300, $^{206}Pb/^{204}Pb$=19.50, $^{207}Pb/^{204}Pb$=15.60, $^{208}Pb/^{204}Pb$=38.50, Sr=600 ppm, Nd=30 ppm and Pb=2 ppm), which is contaminated (in the source?) by a hypothetical EMI-like component ($^{87}Sr/^{86}Sr$=0.7060, $^{143}Nd/^{144}Nd$=0.51210, $^{206}Pb/^{204}Pb$=17, $^{207}Pb/^{204}Pb$=15.45, $^{208}Pb/^{204}Pb$=37, Sr=250 ppm, Nd=20 ppm and Pb=10 ppm). After only ~15 % of contamination the resulting melt acquires unradiogenic lead isotopes similar to those observed in the ESPMAR simultaneously retaining its low Sr and high Nd isotope ratios. In the second step these contaminated magmas are further mixed with lithospheric melts having orogenic geochemical characteristics (average primitive Serbian ultrapotassic rock). The second step mixing is, hence, responsible for other geochemical characteristics shown by ESPMAR, such as the positive correlation between Sr isotopes and K_2O and Rb contents. Geotectonic implications of such a model are difficult to discern in this stage but they will be better known after constraining the EMI-like end-member more in detail.

Keywords: alkaline magmatism; intraplate setting; post-collision; Balkan Peninsula; Southeast Europe

Tracking post-collisional dynamics of orogenic mantle in Southwestern Anatolia, using ultrapotassic mafic rocks as geochemical proxies

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High-Mg ultrapotassic volcanic rock occurrences of lamproitic affinity are exposed in southwestern Anatolia, mostly in proximity or within the Menderes Massif. From north to south this volcanism shows increasingly younger ages ranging from 20 to 4 Ma. Volcanism is contemporaneous with more voluminous shoshonitic, high-K calc-alkaline, and ultrapotassic magmatic activity in the Simav–Selendi, Uşak, Kırka, Köroğlu, Afyon and Isparta–Gölcük areas. The southward decrease in the age of the volcanism correlates with changes in geochemical composition, particularly a decrease in $^{87}Sr/^{86}Sr$, $^{207}Pb/^{204}Pb$, Zr/Nb and Th/Nb, and an increase in $^{143}Nd/^{144}Nd$, $^{176}Hf/^{177}Hf$, $^{206}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$ and Ce/Pb, thus delineating a systematic change from orogenic (crust-like) to anorogenic (convecting mantle-like) signatures. Rare earth element compositions of clinopyroxene phenocrysts demonstrate an increasing role for residual garnet for locations in the central parts of the Menderes Massif, indicating a lithosphere thickness greater than 80 km. In contrast, K_2O abundances remain nearly constant at around 7%, indicating buffering by phlogopite in the mantle source.

Magma genesis in Southwestern Anatolia is controlled by post-collisional extensional events initiated after major lithospheric thickening. Geochemical constraints suggest that the mantle source experienced two main geodynamic stages. The first stage caused ultradepletion of the mantle and subsequent metasomatic enrichment, which allowed coupling of the geochemical signatures of ultradepleted harzburgite with those of crust-derived sediments. This most probably happened during the final closure stages of the southern Neotethys Ocean and the accretion of forearc oceanic lithosphere (island-arc type), as shallowly subducted material to the Anatolian lithosphere. The second stage is post-collisional, and is related to the collapse of the orogenic belt and the development of extension-related horst and graben structures. This stage is concurrent with the initiation of a thermal anomaly originating from a gap, identified by seismic tomography, in the subducted slab under western Anatolia. We propose that the lithospheric mantle underwent intense 'asthenospherization' owing to lithosphere–asthenosphere interaction, caused by the southward expansion of this gap during slab roll-back. The geochemical resemblance of the lamproites to more voluminous, contemporaneous shoshonitic magmas implies their derivation from a heterogeneous mantle source that had been affected by similar processes. These mantle processes may be closely associated with the major episode of uplift in the Menderes Massif.

Keywords: lamproites, Menderes, slab tear

Geochemical and geochronological implications of the Gölcük volcano, SW Turkey

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Post-collisional alkali-potassic to ultrapotassic magmatism along the N-S oriented Kırka-Afyon-Isparta trend in SW Turkey initiated during Late Miocene and active throughout the Pliocene and Quaternary. In the Isparta district, magmatic activity termed as Gölcük volcanism can be divided into two main phases of igneous activity such as Pliocene lava extrusions and Quaternary explosive volcanic activities. The older Pliocene volcanics mainly comprise lamprophyre (minette), basaltic trachyandesite, trachyandesite, and trachyte. Field mapping and radiometric data indicate that the main volcano-forming stages of the Gölcük volcano consist of three main eruptives cycles. (1) Cycle I, starting around 200 ka with major explosive events represented by at least six ignimbrite sheets, (2) Cycle II, represented by tephriphonolite lava dome-flows currently found along the rim of the present crater that occurred between 115 ± 3 ka to 62 ± 2 ka with probably some associated tephra deposits, (3) Cycle III, made up of tuff-ring deposits with plutonic enclaves related to several phreatoplinian eruptions of a maar-type volcanic activity that formed from 72.7 ± 4.7 ka to 24 ± 2 ka. This youngest cycle ends with trachytic domes protruding within the maar crater.

The Gölcük flows and pyroclastics are mainly characterized by strong incompatible element enrichment in large ion lithophile elements (LILEs; e.g. Cs, Ba, U, and Th) relative to K, Rb, and high-field strength elements (e.g. Nb, Ta, and Ti) on the mantle-normalized incompatible trace element diagrams. They also show strong LREE enrichment on the chondrite-normalized REE diagrams, suggesting a metasomatized lithospheric mantle source. In the older (Pliocene) lavas, $^{87}Sr/^{86}Sr$ isotope ratios of the evolved trachyte–trachyandesites range between 0.70366 and 0.70504, whereas these ratios are lower in the less evolved basaltic trachyandesite and lamprophyres, varying in narrow ranges around 0.70365 and between 0.70374 and 0.70453, respectively. The $^{143}Nd/^{144}Nd$ values lie between 0.51264 and 0.51273 in trachyandesites, 0.51267 and 0.51273 in basaltic trachyandesites, and 0.51270 and 0.51274 in lamprophyres. The $^{87}Sr/^{86}Sr$ isotope ratio is 0.70361 in the tephriphonolite and 0.70388 in the trachytic lava dome within the crater. The $^{143}Nd/^{144}Nd$ isotope ratio is 0.51274 in the analysed tephriphonolitic flow and 0.51271 in the intracaldera trachytic lava dome. The eNd values of the Gölcük volcanics range between 0 and 2.0. The isotopically depleted and incompatible enriched nature of the Gölcük lavas point to recent enrichment processes prior to partial melting of the mantle source. All the geological and geochemical data show that the alkaline Gölcük lavas display a gradual decrease in silica content with decreasing eruption age, suggesting major extensional fault systems that acted as natural conduits for the transport of less contaminated alkaline magmas to the surface. Therefore, the asthenospheric melt component became more important over time in an extensional tectonic regime since Pliocene time in the Isparta district, consistent with the Western Anatolian setting controlled by the Aegean extension during recent Pliocene-Quaternary times.

Keywords: Gölcük volcano, potassic magmatism, tephra, mantle, Quaternary

Geochemical and Sr-Nd isotopic constraints from volcanic and plutonic associations in the central part of the Menderes Metamorphic Core Complex: role of crust and mantle components

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Volcanic and plutonic associations in the Central Menderes metamorphic core complex is one of the most suitable regions in order to understand the magma forming processes in extended terrains. This study deals with geochemical features and geodynamic setting of the syn-extensional Salihli and Turgutlu granitoids and coeval Toygar andesite to explore a possible genetic relationship between the volcanic activity and granite magmatism in a syn-extensional setting during Middle Miocene in western Anatolia. Geochemical features of these magmatic rocks were also modeled in order to estimate the relative contribution of mantle and crust sources into magma budget. Salihli and Turgutlu granitoids have granodioritic composition and contain mafic microgranular enclaves of monzonitic-monzodioritic composition. They are transitional metaluminous/peraluminous, calc-alkaline to high-K calc-alkaline and I-type character. The SiO_2 versus major element plots consistently show regular distribution patterns and negative correlation for Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, TiO_2, P_2O_5, Sr, Y, Nb and Zr, but positive correlation for K_2O, Ba, Rb, Th. All of the rocks display enrichment in large ion lithophile elements (LILE). The Toygar andesite contains plagioclase, hornblende and biotite and are composed of medium- to high-K calc-alkaline andesitic lava flows (SiO_2=59.6–62.4 *wt*%). Their primitive mantle-normalized trace element patterns show that they were enriched in LILE and LREE with respect to HFSE and HREE, and negative Nb, Ta and Ti anomalies. The Sr-Nd isotopic composition of the Salihli and Turgutlu granitoids and Toygarlı andesite is $^{87}Sr/^{86}Sr_{(Salihli)}$=0.71101-0.71226, $^{143}Nd/^{144}Nd_{(Salihli)}$=0.51218-0.51221, $^{87}Sr/^{86}Sr_{(Turgutlu)}$=0.71135-0.71163, $^{143}Nd/^{144}Nd_{(Turgutlu)}$=0.51227-0.51229 $^{87}Sr/^{86}Sr_{(Toygar)}$=0.71012 and $^{143}Nd/^{144}Nd_{(Toygar)}$=0.51223. Salihli and Turgutlu granitoids are slightly evolved than the Toygar andesite. It can be suggested that the syn-extensional Salihli and Turgutlu granitoids together with volcanic equivalents, e.g. the Toygarlı andesite, have close similarities in terms of their geochemical and isotopic characteristics and therefore they appear co-genetic. These magmatic rocks were formed by hybrid magmas that were affected by various magma processes. Fractional crystallization, partial melting and crustal contamination processes have relatively minor affect with respect to mixing of mantle-derived mafic and crustal-derived felsic magma. These processes might have been formed due to the retreat of a lithospheric slab that caused development of extensional regime leading to formation of metamorphic core complexes together with volcanic/plutonic associations in western Turkey.

Keywords: Granitoid; Sr-Nd isotopes; volcanic/plutonic association; Menderes Metamorphic Core Complex; crust/mantle interaction

Long-term exhumation of an Aegean metamorphic core complex granitoids in the northern Menderes Massif, western Turkey

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The Menderes Massif, located in southwest Turkey, is the largest known metamorphic core complex on Earth, covering an area of >40,000km2. A core complex forms when lithospheric extension accommodated by detachment faults exposes lower crustal rocks. In many of these systems, including in the Menderes Massif, igneous rocks are cut or deformed by large-scale extensional structures. These rocks may play an important role in the development of core complexes by thinning and weakening crust and driving isostatic doming. They may also time extension by the nature of their structural relationships. Magma bodies can also drive the formation of back arc basins, of which the Aegean Sea is considered by many to be a classic locality. Sources of magma in a back arc setting may be the melting of a subducting slab, a random mantle plume, and/or delamination. Magmas may migrate and geochemically evolve due to the roll back of the subducting slab, a tectonic process that is likely occurring in the Aegean region. Here we focus on understanding the timing and geochemical evolution of three granitoid plutons (Egrigoz, Koyunoba, and Alacam) located in the northern Menderes Massif to understand how extension in the Aegean region is recorded by these bodies. To gain a better understanding of their exhumation history, zircon ages, geochemical analyses, and cathodoluminescence (CL) images were acquired to search for evidence of micro- to macro-scales of deformation. In situ ion microprobe 238U/206Pb zircon ages of the granites range from 30.0+/-3.9 Ma to 14.7+/-2.6 Ma and indicate the plutons crystallized over ~15 m.y. The dated zircons typically show CL zoning consistent with igneous crystallization and are only located in or adjacent to biotite grains. The youngest ages are dominated by a blue color in CL, whereas a majority of older zircon ages are yellow. Most chemical analyses of these granites indicate they are magnesian, calc-alkalic and peraluminous granite to granodiorites, but variations exist, likely reflecting heterogeneity in the plutons themselves caused by magma mixing, partial melting, crustal contamination, and post-emplacement fluid interactions as evidenced by their thin section-scale CL images. Sources for the generation of Northern Menderes Massif granites include simple slab induced upwelling from the subduction of the African plate along the Hellenic arc, adiabatic decompression as the northern edge of the Anatolide-Tauride block delaminates, and upwelling asthenosphere as the continental lithosphere thins during extension. We present a model in which western Turkey is an amalgamation of stacked subduction zones that transition from north to south over time. Northern Menderes Massif granites document their complex tectonomagmatic history in their ages, chemistry, and textures.

Keywords: Menderes Massif; zircon geochronology; cathodoluminescence; magmatism; Aegean

Post-orogenic extension and hydrothermal ore formation: High-precision geochronology of the Central Rhodopian Metamorphic Core Complex (Bulgaria – Greece)

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The Late Alpine evolution of the Rhodope Massif in southern Bulgaria and northern Greece involved post-collisional extension, which generated detachment faults, syn-deformational sedimentary basins and uplift of a metamorphic core complex composed of gneisses and marbles: the Central Rhodopian dome. High-precision geochronology using complementary Ar-Ar, Rb-Sr and U-Pb dating methods resolves how this process of tectonic denudation from deep crustal metamorphism to near-surface ore formation occurred within a period of about 12 million years.

After an Early Alpine phase of accretion, eclogite-facies metamorphism and orogenic nappe stacking, the Late Alpine post-collisional evolution of the Central Rhodopian dome started with the intrusion of granitic bodies at about 42-41 Ma, the beginning of extension and core complex formation. The granites are then cut by tens of kilometers of horizontal displacement along an evolving detachment system. This main phase of extension was followed by cooling of the hanging wall of the dome through ~300°C at about 40-38 Ma (Rb-Sr and Ar-Ar metamorphic biotite). In the footwall of the dome, high temperatures of metamorphism and decompression persisted, resulting in partial melting and the formation of migmatites at 37 Ma. The emplacement of pegmatitic dikes at about 36 Ma marks the latest event in the high-temperature history. Cooling of the footwall below ~300°C occurred between 36 and 34 Ma, followed by emplacement of undeformed subvolcanic rhyolite porphyry dikes and the extrusion of volcanic products deposited onto the surface-exposed centre of the dome at about 33-30 Ma. The hydrothermal ores were formed around 30.5 Ma in the south and around 29.3 Ma in the northern part of the dome, as the last major event of localized heating of near-surface rocks to 270-330°C, by hydrothermal fluid advection.

Field and geochronological constraints indicate that formation of the Pb-Zn deposits (~31-29 Ma) is about 2 Ma younger than the local rhyolitic magmatism, which is volumetrically minor in the mineralized core complex. This contrast with ore formation related with calc-alkaline magmatism in the Eastern Rhodopes, where polymetallic Cu-Au-Ag-Pb-Zn mineralization was found to be coeval with the latest phases of igneous activity (~32 Ma). The chemically simpler but considerably larger metamorphic-hosted Pb-Zn deposits of the Central Rhodopian dome were generated by large-scale hydrothermal fluid circulation driven by the high heat flow attending core complex formation, rapid uplift and anatectic melting in the subjacent thinned crust. Ore formation is therefore directly related to the final stages of orogenic collapse that created the anomalous high heat flow as well as the required large-scale fracture permeability.

At the lithosphere scale, the thermal to hydrothermal history of the Rhodopes was driven by asthenospheric upwelling (Burg, 2012), which followed the southward retreat and eventual break-off of the Mesozoic slab that had driven the large porphyry-Cu-Au systems of southeastern Europe during the Late Cretaceous (von Quadt et al., 2005). This slab retreat and break-off beneath the Rhodopes during the Eocene to Oligocene was later followed by further migration of subduction towards the south, through to the present position of the Hellenic arc and its Aegean back arc basins.

Keywords: geochronology; Pb-Zn deposit; metamorphic core complex

Geochemical, geochronological and geobarometric constraints on lamprophyres from the central Menderes massif – implications for regional geodynamics

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One of the most prominent features of Western Turkey is the Menderes massif, which is regarded as a section of lower continental crust exhumed in the Late Miocene during a period of extension that affected the entire Aegean province. However, there is still much debate on the timing and cause of this extension, particularly with respect to the role of magmatism.
We present the results of work on lamprophyre sills, the only mafic to intermediate igneous rocks in the central Menderes submassif. Our holistic approach to investigation of the lamprophyres includes acquisition of whole rock major element, trace element, and radiogenic isotopic compositions as well as major and trace element analysis of major phenocrysts. Furthermore, U/Pb ages and Hf isotopic compositions of zircon were analysed *in situ* by LA-ICP-MS.
The 15 Myr old lamprophyres are of calc-alkaline affinity and show a continuous range in major element compositions (Mg# 50–66, Cr 84–282 ppm, CaO 3.0–7.2 wt%). Relatively high Mg# and abundances of compatible elements imply that their parental magma was derived from the mantle. The lamprophyres are highly enriched in trace elements (e.g. La 30–73 ppm) and their primitive mantle normalised trace element pattern is similar to subduction zone volcanics, with a peak for Pb and troughs for Nb, Tb and Ti. Whilst showing only little variation in Nd isotopic composition (-1.4 to -3.2 εNd_{15}), initial $^{87}Sr/^{86}Sr$ varies significantly (0.70609–0.71076), even between samples from the same sill (0.70640–0.71059). We attribute this to the incorporation of calcium-carbonate rich in radiogenic Sr, which can be found in most of the rocks in the form of ocelli. This, and the occurrence of different crustal xenoliths, implies that the lamprophyres' parental magma must have undergone compositional changes during its ascent. These changes are also reflected in the composition of amphibole and clinopyroxene phenocrysts, which are sharply zoned into a primitive core (Mg# 77–85, Cr_2O_3 up to 0.95 wt% in clinopyroxenes and Mg# 72–76 in amphiboles) and a more evolved rim (Mg# 68-74, Cr_2O_3 0.07–0.25 wt% in clinopyroxenes and Mg# 69–71 in amphiboles). Trace element ratios between different cores may vary significantly (e.g. Dy/Yb 2–5 in amphibole cores), whereas they are less variable between different rims, which show a general enrichment in trace elements compared to cores.
The lamprophyres fit the general trend of Western Anatolian intermediate to mafic magmas derived from a subduction influenced mantle. Geothermobarometric investigations imply crystallisation of phenocryst cores at 7–8 kbar. During subsequent ascent and emplacement, a change in magma composition must have occurred, which is recorded in phenocryst rims. The final intrusion depth of the sills was about 15 km. This implies a total crustal thickness of about 50 km at the time of intrusion, which fits well with previous metamorphic estimates for the peak of the Menderes massif metamorphism. Zircon ages of 15 Ma correspond to the maximum crustal thickness and therefore date onset of extension after the metamorphic peak.

Keywords: lamprophyres; central Menderes massif; geothermobarometry; zircon ages; isotopes

Mineralogy and petrogenesis of alkaline and calc-alkaline lamprophyres in the NW Iran: implication for mantle heterogeneity

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In northwestern Iran, mica- and amphibole-rich lamprophyres occur mainly as dykes, cutting Pre-Pliocene strata. Two types of lamprophyres are recognized, based on mineralogy, mineral chemistry and whole-rock geochemistry. The rocks from the first group are named alkaline or amphibole-rich comptonitic lamprophyres. They contain kaersutite and diopside, subordinately olivine and phlogopite phenocrysts, in a matrix of the same mafic minerals, feldspars and altered glass. The rocks from the second group can be classified as calc-alkaline lamprophyres or minette. They contain phlogopite and diopside phenocrysts in a matrix of the same mafic minerals, abundant glass and secondary minerals.
Alkaline and calc-alkaline lamprophyres show different evolutional trends in the Harker type diagrams. In comparison to alkaline lamprophyres, calc-alkaline lamprophyres show high K_2O (3.85-8.06 wt%), Rb (69-262 ppm) and Ba (1090-3270 ppm) contents. In the spider diagrams, alkaline lamprophyres show high LILE and LREE abundances without Nb-Ta-Ti anomalies, while calc-alkaline lamprophyres show high LILE and HREE with significant Nb-Ta-Ti troughs. Alkaline lamprophyres suggests characteristics of a magma originated from OIB-type mantle source. Calc-alkaline lamprophyres show characteristics of magmas originated from mantle that was metasomatized by subduction-related processes.
Contrasting geochemical composition and different mineralogy of the rocks from two lamprophyre types demand that they originated from heterogeneous mantle with different proportions of spinel, garnet and hydrous minerals (e.g. phlogopite and amphibole). Calc-alkaline lamprophyres originated from lithospheric mantle enriched in phlogopite and alkaline lamprophyres originated from OIB type mantle enriched in amphibole. Both studied lamprophyre types occur after collision between Iranian and Arabian plates in the post collisional tectonic setting.

Keywords: lamprophyre; alkaline; calc-alkaline; petrogenesis; Iran

Scientific delirium vs. scientific dogma in basalt petrogenesis

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In ancient Greek the "lyra" was the track left by a plough (the "lystron"). To go out of (or jump) the "lyra" was considered a sort of lapse of reason, a raving or, more properly, a delirium. In doing Science, it should be easy to distinguish delirium (i.e., proposing unconstrained or unnatural hypotheses and models) from dogma (i.e., the basic rules governing the systems). Strictly speaking, scientific theories can be falsified, in contrast with dogmas (assumptions) which do not need to be verified. In reality, the distinction between delirium and dogma is not easy, particularly in the Earth Sciences.
The thermal state and chemical composition of Earth's mantle are not yet well known. Not only are the detailed structure and distribution of the chemical and mineralogical heterogeneities unknown in detail, but also the gross features are at best cloudy. Basic and intuitively simple concepts such as geotherm, mantle adiabat, potential temperature, lithosphere asthenosphere and others probably need to be re-thought. The message given by an igneous rock allowing one to infer the characteristics of its mantle source or the tectonic setting of formation is not yet fully understood and may not be understandable at all. There is much chemical and geophysical evidence arguing for disequilibrium at different depths in the Earth's mantle, diminishing the importance of classical thermodynamic approaches. The problem of the scales at which the processes develop must similarly be taken into consideration. As a consequence, the basic assumption that there is chemical equilibrium in the upper mantle also needs re-thinking.
In this framework the more logical scientific hypotheses have been defined as delirium, while other "untouchable" hypotheses (dogma), such as the alleged presence of mantle plumes rooted in the core-mantle boundary layer, survive as zombies. A few didactic concepts will be presented to show how distant we probably are from true understanding of the Earth's mantle dynamics.

Keywords: Basalts; igneous petrogenesis; mantle plume; geochemistry; tomography; petrology

Relationships between very high pressure subduction complex assemblages and intrusive granitoids in the Tavşanlı Zone, Sivrihisar Massif, central Anatolia

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The Sivrihisar Massif of central Anatolia exposes blueschist and eclogite facies metasedimentary and metabasaltic rocks in close association with granitoid plutons. The massif is located within the Tavşanlı Zone, the subducted and exhumed northern continental margin of the Anatolide-Tauride Block. The relationship of the very high pressure assemblages to co-existing granitoid plutonic bodies (Kaymaz and Sivrihisar) is unclear as the region can be considered the type locality for the entrainment of excess argon in K-bearing minerals. Samples from its granitoids and a subduction complex assemblage were collected, imaged with cathodoluminescence (CL), and dated using zircon U-Pb in situ (in thin section) ion microprobe methods. The granitoids are heterogeneous as evidenced by CL images and geochemical variations. Finer-grained Sivrihisar samples are syenite and show plagioclase replacing K-feldspar, whereas coarser-grained rocks are monzonite and show the opposite reaction. Our samples of the Kaymaz granitoids are extremely Si rich (~82-97 wt% SiO_2) and have experienced sericitization. CL images of both granitoids show evidence for fluid interactions at both the subsolidus and lower temperature stages in their tectonic history. Subduction along the Tavşanlı Zone was ongoing during the Early to Late Cretaceous and entrained zircons with igneous zonation in CL that crystallized as early as the Paleoproterozoic. Sivrihisar Massif granitoids record zircon crystallization from the Late Cretaceous to Early Oligocene. Here we present a model in which the Sivrihisar and Kaymaz melts source from a subducting slab along the Afyon Zone further to the south and mix with an igneous component generated during decompression due to break off of the Tavşanlı slab. The model speculates that the Tavşanlı Zone is the northernmost segment of an amalgamation of stacked subduction zones that transition in activity from north to south over time.

Keywords: Sivrihisar Massif; Tavşanlı Zone; zircon geochronology; cathodoluminescence; slab breakoff; high pressure subduction

Petrogenesis of Süphan Stratovolcano, eastern Anatolia, Turkey

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Süphan is a 4050 m high Quaternary stratovolcano in eastern Anatolia, Turkey, with eruptive products extending over an area of approximately 2000 km^2. In this study we investigate the evolution of Süphan in terms of volcanostratigraphy and geochemistry by field studies, new radiometric age, isotope and whole rock data. Our ^{40}Ar-^{39}Ar and previously published K/Ar data reveal that the volcanic products of the Süphan, emplaced over the Miocene and Pliocene-Pleistocene sedimentary units, range between 0.76-0.06 Ma in age. The eruptive products of Süphan Stratovolcano include lavas, domes and pyroclastics consisting of transitional calc-alkaline to mildly alkaline basalts, basaltic trachyandesites, trachyandesites, trachytes, dacites and rhyolites. MELTS modeling is used to assess the possible roles of fractional crystallization and magma mixing on the compositional diversity of Süphan volcanics. Based on the major element compositions, the model (MELTS) suggests that the majority of Süphan volcanics are products of mixing of basaltic trachyandesitic and rhyolitic magmas at lower crustal pressures. EC-AFC modeling of trace element and isotope compositions indicates that the assimilation of the older upper crustal rocks contaminated the Süphan volcanics in the range of 2% to ~10 % on the way of surface. Ba/Th, Pb/Ce, Ba/La, Th/Ce, $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$ ratios suggest that mantle source of the Süphan volcanics was modified by subducted sediments. Partial melting models using the Süphan, as well as the most primitive rocks of the eastern Anatolian volcanics erupted during Miocene to recent time interval point to variable mixing between asthenospheric and lithospheric sources. Melting degree and contribution of the lithospheric mantle appear to have increased from Miocene to Quaternary.

Key Words: Süphan; eastern Anatolia; mixing; asthenosphere; lithosphere

Growth, destruction and resurgence of three volcanic centers in the Miocene Uşak-Güre basin, western Turkey: subaqueous-subaerial volcanism in a lacustrine setting

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Early to Mid-Miocene extension in western Anatolia, related to plate tectonic motions, resulted in the development of a number of normal fault-bounded sedimentary basins as well as a range of styles and compositions of volcanic activity. The Uşak and Güre basins accumulated a thick fluvio-lacustrine fill in which three distinct volcanic edifices (Elmadağ, İtecektepe and Beydağı) and their deposits can overlap with each other and with the sediments produced by the background sedimentation. In addition, complete facies architectures of small-volume (monogenetic) volcanoes have been recognized in association with the three large complex (polygenetic) volcanoes providing a complex mixed siliciclastic and volcaniclastic basin infill in the respective basins where volcanism took place.
The evolution of three previously undescribed volcanic edifices in western Anatolia has been presented for the first time. The stratovolcanoes were generated in a subaqueous-subaerial environment and all the volcanic sequences form a complex succession of effusive-extrusive and explosive deposits with associated reworked deposits. Peperitic textures developed at the base and tops of coherent lava flows are evidence of magma-water interaction during the effusive phases of cone growth.
Elmadağ stratovolcano includes eight distinct pyroclastic flows (ignimbrite; P_1-P_8), three debris flows (D_1-D_3), two block-and-ash flows (B_1 and B_2) and several undefined volcanic debris avalanche deposits; İtecektepe has three pyroclastic flows (P_1-P_3), two debris flow (P_1-P_2), three volcanic debris avalanche deposits (T_1-T_3); and Beydağı exhibits seven pyroclastic flows (P_1-P_7), three debris flows (D_1-D_3) and several volcanic debris avalanche deposits.
Accumulation of the debris flow and volcanic debris avalanche deposits occurred in a subaqueous environment by explosive fragmentation in the presence of water (İnay Lake). Evidence of magma-water interactions are present within the central volcano-tectonic collapse structures of all three edifices, locally interbedded with lacustrine sediments. This indicates that lacustrine conditions persisted during post-destructive stages of volcanic activity.
Collapse and destruction of the three volcanic centres is strongly correlated with tectonic activity. Elmadağ appears to have experienced multiple episodes of sector collapse associated with movements on NE-SW trending basement faults that uplifted basement metamorphic rocks now exhumed in the core of the volcano. In contrast, at İtecektepe and Beydağı the presence of voluminous pyroclastic flow deposits (ignimbrites) suggests that edifice destruction was a consequence of explosive volcanism and caldera formation. It is suggested that the Beydağı area displays a nested caldera structure based on its elongate circular shape and wide-spread and thick pyroclastic flow deposits (e.g. ignimbrites) which widely cover the lacustrine deposits of the Ulubey Formation.

Keywords: Explosive volcanism; phreatomagmatism; volcanic centers; subaqueous-subaerial volcanism; Uşak-Güre basin

Volcanological and petrological features of the south-eastern part of Yamanlar and Yuntdağı volcanic fields (Western Anatolia)

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The Early-Middle Miocene Yamanlar and Yuntdağı (Western Anatolia) volcanic fields occurred along a NE−SW-trending corridor known as İzmir-Balıkesir Transfer Zone. This is a deformed crustal–scale strike-slip fault zone consisting of Upper Cretaceous flysch extending to the NW-boundary of the Menderes Massif. The volcanic activity in Yamanlar and Yuntdağı is closely related to extensional tectonics of (i) İzmir-Balıkesir Transfer Zone and (ii) episodic core-complex denudation of the Menderes Massif. From the volcanological point of view the study area can be characterized as developed from a series of composite volcanoes, whose present vent area is strongly eroded as cut by a variety of fault systems, the transcurrent NW-SE being the dominant one. The remnants of the vent areas, most probably a crater complex, illustrate the presence of numerous dykes or various-size neck-like intrusions and lavas, typically associated with hydrothermal alteration processes (propylitic and argillic). Such vent area was observed in each examined volcanic field, having ca. 6 km in diameter and being much more eroded than the surrounding volcanic products. Lava flows and lava domes, sometimes with associated block-and-ash flow deposits in the vicinity of vent areas constitute the proximal volcanic facies. In the medial facies part, besides lava flows and remnants of lava domes, rare pumice-rich pyroclastic flow deposits have been observed, as well a series of debris-flow deposits.
The rocks have an andesite-dacite composition, display a porphyritic texture and contain in various proportions plagioclase, clinopyroxene, orthopyroxene, amphibole, rare biotite and corroded quartz. The most alkalic rocks have been found in the Yuntdağı volcanic area and include plagioclase, K-feldspar, biotite and amphibole as phenocrysts. From the geochemical point of view the rocks fall at the limit between calc-alkaline to alkalic field, and plot predominantly in andesite and dacites toward trachyandesite and trachydacite fields. From the petrologic point of view, according to the trace element distribution the sampled succession suggest fractional crystallization processes and imply to be derived from a metasomatized lithospheric mantle source.
These preliminary results are part of a volcanological base study in an effort to evaluate the geodynamic controls of the emplacement of the Yamanlar and Yuntdağı volcanic field.

Keywords: Western Anatolia, volcanology, K/Ar age, geochemistry, Miocene volcanism

Kula volcanics and some geophysical signatures

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Kula is located on a block of crystalline rocks of the Menderes Massif, which is delimited by a southward-tilted footwall block of the Simav Graben or a southward-tilted hanging-wall block of the Alaşehir graben. The Kula volcanic area (Burnt Country "Katakekaumene") is on the main İzmir-Ankara road, which has a number of interesting volcanological aspects. The youngest volcanics of western Anatolia, with widespread plateau basalts and well-preserved craters and lava flows, are excellent examples of an alkali basalt province in an area of active rifting. These older grabens (SW-NE trending Gördes, Demirci and Selendi) have thinner sedimentary fills (less than 1 km).

With respect to the extensive volcanism and high heat flow values, the Kula volcanic region and the Yellowstone area in USA show great similarities. The Yellowstone area volcanic field is one of the Earth's most voluminous accumulations of rhyolitic and basaltic material was ejected in three eruptive events, starting about 2 Ma, each of which vented hundreds to thousands cubic kilometers of pyroclastic deposits. The diminutive size of the Kula cinder cones is probably a result of a very low flow rate of magma to the surface and this small volume reflects the small amount of extension in the region ($\beta < 1.2$ where β = final length of crust: initial length of crust).

Plateau basalts do not have magnetic signatures. Magnetic anomalies are very distinctive and these are easily correlated with the second and third phase basaltic intrusions (first and second phases of volcanic cones) of the region having the magnitudes up to 3000 nT. The cones of the volcanoes are at the intersections of the SW-NE trending faults separating the grabens of Demirci and Selendi. The depths and widths of these bodies are in the ranges of 100-200 m and about 1000 m, respectively. These intrusions are almost vertical or slightly inclined northwards.

According to our aeromagnetic results, there are two main magmatic bodies at depth, although at least five volcanic cones have been observed at the surface. In addition to that, these two magmatic bodies are located south of their volcanic products indicating that there should be an available tectonic setting which cause to reaching of the mantle materials to the surface.

Keywords: Burnt Country "Katakekaumene"; Kula Volcanics; Aeromagnetic Anomalies

Heat flow distribution on the Caucasus collision zone

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The Caspian region as the eastern end of the Caucasus collision zone with its energetic resources has been in the centre of attention for a long time. The South Caspian Basin (SCB) for a Pliocene period subsided deeply. The total thickness of sedimentary layer is about 30 km. Investigation of the thermal field is very important for the assessment of oil and gas potential of the region. Different companies conduct vast numbers of geothermal investigations in this region: in deep zones of the water area – by marine and in the shelf – by well technique.
To construct the map of heat flows in the water area of the Caspian Sea there were used results of the determination of the heat flow by marine thermal probes. Moreover, there were used data obtained by the well method in the shelf zone and in the on-shore territory.
It is necessary to note that the shattered areas in SCB are characterized by high fluid activity, which promotes formation of local abnormally high heat flows. In particular as a result of temperature measurements in a crater field continuously working of mud volcanoes of Azerbaijan, which was established the local abrupt anomalies of temperature gradients and heat flows, on three orders exceeds regional background value of appropriate parameters. These results are confirmed by measurements of heat flow in area of a Haakon Mosby mud volcano in the Barents Sea, reaching 1045 mW/m^2. The similar local anomalies of a heat flow (210-600 mW/m^2) were found out in Caspian Sea.
This data demonstrate disintegrated character of the crust and high fluid-dynamic activity in the boundaries of the dissected areas. In these boundaries processes of heat-transportation are shown by equations of heat-mass transportation in porous media. As a result in local areas abnormally high heat flows may be formed.
On the meridional direction are two large (more than 100 mW/m^2) anomalies of heat flow: 1 - north of the Absheron threshold (up to 209 mW/m^2); 2 - in the most loaded part of the SCB-term (600 mW/m^2). The first anomaly is probably the surface manifestation of the modern generation of heat during the past processes of deformation, subduction. They may be echoes of an active subduction in the Cretaceous, which ended in the late Cretaceous (65 Ma). The second anomaly, possibly due to the proximity of partially molten mantle with high-temperature, to the base of the oceanic crust and its compressed state between the continental plates. Due to the badly conductive sedimentary cover with great thickness, the thermal signal from the oceanic crust is strongly delayed. Therefore, there is a low regional background. Nevertheless, there are high local anomalies associated with zones of active tectonic movements, the activity of mud volcanoes and the removal of hot deep fluids to the surface.

Keywords: collision; heat flow; heat flow anomaly;

Petrogenesis of vaugneritic enclaves in the monzonitic plutons of Arasbaran magmatic zone, NW Iran

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Vaugnerites are mica-rich meladiorites, geochemically intermediate to basic (SiO_2<60 wt%) and high-magnesium and-potassic rocks (MgO> 4 wt%; K_2O> 3 wt%) that were firstly reported in the French Massif Central. They can be considered as plutonic equivalent of kersantite-type lamprophyres. In the Arasbaran magmatic zone (AMZ) in NW part of Zagros suture zone (NW Iran), vaugneritic enclaves occur in monzonitic plutons. Shoshonitic monzonitic intrusives are widespread in the AMZ with ages ranging from 29 to 26 Ma. The compositions of intrusive rocks range from monzodiorite, quartz-monzonite to quartz-syenite. Enclaves and host intrusives are coeval, and enclaves often show lobate and gradual contacts. Also, enclaves with fine-grained, chilled margins are common, especially in the marginal part of the intrusions. The size of the enclaves ranges from less than 10 cm up to 10 m and show poikilitic, porphyry and pegmatitic textures. Phlogopitic mica, diopsidic clinopyroxene and kaersutite amphibole are common mafic minerals. Some green amphiboles with hornblende-actinolite composition occur in smaller enclaves. Potassium feldspar and plagioclase mainly occur in the matrix. Potassium feldspars are mainly pertitic and hypersulvus in the central parts of the crystals. Host monzonitic intrusives include diopside, phlogopite, kaersutite, and green amphiboles as the main mafic minerals, and plagioclase, potassium feldspars and quartz as the felsic minerals. In some samples, pseudomorphs of olivine can be found that are partially or totally replaced by phlogopite.
Studied enclaves have shoshonitic composition and contain SiO_2 (52-48%wt), TiO_2 (>1.5%wt), FeO (>8%wt), MgO (>5%wt), CaO (>7%wt), MgO/CaO (0.7-0.9), high total alkali (5-7%wt) and K_2O/Na_2O (1.53-1.83). In the studied vaugneritic rocks K-number (K#=mol (K_2O/K_2O+Na_2O)*100) varies from 60 to 65 and Mg-number (Mg#=mol (MgO/MgO+FeO)) varies between 31-35. Pegmatitic enclaves show high contents in compatible elements (e.g. Ni: 249-630 ppm) indicating their primitive character. Studied rocks represent high LREE, low HREE and $(La/Yb)_N$ between 16-19. In the primitive mantle-normalised spider diagrams they show Nb-Ta negative anomalies and high LILE contents that support a mantle source region, which was affected by subduction-related metasomatism. Vaugneritic magma originated from low degree partial melting of lithospheric mantle, which was metasomatized during previous subduction event. Partial melting of garnet-bearing peridotite, with abundant phlogopite veins, produced potassic basic magma that experienced, fractionation during ascend from the source and emplacement in the final monzonitic magma chamber.

Keywords: vaugnerite; enclave; petrogenesis; monzonite; Arasbaran; Iran

Botev Vrah Thrust – an example of thick skinned compression in Central Balkanides

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The Mesozoic and Cenozoic geodynamic evolution of the fold-and-thrust belt of the Balkanides was related to Early and Late Alpine compressional stages. During the late Alpine collisional stage in Bulgaria the main vergence of the orogen was to the south whereas in its external parts, along Stara Planina Mountain, northward thrusting occurred. The Botev Vrah Thrust is one of the most impressive features related to the Late Alpine crustal shortening in the Balkanides, covering a great part of Central Stara Planina Mountain. The thrusting represents emplacement of pre-Permian crystalline basement over various rocks, the youngest of which are of Upper Cretaceous-Paleocene age.

The carried out investigation aimed obtaining new data for the structure, emplacement mechanisms and age of the thrusting. The principal study methods include field observation and detailed geological mapping, structural investigations along traverses, meso- and microstructural analysis of deformed magmatic, metamorphic and sedimentary rocks of both the hanging wall and footwall, as well as fission-track (FT) analysis.

A characteristic feature of the thrust footwall at the south foot of Stara Planina Mountain is the presence of multiple decametre-scale imbricate structures and duplexes, involving the crystalline basement as well as rocks of the sedimentary cover. This complex thrust zone is reworked during later Alpine extensional events and it is also supposed to reactivate previous zone of weakness – the contact between two different Variscan basement units.

Meso- and microstructural characteristics of tectonites and estimation of deformation related to thrust emplacement in both the hanging wall and the footwall are performed. The observed structural features as well as the data obtained from zircon and apatite FT dating give evidence that the Botev Vrah Thrust represents a brittle fault zone formed at shallow crustal levels, at temperatures 120–250°C. Related to thrusting deformation are the narrow discreet surfaces, built of brittle fault rocks. Only the thrust contact with the Upper Cretaceous–Paleocene sediments in the footwall represents a wide zone of penetrative brittle-ductile deformation. Some mesoscale asymmetric structures observed along this contact provide the first kinematic data for top-to-the N movement of Botev Vrah Allochthon.

The analysis of continuous sections of the Upper Cretaceous–Paleocene deposits, building the immediate footwall, gives evidence for the existence of a relatively shallow foreland basin in front of the advancing Botev Vrah Thrust. The lack of Lower Maastrichtian deposits along the hanging wall and the Late Maastrichtian-Early Paleocene age of the foreland basin, confirms the Late Maastrichtian-Paleocene inversion and initial thrusting. The zircon FT data also confirm the Late Maastrichtian-Paleocene beginning of the thrusting. Synchronous events were documented west- and eastward of the reported area as well along the Balkanides thrust front.

The involvement of basement rocks in the process of thrusting, the relatively small lateral translation of the allochthon, the existing imbrications and the presence of a foreland basin, suggest that the Botev Vrah Thrust is an example of thick-skinned tectonics in the external, peri-platform parts of the orogen, developed during Paleocene–Middle Eocene period.

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Keywords: Botev Vrah Thrust; Central Balkanides; thick-skinned tectonics; foreland basin; Paleocene-Middle Eocene thrusting

Effects of dissolution of mantle orthopyroxene on crystallization of cognate clinopyroxene: evidence from study of Serbian Paleogene xenolith-bearing alkaline rocks

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Paleogene mantle xenolith-bearing alkaline rocks of East Serbia contain five clinopyroxene types (A-E). Type-A (high-Al diopside) appears as megacrysts and has high $^{VI}Al/^{IV}Al$ (>0.8) and Mg# (82-86). Green/colourless-cored phenocrysts are Type-B clinopyroxene and correspond to salite and Fe-Al-rich augite. They also display high $^{VI}Al/^{IV}Al$ (≥1) but distinctively lower Mg# (mostly <75) in contrast to Type-A. Around them occur overgrowths of Type-C clinopyroxene. It is a high-Al diopside with Mg#=72-89, Al_2O_3=4.5-9.5 wt%, TiO_2=1-2.5 wt%, Na_2O=0.35-1 wt% and Cr_2O_3=0.1-1.5 wt%. Type-C clinopyroxene also appears as cores of homogeneous (micro)phenocrysts and cellular interiors of sieve-textured phenocrysts. The rims around Type-C clinopyroxene as well as tiny clinopyroxene microliths correspond to Type-D. It is titanian-rich diopside to salite having Mg# <78, Al_2O_3=6-13 wt%, TiO_2=1.5-4.5 wt%, and Na_2O=0.4-0.8 wt%. Type-C and Type-D clinopyroxene usually show gradual compositional changes. Finally, clinopyroxene occurring exclusively in the reaction selvages around orthopyroxene xenocrysts is Type-E. It is the most MgO-rich clinopyroxene with lower Cr_2O_3 and higher Al_2O_3 and Na_2O_3 contents for given Mg# in comparison to Type-C clinopyroxene. According to Cr/Al vs Al/Ti and Cr/Al vs Na/Ti modelling, the calculated clinopyroxene obtained from a mixture of the host basanite magma and 2-20 %wt mantle orthopyroxene is compositionally similar to Type-C clinopyroxene. On the other hand, there are textural characteristics suggesting that Type-C, D and E crystallized directly from the host basanite. By contrast, Type-B clinopyroxene displays strong textural evidence of disequilibrium conditions with the surrounding melt and is interpreted as xenocrystic in origin. Type-A displays characteristics of both 'xeno' and cognate origin. A MELTS model using average composition of host basanites from (Mg#~70) as a proxy for parental magma showed that the calculated near-liquidus clinopyroxene is generally similar in composition to the Type-A. Despite this, some Type-A megacrysts show evidence of having been xenocrystic in origin (e.g. crystal shapes, similar composition to clinopyroxene occurring within fertile xenoliths and spongy domains or veinlets that indicate that they underwent pyrometamorphic processes upon entrapment). Based on the $FeO/MgO^{cpx/melt}$ modelling and geobarothermometric calculations the crystallization of the studied East Serbian basanites is divided into four stages. The first stage includes the precipitation of clinopyroxene from the host basanite at ~1250 ^{o}C and at ~1.5 GPa (Type-A). The next step is crystalization of a more Mg-rich clinopyroxene. This clinopyroxene has precipitated after the megacrysts but before the Type-D clinopyroxene. Therefore, we suppose that dissolution of orthopyroxene is responsible for decreasing of FeO/MgO^{melt} and for crystallization of Type-E and Type-C clinopyroxene. These two clinopyroxenes crystallized at pressures and temperatures ranging 0.3-0.8 GPa and 1200-1050 ^{o}C, respectively (stage 2 and the first part of stage 3). During the first part of the stage 3 probably crystallized most sieve-textured clinopyroxene. Afterwards, the melt composition gradually shifted towards higher FeO/MgO^{melt} ratios precipitating more evolved Type-C (second part of stage 3) and subsequently Type-D approaching near-solidus conditions (stage 4). According to the model, the clinopyroxene crystallization has terminated at pressures of <0.3 GPa and temperatures of around 950 ^{o}C.

Keywords: alkaline magmatism; xenoliths; megacrysts; xenocrysts; orthopyroxene; resorption

Geochemistry and geochronology of the Paleogene magmatic rocks from Eastern Macedonia and Western Bulgaria

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This study provides geological data about the geochemistry, isotopic composition and the U-Pb isotopic age of the Paleogene magmatic rocks from Kyustendil magmatic zone in Western Bulgaria and from the northern part of the Kratovo-Zletovo area in FYR Macedonia. Most of the described magmatic rocks outcrop in the Serbo-Macedonian Massif and in the Vardar zone, which are major geotectonic units within the Alpine-Mediterranean mountain belt.

The major elements were determined by X-ray fluorescence (XRF) spectrometer using glass beads at ETH, Zurich. The trace elements were analysed with LA-ICP-MS at GI–BAS, Sofia. Pellets with zircons were prepared for “in situ” U-Th-Pb LA-ICP-MS age dating. CL-BSE images of the zircons are made by SEM–EDS (JEOL JSM–6610 LV) scanning electron microscope at the University of Belgrade and CamScan CS 4 scanning electron microscope at ETH, Zurich. Sr and Nd isotopic ratios were obtained by ID-TIMS (Triton Plus) in the laboratory of ETH, Zurich.

The Paleogene magmatic rocks from the Kyustendil area have predominantly acid composition and those from the northern part of the Kratovo-Zletovo area plot in the field of the trachyandesites (latites) and the trachydacites. The igneous rocks from the both regions have high-K calc-alkaline magmatic affinity. Similar geochemical profile is indicated by the contents of the trace elements normalized to primitive mantle, which show high values of K, Cs, Rb, Ba, Th, U, and Pb, and well pronounced negative anomaly for Ta, Nb, P and Ti. The REE-normalized patterns show steeply- deeping slope from LREE to MREE and almost flat HREE distribution. On the diagrams for recognition of the tectonic settings they plot mainly in the field of volcanic arc granites and only the sub-volcanic to intrusive rocks fall entirely in the field of the post-collision granites. The corrected for 30 Ma initial $^{87}Sr/^{86}Sr$ ratio for the Kyustendil magmatic rocks range from 0.708838 to 0.712235, and for the Kratovo area vary in range from 0.706027 to 0.710090, respectively. The LA-ICP-MS U-Pb zircon dating of the studied rocks from the both area define a geochronological time span from 32.5 to 27.5 Ma. The analyses of the zircon population show that the magmatic rocks from Kyustendil area contain large amount of inherited old zircons with two major age diapasons 220- 260 Ma and 400-460 Ma, respectively. In the samples from Northern Kratovo area the inherited zircons are rare or totally absent.

The Paleogene magmatic rocks in the research area have intermediate to acid composition, plot in the high-K calc-alkaline magmatic series and show magmatic arc geochemical signature (VAG) according to their trace elements contents. The REE-normalized patterns infer magma formation in the continental crust. The inherited zircons in the rocks from Kyustendil area suggest that they probably originate by melting of, or by contamination with the rocks of the Vertiskos/Ograzhden unit, which is not exposed on the near surface at this place. The inherited zircons in the samples from Northern Kratovo are rear and have no particular geological significance.

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Keywords: magmatic rocks; trace elements; LA–ICP–MS; U-Pb age dating; zircon.

The petrogenesis of Sarıçimen (Çaldıran-Van) pluton in the east Anatolian collision zone, Turkey

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Eastern Anatolia is a very special area from the point of view of global tectonics. The study area is situated within a typical ophiolitic mélange comprising serpentinite, peridotite, marine and continental sedimentary units, and mafic to intermediate igneous units. In this study, we present major and trace element compositions, K–Ar age and sulfur isotope data from a set of quartz monzodioritic rocks in this region. Quartz monzodiorite porphyry crops out in five different locations in the map area. The Sarıçimen quartz monzodiorite plutons are clearly subduction-related and are exposed as a sub-volcanic pluton within the Upper Cretaceous ophiolitic rocks in East Anatolian Accretionary Complex (EAAC). Quartz monzodioritic pluton consists of feldspar, hornblende, and biotite phenocrysts set in a fine-grained matrix. It shows holocrystalline porphyritic texture. It consists of euhedral prismatic plagioclase phenocrysts up to ~3 mm in size with minor amphibole, biotite and K-feldspar. The groundmass is completely microcrystalline. Major element geochemistry indicates the pluton is of high-K, calc-alkaline, metaluminous character, with a low (0.81–0.90) Aluminum Saturation Index (ASI). Trace element and sulfur isotope geochemistry suggests that the Sarıçimen porphyry was mantle-derived and contaminated by crustal materials during ascent. These rocks parallel the suture zone between the EAAC and the continental crust of the Eurasian continent. Tectonically, this and related volcanic and plutonic rocks in eastern Turkey and Iran are subduction-related and comprise the earliest documented neotectonic igneous activity associated with the final closure of the neo-Tethys between the Arabian and Eurasia plates at ~14–13 Ma (Late Middle Miocene).

Keywords: Sarıçimen; quartz monzodiorite; isotope; K-Ar dating

Geochemistry and geochronology of Ilovitsa magmatic rocks, SE FYR Macedonia

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Subvolcanic bodies (stocks) and numerous dikes and related Ilovitsa Cu-Au deposit are formed during the Oligocene in the area of Ilovitsa village, SE FYR Macedonia. The magmatic rocks cross cut Triassic coarse orthoclase-phyric granite which is intruded in the orthogneisses and amphibolites of Vertiscos-Ograzhden Unit of the Serbo-Macedonian massif. The present study provides new data for the geochemistry and geochronology of the Tertiary magmatic rocks. The aim is to constrain better the time of magma generation and the magma sources.

Major and trace elements are determined on fused pellets using a Philips PW2400 XRF spectrometer (at ETH-Zurich) and LA-ICP-MS (at GI-BAS, Sofia). In-situ U-Th-Pb age dating of the zircons is made applying the LA-ICP-MS method (GI-BAS) and ID-TIMS (at ETH-Zurich). The whole-rock $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios are obtained after a chromatographic cleaning procedure by ID-TIMS (TritonPlus), and the $^{176}Hf/^{177}Hf$ ratios of the heterogeneous zircons are achieved by spatial controlled in-situ LA-MC-ICP-MS (at ETH-Zurich).

The rocks are presented predominantly by granodiorite-porphyry composed of phenocrysts of plagioclase, biotite, rarely K-feldspar and hornblende and accessory apatite, zircon and magnetite set in a fine-grained groundmass of plagioclase, biotite, amphibole and K-feldspar. In some dykes the groundmass has more volcanic-like appearance and they can be considered as dacites. In the granodiorite-porphyry stock mingling between two texturally different but compositionally similar varieties is observed.

The analyzed samples show relatively constant SiO_2 contents ranging from 62.9 to 64.4 wt %. The rocks are high-K calc-alkaline with total alkalis in the range of 6.6–7.55 wt. %. They show high contents of LILE and steep LREE and MREE chondrite-normalized patterns and almost flat HREE normalized patterns. The Eu anomaly is 0.6–0.9, with La_N/Yb_N ratio raging from 7.2 to 13.4. On a primitive-mantle normalized diagram, the rocks show peaks in LILE (U, Th, Pb) and troughs in Nb, Ta, Ti and P. The $^{87}Sr/^{86}Sr_{(i)}$ ratio of 0.70791-0.70883 and εNd -5.25/-7.14 is most probably due to mantle derived magma affected by crust assimilation.

For the present study 7 samples from the Tertiary subvolcanic bodies and dykes, 1 sample from the Triassic granite and 1 from a granite xenolith have been dated using LA-ICP-MS method. To distinguish the small temporal variations between the Tertiary magmatic rocks the precise ID-TIMS method is used. The granodiorite-porphyry stock that hosts the Cu-Au mineralization is formed in two magmatic phases dated by ID-TIMS at 30.31 ±0.054 Ma and 30.126 ±0.032 Ma, respectively. The ages of the dykes range in the interval of 28.8-29.6 Ma but inherited zircon grains with age around 31.5 Ma are also found. The hosting coarse orthoclase-phyric granite is dated at 251.9 ±0.89 Ma and the metagranite xenolith age is 549.0 ±4.6 Ma. The xenocrystic zircons and inherited cores are poorly presented. The LA-ICP-MS age data define several clusters of inherited component with ages of 240-250; 300-360; 420-430; 520-560; 630 and 1070 Ma. The εHf_i of the autocrystic zircons and zircon rims show large variations in the range of -5.2 and +3.5 which can be related to different magma sources (once being mantle dominated), magma mixing and crustal assimilation.

Key words: U-Pb zircon dating, geochemistry, Nd-Sr-Hf isotopes, SE FYR Macedonia

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Petrographic and petrochemical evolution of calc-alkaline volcanic associations of western Turkey: Susurluk volcanites

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Susurluk (Balıkesir) volcanic field, a poorly known magmatic domain of western Anatolia, includes various volcanic products of Miocene magmatism. There are two main volcanostratigraphic groups in the Susurluk volcanites; 1) felsic lavas and associated pyroclastic rocks corresponding to the lower part of volcanic sequence and 2) intermediate lavas and related pyroclastic units representing upper part of the volcanic sequence. Both groups were produced by sub-plinian eruptions of small vents surrounding the Çataldag pluton. Petrographical and geochemical investigations on Susurluk volcanites indicate that they are dacitic (felsic group), andesitic and trachyandesitic (intermediate group) in composition that is consistent with our field observations. The lavas of Susurluk volcanites display mineralogical and textural evidence for interaction between magmas with contrasting compositions. Petrographically, this is evidenced by disequilibrium textures shown by both dacite and andesite lavas. Dacitic and andesitic lavas are medium- to high-K calc-alkaline in composition and have similar major-trace element characteristics. They show enrichment in large ion lithophile elements (LILE) and light rare earth elements (LREE) relative to the high field strength elements (HFSE), similar to the geochemical characteristics of subduction-related or active continental margin magmatic associations. They have high initial $^{87}Sr/^{86}Sr$ ratios (0.707099-0.708785), low $^{143}Nd/^{144}Nd$ (0.512407- 0.512575). $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ values vary from 18,831 to 18,952 and 15,696 to 15,704, respectively and εNd values range between -4.0 and -0.72, indicating that felsic and intermediate groups are co-genetic and they were originated from a common magma derived from enriched mantle (EM II type). Petrographical observations, geochemical and Sr-Nd-Pb isotope data suggest that both mantle enrichment and interaction (magma mixing/AFC) between magmas with contrasting compositions are required to explain the magmatic evolution of Susurluk volcanites.
Our new field observations together with the evaluation of petrographic and geochemical data obtained from Susurluk volcanic field are consistent with enriched-mantle derived and crustally contaminated magmas in a post collisional tectonic setting.

Keywords: NW Anatolia, Susurluk volcanites, Miocene magmatism, Sr-Nd-Pb isotope, post-collisional

Timing and origin of continental (K-type) adakites in NW Anatolia (Turkey)

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We document the occurrence of continental (K-type) adakites in NW Anatolia and present their petrography, major-trace element geochemistry, Sr-Nd isotope compositions and $^{40}Ar/^{39}Ar$ radiometric ages in order to constrain the timing and origin of Adakitic magmatism in NW Turkey. During the Eocene, numerous plutons and porphyries of diverse composition, various forms and sizes intruded into the Izmir-Ankara suture zone (IASZ), which represents the collision zone between Anatolide-Tauride platform and Sakarya continent.
Adakitic rocks are represented by porphyry stocks, sills and dikes that are spatially and temporally associated with some of these Eocene plutons emplaced into ophiolitic and blueschist rocks of Tavşanlı zone. They can be classified as porphyritic microgranite, and microgranodiorite according to their petrographical features. They show holocrystalline, microgranular porphyritic textures, and consist mainly of plagioclase, K-Feldspar, quartz, hornblende and biotite. $^{40}Ar/^{39}Ar$ ages obtained from adakite-like porphyries (53.7 to 54.0 Ma) indicate that adakitic magmatism occurred during the Early Eocene in NW Anatolia.
Adakitic rocks have high K_2O (3.17- 4.91), SiO_2 (69.4-63.8), Al_2O_3 (15.4-16.6) contents, high Sr/Y (113-215) and $La/Yb_{(n)}$ (35-80) ratios and low Y(6.2-11.5), Yb (1.07-0.54) contents, and display enrichments of LILE and LREE , depletion of HFSE and lack of Eu anomaly. They also have moderately enriched $^{87}Sr/^{86}Sr$ (54) (0.70620–0.70660) and low εNd (54) (−2.73 to 0.59). With these geochemical and isotopic features, they can be classified as continental or potassic (K-type) adakites.
Regional geological correlations and overall evaluation of geochronology and geochemistry of adakitic rocks of NW Anatolia suggest that adakitic magmatism was not formed above an actively dehydrating subducted slab, instead, our observations show that they most likely to be produced by partial melting of garnet-bearing lower crustal lithologies and its interaction with mantle melts. Assimilation combined with fractional crystallization (AFC) was also played an important role during the evolution of these melts at shallower crustal levels. We propose that the Eocene break-off of Neo-Tethyan slab might have provided the heat required for the melting of the lower continental crustal lithologies and previously metasomatized SCLM, and induced continental adakitic magmatism in NW Anatolia.

Keywords: Continental adakites; NW Anatolia; Eocene; Magmatism

Origin of the Quaternary bimodal volcanism from the Cappadocian Volcanic Province, Central Anatolia, Turkey: new geochemical and geochronological data

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Neogene-Quaternary Cappadocian Volcanic Province (CVP) is an important and impressive volcanic field in the central Anatolia of Turkey. The Late Neogene evolution of the CVP generally initiated with the eruption of extensive andesitic-dacitic lavas and ignimbrites, and minor basaltic lavas. This stage was followed by a Quaternary bimodal magma suite which forms Na-alkaline/transitional basaltic and high-K calc-alkaline to alkaline silicic volcanic rocks. In this study, we present new geochemical (whole rock and mineral chemical), isotopic (Sr-Nd-Pb and $\delta^{18}O$ isotopes) and geochronological (Ar-Ar and U-Pb) data for the bimodal volcanic series of the Niğde region located in the south of the CVP.
Geochronological data suggest that the bimodal volcanic activity in the study area developed between ~1.1 and ~0.2 Ma (Pleistocene). The Pleistocene bimodal volcanism is represented by (i) felsic volcanics consisting of rhyolitic rocks and pumice-rich pyroclastic fall out and surge deposits, and (ii) mafic volcanics consisting of basalt, trachybasalt, basaltic andesite and scorias, although widespread Late Neogene intermediate compositions are also observed in the region. Felsic volcanic rocks define a narrow range of $^{143}Nd/^{144}Nd$ isotope ratios (0.5126-0.5127), and show virtually no difference in Pb isotope composition ($^{206}Pb/^{204}Pb$ = 18.84-18.87, $^{207}Pb/^{204}Pb$ = 15.64-15.67 and $^{208}Pb/^{204}Pb$ = 38.93-38.99). $^{87}Sr/^{86}Sr$ isotopic compositions of the felsic (0.704-0.705) and mafic volcanic rocks (0.703-0.705) are rather similar reflecting a common source. The most mafic sample from basaltic rocks related to monogenetic cones is characterized by $^{87}Sr/^{86}Sr$ = 0.704, $^{143}Nd/^{144}Nd$ = 0.5127, $^{206}Pb/^{204}Pb$ = 18.80, $^{207}Pb/^{204}Pb$ = 15.60 and $^{208}Pb/^{204}Pb$ = 38.68, suggesting a moderately depleted signature of the mantle source. The felsic rocks have relatively low $\delta^{18}O$ values (5.4-6.0) overlapping mantle values (5.7 ± 0.2%), consistent with an origin by fractional crystallization from a mafic melt. The slightly elevated $\delta^{18}O$ values estimated for the rhyolitic melts suggest some contamination within the crust.
The geochronological and geochemical data suggest that felsic and mafic volcanic rocks are genetically closely related to each other. $^{87}Sr/^{86}Sr$ ratios vs Th relations of the bimodal volcanic rocks indicate that multi-stages of FC and/or AFC processes, instead of unique differentiation, have operated in their genesis. The mafic rocks show a positive trend between $^{87}Sr/^{86}Sr$ and Th whereas the felsic rocks are characterized by a flat or slightly negative variation. These relations indicate that the mafic rocks should be contaminated by wall-rocks having high $^{87}Sr/^{86}Sr$ ratios, while the felsic volcanics were either evolved via pure FC or contaminated by wall-rocks having low $^{87}Sr/^{86}Sr$ ratios. The AFC model results show that the geochemical features of the mafic rocks require assimilation of gneissic rocks with $r \approx 0.35$ (r is the ratio of assimilated to crystallized material) and F≈50% (F is the fraction of melt remaining). However, the AFC model results indicate that the felsic rocks can be modeled starting from an evolved mafic rock sample by $r \approx 0.35$. Consequently, mantle-derived differentiated basaltic melts related to the mafic rocks in the study area, which experienced low degree of crustal assimilation are suggested to be the parental melt of the felsic volcanics.

Keywords: Cappadocia; Pleistocene; bimodal; volcanic; geochemistry; geochronology

ISC - 09

ACTIVE TECTONICS & PALEOSEISMOLOGY & ARCHAEOSEISMOLOGY

Conveners:
Mustapha Meghraoui, Erhan Altunel and Stathis Stiros

Seismic Zones Of The Eastern Mediterranean

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The active tectonics of the Eastern Mediterranean region is the result of the northward motion of the African and Arabian Plates with respect to the Eurasian Plate. The convergence of these plates and the active continental collision create the Aegean and Cyprus subduction zones in the west and the Bitlis-Zagros Fold & Thrust belt in the east.

The Eastern Mediterranean is a seismically active region that both shallow (h<50km) and deep (50 km<h<200km) earthquakes occur. The two prominent seismic zones in the region are the two arc shaped regions which cover the Aegean and Cyprus subduction zones. These two arc shaped seismic zones intersect in SW Turkey, in a region called as Isparta Angle around which significant earthquakes occur. The deep earthquakes occur to the west of Cyprus around Antalya Basin. This area is also characterized by compressional deformation of young shallow sediments. The left-lateral shear zones, namely Pliny, Strabo and Paphos transform faults and the Burdur-Fethiye Fault zone in this area transfer stresses to the Antalya Basin and the Isparta Angle in the region to the west of Cyprus.

In this study we have prepared digital active fault maps for the Eastern Mediterranean. The parameters of active faults have been determined and compiled and a homogeneous and a dynamic database of active faults was created. We have also prepared a comprehensive, declustered seismic catalog for the region. We have examined the seismicity of the Eastern Mediterranean and surrounding regions (bounded by 33˚-38˚ N latitude and 28˚-38˚ E longitude) in the period between 1900-2010. We have delineated 12 seismic source zones taking into account not only seismicity, but also active faults, GPS measurements, and strain rates. The Gutenberg-Richter parameters (a and b values) were determined and their spatial and temporal distributions were mapped for each seismic source zone. In general the b-values obtained from frequency-magnitude relationships are inversely proportional to the state of stress in the earth's crust. The computed spatial distributions in the b-values vary between 0.7 and 1.8 in the eastern Mediterranean region. The most notable seismic energy release regions are the Aegean and the Cyprean subduction zones.

Key Words: Eastern Mediterranean, b value, seismicity, seismic zones, seismic hazard

Late Holocene seismic coastal uplift and subsidence in Rhodes island, SE Aegean Arc, Greece: evidence from ancient shipsheds

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Remains of a ramp of the shipsheds of the ancient (2,300 years old) harbour of Rhodes City on the SE edge of the Aegean Arc were studied in order to shed light on the problem of alternation of coastal uplift and subsidence in this island. Coastal movements are derived from Holocene notches, up to 3.8m high, and are controlled by a major thrust with a lateral component bounding a >4km deep marine basin SE of Rhodes.
The ancient ramp consists of an original structure, atop of which an about 1m layer was built, obviously to counteract a relative sea-level rise. The subsidence and the reconstruction of the ramp occurred BC250/225 and around 150BC according to archaeological evidence, in broad agreement with radiometric dating. Subsidence of circa 1m is assigned to a destructive earthquake circa BC227, known from literary sources, and the wider coast was subsequently uplifted by around 3m during a strong earthquake, probably between 150/120BC and 100BC, as historical, archaeological and coastal data imply.
Island-wide alternation of uplift and subsidence may be explained by shifting of the tectonic activity between two subparallel splaying upward segments of a main thrust offshore SE Rhodes and leading to strong (minimum magnitude >7.5) earthquakes and island-wide coastal uplift. However, subsidence in the town of Rhodes, deduced from the ancient ramp and the lowering of the elevation of uplifted notches, is assigned to a secondary normal fault, reactivated either in response to compression (lateral spreading) or due to local extension in response to oblique thrusting.

Keywords: Rhodes, shipshed, coastal uplift, earthquake

Earthquake potential of Küçük Menderes graben in view of past-present seismicity, tectonic features, crustal deformation and archeological evidences

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There are some major earthquakes (i.e. 17, 262, 4th century, 614, Efes; 1890 M6.2 Efes; 1653 M7.5, Ödemiş; 1880 M5.6 Tire; 1900, 1901 M5 Bayındır etc.) in Küçük Menderes graben in the past. There was a very high seismic activity in the graben during 2002. The graben is bounded by E-W trending normal faults and NE-SW and NW-SE trending parallel sets of strike-slip faults. One can easily recognize those faults in the field. Furthermore, there were some surface cracks occurred in the close vicinity of Ödemiş in 2000-2001, although some tried to relate those surface fractures to excessive water pumping.
The first outhor of this study carried research on the crustal straining and stress variations of the graben using the GPS measurements during 1988-1994. It was pointed out there were noticable variations in the Küçük Menderes graben. The evaluations using the recent measurements reported on different studies indicated such crustal straining and stress variations of the graben have been still continuing.
It is also well known that the historical antique city called Efes (Ephesus) have been destroyed by the earthquakes in the past and the city was abandoned following the earthquake in 10th century. The recent archeological excavations clearly showed the traces of such events of past earthquakes.
In this study, the authors first describe the past and present seismicity, the implications of tectonic features in relation to possible earthquakes in the past, crustal straining and stress variations of the graben and archeological evidences of seismic events. Then the earthquake potential of tectonic features of the graben are evaluated on the basis of the outcomes and conclusions from an integrated review of various aspects related to the seismic events.

Keywords: Küçük Menderes basin, seismicity, tectonic, deformation

A Geo-archealogical evaluation Of 647 AD earthquake affecting Hierapolis And Laodikeia in Denizli region in Turkey

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Turkey is a unique country in accommodating various civilizations in its long history. As a result there are many antique cities and settlements all over Turkey. Most of the antique cities were established by Hatties, Hittites, Phrygians, Karians long before their colonization by Romans and old Greeks although they could have been grown in size and importance during the Roman or Hellenic periods.
Most of the antique cities were established along active the fault zones where there are thermal water spring discharges. Most of these cities were destroyed by strong earthquakes occurred in ancient times. For examples Hierapolis, Tripolis, Laodikeia, Colossea in Denizli, Aphrodisias and Magnesia in Aydın, Ephesus in İzmir and Lagina in Muğla.
An earthquake occurred in the 7th century Lykos (Çürüksu) Valley of Denizli, which affected both Hierapolis and Laodikeia antique cities. The earthquake caused heavy destruction in both cities, resulting in people to leave the city. The recent archeological excavations clearly revealed surface ruptures associated with the earthquake in Hierapolis and Laodikeia
In this study, the authors first describe the evidences of damage to the structures by the 7th century AD earthquake and document the surface ruptures and their characteristics. Then, possible seismic characteristics of the earthquake are evaluated using the empirical relations developed by Aydan in 1997 and in 2007 mainly for Turkish earthquakes. They are then compared with the documented modern time earthquakes in the close vicinity of these antique cities and their implications on Denizli City and close vicinity are discussed.

Keywords: Hierapolis, laodikea, geo-archeology, earthquake

Paleoseismological slip rate on the East Anatolian fault zone around Türkoğlu,

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The left lateral East Anatolian Fault Zone (EAFZ) is one of the most significant tectonic structures of the Turkey. It extends for a distance of about 550 km from Karlıova in the NE and Mediterranean Sea in the SE. The slip rate on the EAFZ previously estimated from recent GPS campaigns, geological and geomorphological data is about 4-11 mm/yr. Geologic and geomorphologic studies along the Gölbaşı-Türkoğlu part of the EAFZ show the recent activity of the fault. The fault is characterized by left laterally offset stream beds and ridges. In order to obtain offset features of surface faulting earthquakes we conduct trench studies around a stream channel. The channel crosses the fault trace perpendicular and it is left laterally offset by 48±5 m. The trench studies on both sides of the channel expose repeated surface rupturing earthquakes since the last 8 ka-yr. Furthermore the buried channel of the stream is identified in 3 different trenches on the downstream area. The buried channel fill is mapped by total station survey and the offset is measured by 78±8 m. The radiocarbon samples from the channel fill yield the channel formation age of 13-15 ka-yr. On the basis of this data the slip rate is estimated 5.6±0.5 mm/yr for Türkoğlu segment of the EAFZ.

Key words: East Anatolian Fault, surface faulting, slip rate, paleoseismology.

Long-term faulting history and related seismic cycle of the Dead Sea Fault

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Recent studies in archeo-paleoseismology made along several sites of the Dead Sea Fault provide evidence of earthquake-related faulting and damage. Coseismic offsets and damage of archeological sites have been identified primarily on the Wadi Araba and Jordan Valley Fault segment, between the Sea of Galilee and Hula Basin, and on several sites between the Lebanese restraining bend and the Amik basin to the northern end of the transform fault.

The detailed mapping of rupture zones showing structural restraining bends, releasing step-overs, patch and segment boundaries, and slip distribution along strike illustrate their geometrical complexities. Our results indicate correlations between seismic events and fault segments with predominant earthquake clustering. Taking into account the geologic and geodetic slip rate (2.5 – 6 mm/yr.), a 2.5 to 5.5 m slip deficit is inferred on some sections also showing present-day seismic gaps since nearly 1000 years. In most cases, the clustering of large earthquakes migrates along fault segments and show off sequence seismic events. The mechanical coupling between off sequence distant earthquakes and laterally propagating ruptures depend mostly on the stress change at fault discontinuities and related block tectonics. The temporal clustering and multi-segment earthquakes ruptures during the last 14 ka with coupling between step-overs and stress change suggests the size and probable length of future large earthquakes along this major continental fault.

Keywords: Dead Sea, earthquake faulting, paleoseismology, archeoseismology

Evolution of the Gölbaşı basin and its implications for the long-term offset on the East Anatolian Fault Zone, Turkey

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The left lateral East Anatolian Fault Zone (EAFZ) is one of the most active major neotectonic structures of the Eastern Mediterranean region. The fault zone runs for a distance of about 550 km between Karlıova in northeast and Mediterranean Sea in southwest. Several fault-parallel basins (such as Hazar and Gölbaşı basins) have been forming along the fault zone. The Gölbaşı basin is the largest basin along the EAFZ and it is located near the junction of the Çelikhan–Erkenek and Gölbaşı–Türkoğlu segments of the EAFZ. Different interpretations including pull-apart and fault wedge were made about the evolution of the basin in previous studies. Detailed mapping shows that the Çelikhan–Erkenek and Gölbaşı–Türkoğlu segments are connected by a releasing bend around Gölbaşı Lake. Our study also suggests that Gölbaşı basin was a wide river valley in which the Aksu River flowed and occupied by a large lake. The valley was blocked by a large landslide at least 31,600 ± 500 years ago in the northeastern corner of the basin and as a result, the Aksu River was captured to the SW corner of the basin. Our scenario implies that the Aksu River valley is left laterally offset by the EAFZ about 16.5 ± 0.5 km, which is the largest documented morphological offset on the EAFZ.

Key words: East Anatolian Fault, Gölbaşı basin, Aksu river, Long-term offset

Economic importance of newly development structures along active transverse fault zones in Zagros Orogen, specially Izeh Fault Zone, Iran

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The major structures of Zagros fold- thrust belt are transversely cross cut by two sets of subsurface fault zones during the late Alpine Zagros orogeny. The first set oriented NNW- SSE shows right- lateral strike-slip movement such as Izeh, Kazerun, Sabzpushan and Sarvestan fault zones. The second set oriented NE-SW and demonstrates left lateral strike- slip movement such as Balarud, Nezamabad, Firuzabad and Razak fault zones. Deformations along these zones inform of curvilinear geometry of the major fold axial traces are visible on the satellite images and aerial photos. However other structures such as strike- slip fault duplex and small scale folds with different orientation than the attitude of major structures of the belt can only be recognized by field studies. These structures, which are referred as younger structures in this study are overprinted on the major structures of the belt.The Izeh fault zone trending N-165 is a right- lateral strike-slip fault located in Dezful Embayment. Remote sensing studies of satellite images along the fault zone show presence of structures such as curvilinear geometry of Sulak and Bangestan axial traces, strike- slip fault duplex and few younger folds. Other significant structures such as small younger folds and thrust faults with W- E trending, normal faults with N- S trending and strike-slip fault duplex can only be mapped at field. These structures can be recognized in all rock formations from old one (Ilam- Sarvak Fm.) to younger one (Bakhtyari Fm. and Alluvium) and are mainly developed in offset zones between the en-echelon arrays of the fault pattern. Geometry and kinematics analysis of these younger and newly developed structures show that from south to north, strain is decrease along the fault zone. The activities of Izeh fault zone that are continuing to present time cause to newly developed subsurface folds in the south and development of brittle structures in the north. So it causes to development of the new hydrocarbon reservoirs in the southern areas. The NE movement of Arabian Plate toward the central Iran is in favor for the reactivation, active deformations and exists of new hydrocarbon reservoirs along the N-S trending Izeh fault zone. Therefore it is proposed that such convergence can account for reactivation and newly developed structures occurrence along the subsurface transverse fault zones, like Izeh, in the Zagros fold-thrust belt.

Keyword: Hydrocarbon reservoirs; Newly development structures; Izeh fault zone; Active transverse faults; Zagros Orogen

The relationship between river channel morphology and active tectonics in the Gediz Graben, Western Turkey

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The Gediz Graben is one of the most significant grabens in western Turkey in terms of sedimentary accumulation and fault development. The structure of the Gediz Graben is dominated by normal faults that can be segregated into two distinct categories; (i) high-angle normal faults that delineate the boundaries of the graben to the north and south, and (ii) a major low-angle (0-20°) north dipping detachment fault on the southern margin of the east-west trending graben. The graben is also characterised by a drainage pattern consisting of largely parallel channels cutting perpendicular to the strike of the elevated graben margins, all merging with the axial Gediz River that flows west to east along the graben floor. Rivers are known to be a significant mechanism of landscape evolution, transferring the influences of tectonic perturbations to the surrounding landscape. If the resultant topography represents a filtered signal of tectonics and climate then it should be possible to work backwards to the original boundary conditions. If it is possible to decode these signals it would give a convenient method that would allow the identification of active faults. This project aims to test this hypothesis using computer and field generated data of both river morphologies and locations of known active faults. An ASTER digital elevation model (DEM) has been analysed using the RiverTools software program to extract the regional fluvial network and allow consequent selection and extraction of river long profiles and upstream drainage area. The morphology and slope geometry of river channels that traverse the southern graben margin and cross the major graben bounding fault have been documented and examined for evidence of knickzones. Detachment-limited channels display a break in slope (i.e. a knickpoint, the knickzone is the area over which the change in slope occurs) at the boundary between parts of the channel adjusted to new uplift rates (in equilibrium) and downstream disequilibrium channel reaches. This leads to a stepping back of punctuated adjustment up the channel towards the source and away from the origin of the disequilibrium conditions, therefore the presence of knickzones are characteristic of base-level changes. The locations of the major active faults have been predicted using analysis of DEM and Landsat imagery in ArcMap and published maps, the results of DEM analysis were verified in the field. Subsequently, the locations and heights of the knickzones have been examined along strike of the graben; these results suggest fault linkage has played a part in determining the height of knickpoints in the southern tributaries of the Gediz River in the Gediz Graben. This in turn shows that rivers are a major apparatus for transmitting the influence of tectonics outwards to the landscape.

Keywords: Rivers; Long profile; Tectonics; Gediz Graben

Seismogenic potential sources in the north-eastern Algeria

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There is a consensus that extreme north east of Algeria situated at the active plate boundary in the Tell system, despite its relatively higher deformation rate, exhibits the lowest seismicity compared with all other regions situated within the north Algerian active Tell belt. On the basis of seismotectonic analysis and geodynamic modeling we try to understand and explain both in cross section and in a map the neotectonic features. We subsequently quantify the potential rate accommodated.

Keywords : Neotectonics; North East Algeria; Modeling; Seismotectonic; Tell.

Paleoseismic behavior of the East Anatolian Fault Zone between Gölbaşı and Türkoğlu: implications on 900 years of seismic quiescence

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The East Anatolian Fault Zone (EAFZ) is one of the main active tectonic structures of the eastern Mediterranean. Most parts of the EAFZ ruptured during the last two centuries. However according to historical earthquake catalogues the strand between Gölbaşı and Türkoğlu was last ruptured in 1513. Thus, this part of the EAFZ has a high seismic risk for eastern Mediterranean region.
The main trace of the EAFZ is mapped in detail on the basis of offset physiographic features, geological evidence and geophysical researches between Gölbaşı and Türkoğlu. In order to obtain geological evidences for paleoearthquakes five trenches were excavated in three different sites. Trench studies provided evidence for 9 historical earthquakes. Paleoseismological data showed that a 2-km-wide restraining bend in the Gölalanı area has been controlling the rupture length for the last 10000 years. Comparing trench data with historical earthquake records showed that ~8500 BC, 1600-2400 BC, 200-400 BC, 1114 AD earthquakes took place to the northeast of the restraining bend. ~7500-8000 BC, 5000-5400 BC, 1513 AD earthquakes took place to the southwest of the restraining bend. 3000-3500 BC, 200-250 AD earthquakes ruptured the fault zone between Gölbaşı and Türkoğlu.
On the basis of obtained paleoseismological record, it is suggested that the restraining bend in the Gölalanı area acts like a seismic barrier between Gölbaşı and Türkoğlu during Holocene. Accordingly, the northeastern part of the Gölalanı seismic barrier has the greatest seismic hazard risk along the southwestern section of the EAFZ after 900 years of seismic quiescence.

Keywords: East Anatolian Fault Zone; paleoseismology; seismic quiescence

Morphotectonic features and seismicity of Demre location (Finike-Antalya)

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In this study, we tried to give information about the seismicity and morphotectonic features of Demre. Demre is located at the southeast of the Teke peninsula southwest of Turkey between the towns of Finike and Kaş. The region is generally mountainous and the average height change from 1500 to 3000 meters. However, tectonic valleys were formed between the high mountains with compitable to high topography. Active fractures clearly observed where it controls valleys, ridge and plains seen on digital elevation map. However, demre plain is semi-graben basin which tectonically conrolled.
Demre is sitted on alluvial plain of Demre River whose ancient name was Myra valley. Demre and surroundings quite highest mountains are largely made up of limestone. This limestones is highly folded and normal faulted.
Demre is located at highly seismic area classified as first degree earthquake zone of Turkey. Demre and surrounding area have many ancient cities, such as; Gagai, Rhodiapolis, Myra-Andriake, Aperlai, Kekova. This ancient cities are quite influenced by the earthquakes in the historical period. As a result, these cities have been completely damaged or abondaned. Active tectonic and seismicity of the region has an important role on the destruction and damaged of these ancient cities. The Aegean trench is the most important tectonic structure that affected the earthquake activity of the region. Demre and surrounding area is located at most important tectonic structure which is Aegean Trench. On the other hand, Fethiye-Burdur Fault zone where large stresses has caused significant damage has also affected this region. Local faults in the region such as; Rhodiapolis Fault, Finike Fault and Myra Fault has an important roles on tectonics of the region. First of the historical earthquake and the largest earthquake damaged Demre and surrounding area is A.D. 60-68 earthquake. On the other hand, A.D. 529-530 earthquake which known as Myra earthquake had caused to heavily damage and tsunami in this region.

Keywords: demre; morphotectonic; myra fault; seismicity.

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SEISMOTECTONICS OF THE AEGEAN SEA REGION

Conveners:
Anastasia Kiratzi and Nihal Akyol

IN MEMORY OF ALPASLAN TÜMER

Subduction Related Seismotectonic Features Associated in SW Turkey

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We investigate the seismotectonic features resulting directly and indirectly from the interaction between the northeast moving African plate and the westward moving Anatolian block focusing mainly offshore and onshore of the region between the Fethiye Bay and the Gulf of Antalya. Our data is the broadband waveforms recorded at the seismic stations run by Kandilli Observatory and Earthquake Research Institute. In addition to these stations we deployed three broadband stations along the Mediterranean seaside to improve the network coverage so as to constrain better the source parameters of the smaller events taking place offshore. The recorded 3-componet waveforms of the small to moderate size earthquakes were analyzed to determine a seismic moment tensor for each event. The tectonic implications of the spatial distribution of the events and their focal mechanism solutions shed light onto the present geodynamic processes taking place along the Anatolia-Africa boundary zone.

Our preliminary interpretation of these results points out three distinct patterns of deformation ongoing in the western, central and eastern part of the region. The tectonics in the western part is mainly influenced from the interaction of the motion along the eastern flank of the Hellenic arc and the southwestward extrusion of Anatolia. The intermediate depth seismic activity along the eastern flank of the Hellenic arc where predominantly left-lateral strike-slip faulting occurs extends well below the Fethiye Bay and even further northeast. The piece of knowledge that gives sign for the propagation of the left-lateral motion further beneath the mainland is based on quite recent data acquired from the Cameli Basin which comes both from the field and seismology. The analysis of the data reveals conjugate extensional directions from NW-SE in Mio-Pliocene and NE-SW to N-S in Quaternary up to present. In the western part although the intermediate depth seismic activity exhibits strike-slip faulting the shallow seismicity shows predominantly normal faulting mechanisms. The central part of the project area undergoes different pattern of deformation where most of the seismic activity is confined within the crust and the dominant focal mechanisms are strike-slip and reverse faulting resulting from north to northeast compression and south- to southeast extension. No normal faulting mechanism events are inferred from the seismological data in the central part though the field data points out several recent normal faulting events. The tectonics of the eastern part of the project area is influenced mainly from the subduction process along the western flank of the Cyprus arc. The intermediate depth seismic activity beneath the Gulf of Antalya exhibits mostly reverse and strike slip faulting resulting from NE compression while the shallow seismic activity show predominantly normal faulting.

Considering the three pattern of deformation we suggest that the western part of the study region is influenced from the northeastward propagation of the eastern flank of the Hellenic arc. Subduction process along the western flank of the Cyprean arc is active and effective beneath the Gulf of Antalya. The central part is a transition between the two where no evidence of subduction is observed and this part is probably the most northern tip of the African plate that touch Anatolian block supporting the highly elevated mountains.

Keywords: Earthquakes, Seismic moment tensors, Subduction, African plate, Seismic deformation

Seismicity and seismotectonic properties of the central east Aegean Sea & western Turkey: a complex deformation zone

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Microseismicity, fault plane solutions, and previously published focal parameter data are used to determine the current tectonic activity of the prominent zone of seismicity in the central part of western Turkey and eastern Aegean Sea, and more specifically near Samos Island, Kusadasi bay and Izmir. We study the activation of adjacent faults in this complex strike–slip and normal fault system using several thousand earthquake locations obtained by applying a double–difference location method, using travel time picks and waveform cross–correlation measurements. The use of accurate location methods is especially required when dealing with very complex areas, where several faulting systems or relatively small seismogenic structures exist. In fact, even though routinely determined epicenters are capable of revealing the rough picture of the seismicity, they are not suitable for studies of the fine structure of the causative fault, as their location uncertainties are often larger than the source dimension itself. The lateral extent of the fault segments range from 5 to 10 km and make up a broad, ~50 km long, fault system. The microseismicity map shows major tectonic lineaments that are compatible with geomorphology and the major faults. The geometry of each segment is quite simple and consists of planar faults gently dipping with an average dip of 40°–45°. The fault planes are not listric but maintain a constant dip through the entire seismogenic volume, down to 15 km depth.
Numerous fault plane solutions were determined, by both teleseismic and regional moment tensor waveform inversions and also first motion polarities, revealing that the stress tensor is in agreement with the clear NS trending extension direction. Groups of microearthquakes show either strike slip faulting with a NS extensive stress (T axis), whereas other groups show oblique normal faulting on EW striking fault planes with a strike–slip component, also under NS extension.
The significant contribution of the study is the detailing of the local active structures and their properties, identified by the microseismicity, to forecasting future locations of strong earthquakes. The hypothesis that underlies this approach is that the smaller earthquakes are delineating locations that are capable of generating larger earthquakes.

Keywords: Samos; Kuşadası; İzmir; Aegean

This work was partially supported by the research project titled as "Seismotectonic properties of the eastern Aegean: Implications on the stress field evolution and seismic hazard assessment in a tectonically complex area", GSRT 10 TUR/1-3-9, Joint Research and Technology Programmes 2010–2011, financed by the Ministry of Education of Greece and the Scientific and Technological Research Council of Turkey (TUBITAK 109Y401).

The January 2012 earthquake sequence in southern Aegean Sea: rupture directivity resolved from apparent source time functions

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On January 26 a moderate size (Mw5.0) earthquake sequence burst in the southern Aegean Sea, 50 km southwest of the island of Thira (Santorini). This event was followed on January 27, by another Mw5.3 earthquake. The region of occurrence is characterized by moderate seismicity. Both events were well recorded by the Greek broadband network and by the Turkish stations along the eastern coast of the Aegean Sea.
The focal mechanisms of the sequence, obtained through a time-domain moment tensor inversion, revealed pure strike-slip faulting, with the axis of the extension trending NW-SE in accordance with regional tectonics. Well constrained depths of the strongest events indicate that the sequence was confined in the depth range from 7 to 14 km. The two nodal planes, with vertical dips, strike NS and EW, respectively. Using the technique of the empirical Green's functions, we were able to deconvolve the apparent Source Time Functions of the two M~5 earthquakes. A clear directivity towards south was found for both events, indicating that the N-S trending plane was the fault plane. This result was further supported by the slip models calculated for both nodal planes, in which case, the N-S trending plane resulted in better % Variance Reduction, compared to the EW trending plane. The slip models revealed a rather simple slip distribution on the fault plane, as expected for a moderate size event. Slip was confined in a single patch, 4 km ×4 km in dimensions. Maximum slip reached 45 cm for the Jan 27 Mw5.3 event. In both cases the seismic moment resolved from the slip models was in agreement with the moment resolved from the moment tensor inversion.
The January 2012 sequence, even though moderate in size, it is significant. First of all, because it occurred in a region where well studied events are rare. It is also significant due to its proximity to the island of Thira, where a volcanic unrest was detected within Santorini caldera since January 2011. The volcanic unrest was mainly detected by a significant seismic swarm and by the rapidly (180 mm/yr) expanding radial deformation, imaged by a dense network of GPS stations. The Jan 2012 seismic sequence occurred when the earthquake swarm activity within the caldera was very strong. Even though the 2012 sequence cannot be directly related to the recent volcanic unrest within the Santorini caldera, however the spatial and temporal proximity of the tectonic processes is striking.

Keywords: Earthquake; Aegean; Cretan Sea; directivity

The 19 May 2011 Mw5.8 Kütahya earthquake: focal mechanism and slip model from the inversion of broad band regional waveforms

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On 19 May 2012 UTC 20:15 a strong (Mw5.8) earthquake struck western Anatolia, (epicenter at 39.137°N; 29.074°E), approximately 80 km SW of the city of Kütahya. The region most affected is Simav, with over one hundred people reported injured. The strong event was followed by many aftershocks the strongest of which was Mw4.6.
The mainshock was well recorded by the Hellenic Unified Seismological Network (HUSNET) and the KOERI network. The broad band waveforms of these networks were used to perform a time-domain moment tensor inversion to obtain the source parameters of the mainshock and of the strongest aftershocks. The best double couple solution for the mainshock reveals that a normal fault ruptured at a depth of 9 km with strike 292°, dip 50° and rake -79°. The seismic moment was calculated to be 6.90E+24 dyn-cm.
To obtain the slip distribution model for the mainshock regional distance ground motions recorded on broadband instruments were inverted for slip through a least squares scheme. The applied method requires simplifying assumptions including constant rupture velocity and dislocation rise time and poses slip positivity, seismic moment minimization and smoothing constraints during the inversion procedure. The implied method is capable to determine the gross characteristics of the slip distribution (both along strike and down dip). These characteristics were adequate to incorporate the major source effect on expected strong ground motions. The slip distribution onto the northward dipping plane appears to be concentrated in a single patch, of dimensions 9 × 8 km², where the peak slip reaches 103 cm very close to the rupture initiation point.
The regionally derived slip model was incorporates in the forward calculation of strong ground motion within a grid 50×50 km cantered at the epicentre location. Full velocity waveforms were computed up to 5 Hz and their peak values were retrieved in order to construct the ShakeMap for the mainshock. Site effects at the nodes of the grid were incorporated in the forward calculations based on the topography gradient as a proxy for the Vs30 and the site characterization. For reasons of comparison synthetic PGV values, using empirical scaling relations applicable to the region, were also compiled. The ShakeMap coincides with the region of the observed intense shaking.

Keywords: Earthquake; slip; moment tensor

Minimum magnitude of completeness in a revised Earthquake Catalog of western Turkey

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An earthquake catalogue compilation for the Western Turkey is accomplished by using data published by the ISC and KOERI institutions from 1964 to 2008. New relations for different magnitude scales conversion into equivalent moment magnitude, M_w^*, were established to secure the homogeneity of the catalogue regarding the magnitude. After the catalogue compilation the magnitude of completeness, M_c, is investigated in both space and time domains. For this purpose we modified the Goodness of Fit test of Wiemer and Wyss (2000) in order to be more effective in datasets that are characterized by smaller sample size and higher Mc thresholds. The study region is divided into four smaller ones on the basis of seismotectonic criteria and data covering different periods are tested to seek for spatiotemporal variation of M_c. The results derived are compared with the Maximum Curvature and the original Goodness of Fit methods for the consistency of the three approaches to be tested. M_c identification appeared quite stable among different approaches and in only a few cases their difference exceeds 0.2 magnitude units. Nevertheless, the Goodness–of–Fit method is very sensitive in the selection of the desirable confidence level whereas the proposed here Modified–Goodness–of–Fit method is free from such influence and thus more reliable when applied in datasets demonstrating higher M_c, or for short time intervals containing limited number of events. We believe that the technique introduced here might be easily applied in other regions with relatively low detection level but with high seismic activity such as the eastern Anatolia and the broader Aegean area, given that it can ensure robust and easily obtained results.

Keywords: Seismicity catalogues; magnitude of completeness; western Turkey

This work was partially supported by the research project titled as "Seismotectonic properties of the eastern Aegean: Implications on the stress field evolution and seismic hazard assessment in a tectonically complex area", GSRT 10 TUR/ 1-3-9, Joint Research and Technology Programmes 2010 – 2011, financed by the Ministry of Education of Greece.

Seismic zonation in Greece: the contribution of earthquake geology

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The recently released Greek Database of Seismogenic Sources (GreDaSS) aims at contributing to SHA in Greece. The database contains the crustal seismogenic sources of this area together with their seismotectonic parameters and other supplementary material (*e.g.* images, literature summaries, references list), which can provide the information needed for calculating SHA. The completeness of the database is high both in terms of the sources number and their principal seismotectonic parameters. An important contribution of GreDaSS to SHA is the enhancement of the seismic zonation of the Aegean Region. Indeed, previous maps were based only on seismological data, ignoring the population, pattern and behavior of seismogenic sources. The homogeneity and the advanced level of completeness of the database allows to support a more realistic seismic zonation consisting of 51 zones of which however, 11 lack of completeness in terms of seismogenic sources. Based on GreDaSS, we estimate the maximum expected magnitude, referred to as M_{geol}. For the same polygons, we also estimate a maximum expected magnitude but based on the recent seismicity. For this purpose, we apply both maximum likelihood method and least squares technique. The historical part of the used catalogue contains only the strongest events, whereas the complete part can be divided into several sub-catalogues each one assumed to be complete above a specified threshold magnitude. Uncertainty in the determination of magnitudes has also been taken into account. Among the several seismological parameters obtained with the statistical analyses, we focus on the maximum regional magnitude ($M_{reg} = M_{observed} + 1\sigma$). We then compare these seismologically based values with the ones determined from GreDaSS, based on geological information. This comparison shows that the 'classical' seismological approaches provide systematically lower values, which can be explained from the fact that the former methods cannot 'catch' the seismic cycle for most seismogenic source and hence the corresponding zones. Few exceptions occur with the opposite sign, but in these cases, the M_{obs} and then M_{reg} is based on old events whose magnitude is still debated in the literature and possibly overestimated in the used catalog. One of the added values of GreDaSS is the possibility to determine more likely worst-case scenarios (M_{max}) taking into account the real seismic potential of the active faults affecting the region. It should be a good practice in the future to fully exploit and include geological information when performing SHA analyses.

Keywords: SHA; seismotectonics; Aegean

The Greek Database of Seismogenic Sources (GreDaSS): state-of-the-art for northern Greece

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The Greek Database of Seismogenic Sources (GreDaSS) is a repository of geological, tectonic and active fault data for the Greek territory and its surroundings. In this paper, we present the state-of-the-art of an on-going project devoted to the building of GreDaSS, which represents the results of decades of investigations by the authors and a myriad of other researchers working on the active tectonics of the broader Aegean Region. The principal aim of this international project is to create a homogenized framework of all data relevant to the seismotectonics, and especially the seismic hazard assessment, of Greece and its surroundings as well as a common research platform for performing seismic hazard analyses, modelling and scenarios from specific seismogenic structures. In particular, we introduce and synthetically describe the results obtained (and included in the database) up to date relative to the northern sector of continental Greece and Aegean Sea. As a first step we collected all available data (both published and unpublished) relative to the historical and instrumental seismicity determining the causative faults. Following the experience of recent 'surprising' earthquakes (*e.g.* 1995 Kozani and 1999 Athens), we realized the deficiency of such approach and decided to include in GreDaSS also active faults (*i.e.* seismogenic sources) recognized on the basis of geological, structural, morphotectonic, palaeoseismological and geophysical investigations. A second step is represented by the critical analysis of all collected data for extracting the necessary seismotectonic information enabling the recognition of as many as possible seismogenic sources as well as their characterization and parameterization. The most updated version of the database consists of numerous seismogenic sources categorized in three types: composite (CSS), individual (ISS) and debated (DSS). The amount of information and the degree of uncertainty is different for the three types.

Keywords: North Aegean, seismotectonics, earthquake geology, active faults

Seismotectonics of the Tyrnavos Fault, Central Greece

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The Tyrnavos Fault, central Greece, represents one of the major ESE-WNW trending, dip-slip normal faults bordering the Late Pleistocene-Holocene Tyrnavos Basin (Northern Thessaly), where a seismic gap has been suggested to occur. Based on geological (structural, morphological and stratigraphic) and geophysical (electrical resistivity tomographies and ground penetrating radar) investigations, the geometry and the kinematics of the fault have been reconstructed in detail, while its Late Quaternary morphogenic activity has been well recognised so far. Some of the major seismotectonic parameters, like fault length (12+ km) and the maximum expected earthquake (M=6.5-6.7), have been also quantitatively constrained. In particular, the excavation of several palaeoseismological trenches allows to document the occurrence of Late Pleistocene-Holocene co-seismic surface ruptures (linear 'seismogenetic' features) commonly associated with morphogenic earthquakes characterised by maximum vertical displacements of 20-40 cm and a mean recurrence interval of about 2-2.5 ka. In the central sector of the fault, where past co-seismic displacements are expected to be the largest ones, new palaeoseismological investigations have been carried out. The two new trenches are up to 7 m in depth show the occurrence of more than 12 co-seismic surface ruptures and record a continuous morphogenic activity since the last 25 ka. The palaeoseismological results provide a very long and complete seismic history of the fault and confirm the recent seismic behaviour and the relatively high seismic hazard potential of the Tyrnavos Fault.

Keywords: morphotectonics; SHA; palaeoseismology

The analysis of the characters of the central Alborz zone earthquakes (400 B.C to 1998 A.C), as small model of Alborz geological zone, Iran

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The main objective of this paper is to analyze the characteristics of central Alborz earthquakes as seismotectonic small model of Alborz range. The central Alborz is a subdivision of Alborz range's geological zone, located in north of Iran. The historical and the measured earthquakes data in the selected area have been selected from 400 B.C to 1998 A.C choosing different references whose magnitudes are more than 4. The earthquakes data contains magnitude, focal depth and epicenter that have been analyzed. Then the earthquake's epicenters have been drawn on faults map of central Alborz as seismotectonic map. The active and seismogenic faults have been determined on the base of geological data, Ambraseys and Berberian works and seismotectonic map as earthquakes source. The conclusion of research shows that 32% of central Alborz's earthquakes have a magnitude of more than 5 with a maximum of 7.6 recorded on the Mosha-Fasham thrust fault. The selected earthquakes focal depths are 10 to 40 km. Most of the earthquakes epicenters occurred on and around the Caspian and fewer earthquakes happened on or around Mosha-Fasham. On the contrary, most of the focal depths of earthquakes distributions are around Mosha-Fasham. The central Alborz borders the Caspian in north and Mosha-fasham thrust faults in south, which is a big horst that was uplifted by the active fault mechanism. Since many villages and towns including the city of Tehran Capital of Iran exist in central Alborz which will be influenced by central Alborz seismisity.

Keywords: Earthquakes data; earthquakes characteristics classification*;* *s*eismogenic faults

Peculiarities of propagation of elastic disturbances in the lithosphere of the northern surrounding of Aegean region

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According to registration by stations of European (including Ukrainian) seismic network of earthquakes of Vrancea zone (Romania) and Asia Minor in particular of last strong 23.10.2011 Turkish earthquake some peculiarities of propagation of elastic disturbances from such earthquakes in the lithosphere of Europe and in particular of the Pannonian-Carpathian-Dinaric region are traced. These peculiarities are good shown in the macroseismic field of strong earthquakes of Romanian Vrancea zone. Isoseists of these earthquakes are strongly elongated in the north and accompanying directions toward the East European platform which is primarily due to geomechanics of the focal zone and associated features of the emission of seismic sources. But the peculiarities of the distant isoseists as it is known according to our research in the Carpathians and according to other authors in other regions are specified by features of structure and the stress-strain state of the lithosphere in the way of propagation of seismic waves. In this connection it is made oneself the attention the high (not least then 4-5 times) attenuation of seismic waves from Vrancea zone earthquakes in the direction of Pannonia and Ukrainian Transcarpathians. The same high attenuation was registered in the region also for the waves of earthquakes in Asia Minor in particular for the last strong Turkish earthquake of 23/10/2011. The seismic waves amplitudes from this earthquake in the Ukrainian Carpathians were 2.8-3 times smaller than the mean amplitudes for the corresponding epicentral distances. This similarity in the nature of the propagation of seismic waves due to the fact that the paths of propagation of elastic disturbances in both cases are very close spatially and the seismic waves pass through the same tectonic structures. Similar effects were observed for surface waves of Turkish earthquake of 23/10/2011 which were registered in the Ukrainian Carpathians by various geophysical equipment including our quartz extensometers and working by us pendulum-tiltmeters of Czech researchers (headed by Dr. Pavel Kalenda). In particular, the amplitude of the surface waves here were 5-10 times less than in other points of European tiltmeters network. One of reasons for the such high attenuation is a complex structure of the lithosphere of all Carpathian-Pannonian-Dinaric region with the presence of large discontinuities and massive (with width up to 50-80 km or more and a thickness up to 15-25 km) Carpathian thrust nappes and structures which dissipate and absorbe the energy of elastic disturbances. Another reason may be geomechanics of zone of connection of Eastern and Southern Carpathians and surrounding tectonic structures. Judging by the Vrancea zone geomechanics here is as if a geomechanical rest which resist to geomechanical pressure from the side of Dobrudja. In this case the tectonic structures of Pancardi are as if under a certain geomechanical protection from the effects of elastic disturbances from this direction. Among the more local causes it is the presence in the Transcarpathians lithosphere of extension zones and subhorizontal weakened zones of lowered velocities.

Keywords: elastic disturbances; Europe’s lithosphere; 2011 Turkish earthquake

Geophysical precursors of the tangible earthquakes (by example of earthquakes of Ukrainian Transcarpathians and Anatolian-Black Sea region)

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Seismoprognostic researches are conducted in Ukraine during the past dozens years. They are aimed to study of local seismicity and to search of precursors of local earthquakes in the most seismically active Crimea and Carpathian regions of Ukraine as well as to study the effects of seismic and precursory effects from earthquakes of Romanian Vrancea zone. In Carpathian region of Ukraine the seismic and extensometric (with quartz extensometers) and geoacoustic (active sounding and natural acoustic emission of rocks) and geothermal (in hydrothermal boreholes) and geomagnetic (including magnetovariational) and electromagnetic (different techniques) and other monitoring studies are performed. There is a network of seismic and regime geophysical stations. During of the study period (more than 30 years) a number of different geophysical precursors of local earthquakes in the epicentral distances 15-130 km are registered. In particular by the method of acoustic sounding with measure the velocity of propagation of acoustic waves (V_p) in rocks and associated nonlinear effects the expressed geoacoustic anomalies-precursors of tangible local earthquakes in Ukrainian Transcarpathians were repeatedly registered. These anomalies were observed during the periods from 2-3 weeks to 3-5 months before the next earthquake and they had amplitudes up to 3-5% from the value of V_p in the quiet period (compared to the fluctuations V_p in the quiet period which not exceed of 0.1%). Geomechanical interpretation of such anomalies often pointed to the stretching mode which is consistent with the data of carried out in parallel lines extensometric researches. Also repeatedly and often in sync with the geoacoustic and deformation precursors the geomagnetic anomalies with similar timing and amplitudes up to 3-10 nT (ΔΔT difference method) were registered. By developing in recent years magnetovariational studies have repeatedly detected predictive effects – anomalies of Wiese vectors behavior (in different time windows for periods of geomagnetic field variations) with duration up to several days before the earthquake. Separate predictive anomalies in the rocks resistance variations (with up to 0.2-0.5% amplitudes and durations from 2-3 weeks to 2-3 months) were registered. In 2011 before the tangible local earthquake (in a distance of 17 km) in the hydrothermal borehole the geothermal precursory anomaly with amplitude up to -0.15 ^{0}C and duration of several months were registered which indicates a lessening of rocks stress in observations point on approximately 0.1 bar. In the Crimean region of Ukraine the seismic and extensometric (with laser interferometer) and tiltmetric (with horizontal pendulums) and magnetovariational and monitoring of groundwater levels and other monitoring studies are performed. There is a network of seismic stations and Geophysical Observatory of Taurida National University (Sevastopol). In 2008 by laser interferometer the pronounced deformation anomaly was registered. They was precursor of tangible earthquake with M=4.9 which was occurred at a distance of about 250 km from observation point. A special method of estimating of deformations in the earthquake source by parameters of predictive deformation anomaly was developed and such estimation for a number of earthquakes of Carpathian and Crimean regions was carried out.

Keywords: earthquake; geophysical anomaly-precursor.

Micro-seismic activity around Izmir City

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Earthquakes which were recorded by the accelerometric network of Izmir (IzmirNET) have been located in this study. The IzmirNET is installed at the end of the 2008 and recorded data that are performed to enlighten the local seismicity (depths, magnitudes, epicenters), focal mechanisms and stress tensor. Sufficient number of events has been obtained from this array for interpreting the area. IzmirNET has recorded approximately 1000 events in Izmir and surrounding area. Events which are located by using SEISAN software, exhibit swarm-type micro-earthquake activity, and may play important role to study a future large earthquake or to predict ground motion from a potential future event.
Clusters have been observed around Narlidere city (South of Izmir Gulf) in the south of Guzelbahce, in the NW-SE direction along the Gulf of Izmir, Menemen settlement at the North, and finally Bornova-Konak cities at the East (South part of the study area). The observed seismic activity in the study area indicates that Izmir faces high earthquake risk. Added to seismicity studies, we also investigated kinematics of faultings using by first-motion P-wave focal mechanism solutions for limited number of earthquakes. Mechanisms generally give pure normal or dominant normal faultings with minor strike-slip components. Stress tensor analysis has been also performed starting from the fault plane solutions. The results indicate that the study area is under extension regime along N-S direction.

Acknowledgement: This study was supported by TUBITAK under the project Nr. 106G159.

Keywords: Izmir; earthquake; seismic activity; strong motion

1 May 2012 Foça (İzmir Bay) earthquake and its aftershocks: Normal faulting in İzmir Bay

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The subduction of the eastern Mediterranean oceanic lithosphere under the Aegean and the westward motion of the Anatolian plate, which is transferred into the Aegean as a simple translation, result to the dominance of dextral strike slip faulting of northeasterly strike, along with conjugate sinistral strike slip faulting, while normal faulting is also very evident. Although the study area, which includes Greek Islands and Turkish coastal districts, constitutes a small part of the Aegean, a complex faulting system is observed. The active deformation results to the intense seismic activity, which substantiated by numerous historical earthquakes that caused extensive damage and loss of life in populated areas.
İzmir Bay is one of the most important morphological structures in the western Turkey. The properties of the tectonic structures in the bay are of paramount importance for earthquake hazard studies of the cities, i.e. İzmir that is the 3rd largest city of Turkey. In this study, we have analysed earthquake waveform data acquired by both Turkish and Greek seismological stations, and determined the details of the 1 May 2012 Foça (İzmir Bay) earthquake and its aftershocks. The activity is the best–recorded cluster in the bay. The preliminary results indicate that a normal fault at the centre of the bay is associated with this activity. The fault plane solutions also reveal a significant strike–slip component for a considerable number of events. The accurate locations provided the opportunity to determine the deep structure of the fault segments in this on going study. These results will contribute as an indispensable component to any future hazard assessment of the region.

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Keywords: Aegean; Foça; İzmir Bay; micro–earthquakes; normal faults

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NON-METALLIC AND METALLIC DEPOSITS OF THE AEGEAN AND EASTERN MEDITERRANEAN REGION

Conveners:
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Occurrence of spurrite-tilleyite-rustumite-hillebrandite (spurrite-merwinite Facies) within the limestone-granite contact in the Güneyce-İkizdere area, eastern Black Sea (Pontides), Turkey

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Rare high-temperature and low-pressure contact-metamorphic assemblages have been found in the Güneyce-Ikizdere area, Eastern Black Sea, Turkey (Pontides), well-known for the kuroko-type massive sulfide deposits (e.g., Çayeli, Murgul, Cerrattepe). Plutonic rocks of calc-alkaline affinity (Rize batholith) intrude Cretaceous volcanic and volcano-sedimentary formations. An unusual contact metamorphism resulted in the development of assemblages belonging to the spurrite-merwinite facies at the contact between a cupola of the Rize batholith and lower Cretaceous limestone. The following rare calc-silicate minerals, mostly forming monomineralic masses, have been identified: spurrite $Ca_5(SiO_4)_2(CO_3)$, tilleyite $Ca_5Si_2O_7(CO_3)_2$, rustumite $Ca_{10}(Si_2O_7)_2SiO_4Cl_2(OH)_2$, cuspidine $Ca_4Si_2O_7(F,OH)_2$, hillebrandite $Ca_2SiO_3(OH)_2$, killalaite $Ca_3Si_2O_7.H_2O$, foshagite $Ca_4Si_3O_9(OH)_2$, gehlenite $Ca_2Al(AlSi)O_7$, monticellite $CaMgSiO_4$, dellaite $Ca_6Si_3O_{11}(OH)_2$, bicchulite $Ca_2Al_2SiO_6(OH)_2$, tobermorite $Ca_9Si_{12}O_{30}(OH)_6.4H_2O$, perovskite $CaTiO_3$, thaumasite $Ca_6Si_2(CO_3)_2(SO_4)(OH)_{12}.24H_2O$ and ellestadite-(OH) $Ca_5(SiO_4,SO_4,PO_4)_3(OH,F,Cl,CO_3)$. These minerals are associated in variable proportion with familiar skarn minerals, such as wollastonite, diopside, vesuvianite, garnet (grossular, andradite, Ti-garnet), Ca-rich amphibole, Ca-rich pyroxene, spinel, magnetite, quartz, calcite and graphite. The area contains the second known occurrence of rustumite and killalaite. Up to now, two new minerals, defernite $Ca_6(CO_3)_{2-x}(SiO_4)_x(OH)_7(Cl,OH)_{1-2x}$ and trabzonite $Ca_4Si_3O_{10}.2H_2O$, have been discovered in the area.

Most of these calc-silicates generally develop under high-temperature and low-pressure conditions. They are principally associated with intrusive bodies of mafic composition, but at this locality, the spurrite-merwinite facies seems to occur at the granite contact and at a lower temperature, typical of the hornblende hornfels or of beginning of the pyroxene hornfels facies, perhaps owing to compositional factors. The maximum temperature at the intrusive contact may be estimated at 600-700°C. A series of retrograde minerals (e.g., defernite, trabzonite, hillebrandite, killalaite, bicchulite, foshagite and dellaite) replace and form as alteration products of the primary skarn minerals in an environment characterized by influx of H_2O-CO_2. Rustumite(Cl), cuspidine(F), ellestadite-(OH)(F,Cl), defernite(Cl) and vesuvianite(F,Cl) carry notable concentrations of F and Cl in these high-temperature skarns.

Keywords: Unusual contact metamorphism (Skarn), high temperature, spurrite-merwinite facies, rare calc-silicates, Güneyce –İkizdere area

Ores of rare earth elements

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Rare Earth Elements (REEs) have various sophisticated and critical industrial and military uses. REEs have been much in the news in the past two years because (1) demand is increasing, (2) China has a monopoly on production, and (3) USA, Japan, EU, etc. had no producing mines from 2002 to 2012.
Geochemically, REE are not rare compared to many other elements, but known ore deposits are. The major cost of production is not the mining but the subsequent chemical refining (separation) of the very similar REEs. Mines will not produce the high-priced REE oxides, but much lower-priced concentrates of ore minerals or precipitated REE carbonate, from which the REEs are refined. Because major mining companies are not interested in small deposits and the small markets of specialty metals, REEs will be promoted and developed by small companies. Perhaps, the economic geology of REEs today is much like uranium was before its major deposits were discovered after the 1960s.
Vein-type deposits of all types, including those in alkaline and peralkaline igneous complexes, are too small, too low grade (commonly < 1 % REE), and/or too radioactive to be significant.
Presently, the largest known REE deposits are carbonatites (intrusions), with 10^7 tonnes of ore with < 9 % REE in the carbonate mineral bastnasite or in apatite; the US example is Mountain Pass, CA, which is being revived at a cost of $781,000,000. In some carbonatites, REEs undergo supergene enrichment. Alkaline igneous rocks have 10^8 tons of mineralization, but they are low grade (< 2% REE) and have such poor recoveries (< 50%) that they are not yet economic. Carbonatites and alkaline rocks can be of any age but are restricted to areas underlain (at some depth) by Archean or Proterozoic crust.
Apatite-rich rocks are potential producers; for example, Nolans Bore, Australia, with approximately 3.3 equivalent % REE, is an apatitite that contains microscopic monazite. Other future production from carbonatites or alkaline rocks might come as a co-product of existing or past producers of other commodities (Nb, Ta, Au, F, Cu, Fe, apatite, vermiculite, bauxite, etc.).
Placer deposits, typically with ≤ 0.09 % REE as by-product monazite, are now of limited importance in REE markets because their production depends upon the prices of their major products (Ti, Zr, Sn, etc.).

Keywords: rare earth elements, carbonatites; alkaline rocks; placers; bastnasite; apatite

"Mythical" Gold Sands of Svaneti (Caucasus, Georgia) and Argonouts Expedition Purpose

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The Caucasus collisional orogen represents the Northern segment of the Eastern Mediterranean region and currently it is an expression of continental collision between the Arabian and Eurasian lithospheric plates. Three major unites are distinguished in its Construction: the Greater and Lesser Caucasian mobile belts and the Inner Caucasian Microplate.

Svaneti region (8000 km^2 - part of ancient Georgian Kingdom of Colchis) is situated on the southern slope of the Greater Caucasus and includes the Basin of Enguri River, which enters the Black Sea. The first written data about Svaneti natural resources are considered in the works of the ancient Greek and Roman scientists. Greek historian Strabo (44 B.C.-23 A.D.) wrote about Svaneti and its natives: "In mountain rivers of this country there is a lot of gold mined by these barbarians using the perforated vessels and sheepskin". It is interesting that the ancient Roman historian Apian Alexandrine (90-170 A.D.) in his XII book "The Argonauts Travel in Colchis Kingdom", consider the main aim of a campaign was to the method of gold mining. In his opinion, the "Golden Fleece" implies the sheepskin technique of gold mining.

Recent geological studies of Svaneti also show that high contents of gold are present here and gold concentration data of this region give ground believe that there was enough reason for creating legends and describe the region as the country rich gold. Field work was carried out during 2006-2010 and based on classical geological methods. In more than 800 samples, gold were determined using ICP-MS method in the "ACMELABS" laboratory (Vancouver, Canada).

In spite of the area occupied by Svaneti region is small, numerous ore mineralization of various genetic types occur here. They are connected with magmatic and hydrothermal formations as well as with the sedimentary ones. At the same time, the natives in Svaneti still mine gold from the rivers using special elongated (50x30 cm) ash tree vessels and sheepskin. It is rather interesting that this vessel is unlike to those used for gold-mining in any other region of the world showing that it underwent independent evolution and due to its perfect forms and functional efficiency, it is quite clear that its handicraft manufacturing has a long history.

Thus, proceeding from the research data we can come to the conclusion, that the "gold sands" of Svaneti, mentioned in Greek mythology and in historical sources was a geological reality. After comparing the geological data, artifacts, myths and historical sources, we share the viewpoint of the Roman historian Apian Alexandrine (90-170 A.D.) and suppose that the myth about expedition of Argonauts in quest of the "Golden Fleece" to the Colchis Kingdom, was a real event, and the notion of "Golden Fleece" was associated with the sheepskin technique of gold mining in the rivers.

Key words: gold sands, Svaneti, argonouts, magmatic and hydrothermal formations

Mineralogy and geochemistry of the hematite muscovite schist of Malatya, Turkey: first record of Banded Iron Formation in the Taurids; probably the first known Banded Iron Formation (BIF) in Anatolia

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This research investigates the mineralogy and geochemistry of hematite-mica schist of Malatya, Eastern Taurid, and compares the schist with Banded Iron Formations. Banded Iron Formations (BIFs) occur in the Precambrian sedimentary (Superior Type) and volcano sedimentary (Algoma Type) successions.
The Hematite Mica Schist (HMS) of Malatya is exposed as a thrust slice between the Permian Malatya Metamorphics and the Eocene Maden Complex and probably as a portion of the Neoproterozoic-Paleozoic Pütürge Massif. The HMS is composed of laminae of quartz, mica-disthene (kyanite) and specular hematite. The Fe_2O_3 contents of the HMS (>20 %) and the Al_2O_3 contents (average 22 %), are different from those of Proterozoic BIFs. The TiO_2, K_2O, MgO, CaO and Na_2O contents are much higher than BIFs and average crust values, indicating detrital origin. Trace element and V, Sr, Y, Zr, Nb and Ba contents are higher than in BIF s. Total REE contents of the HMS are much higher than those of BIFs of Proterozoic age and the LREE concentrations are significantly higher than HREE concentrations, both of these indicators can be taken as evidence of detrital origin. Malatya HMS show strong positive Eu anomalies (Eu/Eu*=0.99-1.03) probably originating from a detrital feldspar contribution. The Ce anomalies (Ce/Ce*= 0.003-0.06) of HMS are low positive, indicating a low oxidation state. Data obtained from the studies suggest that the HMS was formed in a sedimentary basin with a low oxidation state, high detrital contribution, low or no hydrothermal contribution. Similar iron formations were deposited in the sequences of glaciomarine settings during the Neoproterozoic.
Banded Iron Formations (BIFs) are not known in Anatolian geologic environment and the HMS of Malatya constitute evidence resembling Neoproterozoic BIF s. Recent studies on the geology of Turkey show that the so called "massif"s are not Paleozoic as a whole and that they have Neoproterozoic cores. Therefore, it is reasonable to assume that they may include economic deposits formed in Precambrian geological environments, i.e. Banded Iron Formations.

Key words: Hematite mica schist, Banded iron formations, Neoproterozoic, Taurids- Turkey, Pütürge Massif

Discovered and undiscovered gold endowment of Turkey: a quantitative mineral resource assessment and mineral prospectivity analysis using GIS and Zipf's Law

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In the last two decades, modern mineral exploration in Turkey has proven that the country forms a favorable target for gold exploration in the Tethyan Metallogenic Belt. Though multi-national companies have expended considerable efforts, large areas still remain underexplored, in particular outside of the known districts, e.g., reconnaissance and grassroots "greenfields" exploration. Predicting the undiscovered gold endowment of a country or terrane is as important as calculating the known gold endowment. Geoscientists have utilized GIS databases to do geostatistical analyses, however statistical analysis and modeling to predict undiscovered mineral endowment remain inadequate, especially compared to other industries such as petroleum.

Based on the discovered gold endowment of Turkey, an assessment of the undiscovered gold endowment is developed using a comprehensive GIS database containing 402 gold deposits and prospects. The majority of these are epithermal, porphyry, volcanic-associated massive sulfides, orogenic gold, and skarn systems, forming more than 90% of the known gold deposits and prospects. Just 87 out of 402, corresponding to 21.6% of the deposits and prospects in the dataset, have current calculated gold reserve and/or resources of 54.885 Moz Au. Current gold reserves of the country are 21.447 Moz constituting 39.1% of the total gold resources, of which 17.1 Moz gold are contained in four deposits. Out of these 87, only 27 contain significant gold reserve and/or resources (defined as equal to or more than 0.32 Moz or 10 tonnes Au), and contain 91.8% of the total gold endowment of the country. The gold endowment of Turkey abides by a power law, called Pareto's law, which states that roughly 80% of the effects come from 20% of the causes in many events.

The cumulative frequency distribution of the gold endowment is modeled and Zipf's rank-statistical analysis is used to predict undiscovered (residual) gold endowment including size and number of undiscovered deposits. The arithmetic mean of the known gold endowment is 0.657 Moz and the Swanson mean size is 0.492 Moz. The arithmetic mean of the 27 significant gold deposits or prospects is 1.94 Moz. The cumulative frequency distribution model abides by log-normal distribution. Observed [and estimated] 10th, 50th (median) and 90th percentiles of the data are 0.0046 Moz [0.0045 Moz], 0.1030 Moz [0.0875 Moz] and 1.4969 Moz [1.6938 Moz] respectively. The 99th percentile of the data is 7.6444 Moz [18.9636 Moz]. Zipf's law estimates are based on the current size of the largest, rank 1, Kisladag porphyry gold deposit with 17.481 Moz gold endowment, including past production. Zipf's law estimates 88.261 Moz total gold endowment; 57.133 Moz or 65% of which has already been found. This predicts at least 31.128 Moz residual or undiscovered gold resources to be found in Turkey, though the lack of full delineation of the rank 1 deposit, Kisladag, means that this figure is very conservative. Estimates calculated for the first time in this study will help decision makers in gold exploration companies as well as policy makers on mineral and land use in government organizations, and investors who want to manage exploration risk.

Keywords: Tethyan Metallogeny; Zipf's Law; Pareto Law; Gold Exploration; Mineral Prospectivity Analysis; Ore deposits Turkey

Sulphur isotope composition of the sulphur mineralisation in the volcanic rocks of the Gashi zone (North Albania)

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The Gashi Tectonic Zone is located in north Albania. It mainly consists of Permian basalts intersected by T_2^1 granitoid massif of Trokuzi as recently determined (2011) by U-Pb analysis in zircons. The sulphur mineralisation in the Gashi Zone is located in the Permian volcanic rocks, mainly basalts and andesites. Mineralisation is mainly of pyrite but in some cases, as in the Rupa ore deposit the mineralisation has polymetallic characteristics. In order to clarify the mineral formation genesis of these mineralisations four samples were analysed for the sulphur isotopic composition. The $\delta^{34}S$ of the sulphur concentrates, mainly pyrite, were measured in the Scottish Environmental Research Centre, Glasgow, Laboratory using the VG SIRA 11 dual inlet, triple collector masspectrometer. The reproduction is ± 0.2 ‰. The standard used is V-CDT (Vienna Canyon Diablo Troilite). Two samples represent the sulphur mineralisation in the basalts and two others in the andesites. The mineralisation is mainly of pyrite but in one of the samples there are some chalcopyrite and sphalerite and in another one magnetite.
The microprobe analyses, carried out in the laboratories of ISTO (CRSCM), Orleans, France, show some differences between pyrites located in basalts and andesites. The andesite pyrites have higher Co/Ni ratios. The ratio As/Fe is higher also in these pyrites, especially in one of the samples that does not contain other sulphur minerals and may represent the first generation of pyrites in andesites. The basalt pyrites have low Co/Ni and ratios As/Fe. The $\delta^{34}S$ of the sulphur concentrates, mainly pyrite varies from 1 $^0/_{00}$ in the sample 62 to 8.8 $^0/_{00}$. The $\delta\ ^{34}S$ fractionation between sulphur minerals ($\delta\ ^{34}S$ pyrite > $\delta\ ^{34}S$ sphalerite > $\delta\ ^{34}S$ chalcopyrite > $\delta\ ^{34}S$ galena, could give a lower $\delta\ ^{34}S$ value if the analyzed pyrites have inclusions of these minerals.
Normally values of $d^{34}S$ between −1 to +3 or +5‰ are considered as close to the values of the mantle sulphur and show a magmatic origin of the hydrotherms, and the values higher than +5‰ testify a mixing of the magmatic sulphur with the reduced sulfates of the sea water. So, we conclude that the first generation of the pyrites in andesites are formed by magmatic source hydrotherms, most likely originated from the granitoides that also occur in the Gashi Zone. The pyrite mineralisation in basalts and the polymetallic mineralisation in andesites have higher $\delta\ ^{34}S$ values (respectively 4.8‰ and 4.5‰) that may show a small contribution of sulfur derived from partial reduction of seawater sulfate. The mineralisation of one of the samples ($\delta\ ^{34}S$ = 8.8‰) represents a mixed contribution of sulfur derived from partial reduction of seawater sulfate, in addition to sulfur from magmatic source.

Keywords: granitoides; Gashi Tectonic Zone, sulphur isotopes

Spatial and temporal relationships of mineral deposits in the Tethyan Metallogenic Belt, Biga Peninsula, NW Turkey: implications for exploration

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The Tethyan Metallogenic Belt (TMB), one of the world's major metal producing belts, extends from Europe through Anatolia to Iran. The mineral deposits of the Biga Peninsula in northwestern Turkey form a prolific sector in the TMB, and, thus, exhibit, in many ways, the characteristics of mineral deposits found throughout the belt. The Biga Peninsula metallogeny research and exploration project, a field based geological, GIS, geochemical and geochronological study, created a GIS inventory of mineral deposits and prospects to evaluate metal endowment and exploration potential of the mainly metallic mineral deposits of the Biga Peninsula within the metallogenic framework of Turkey as well as TMB. Majority of the deposits and prospects were personally visited and evaluated by the author during the course of the present study. The mineral deposits and prospects in the GIS database, consisting of 128 deposits or prospects, were classified using genetic models based on descriptive data. Many new prospects and potential prospects were generated using a combination of geology, structure, geochemistry, and satellite imagery. Geochronological studies were employed to determine spatial and temporal relations between magmatic activity and mineralization-hydrothermal alteration events. Some of the deposits are dated for the first time in this study using $^{40}Ar/^{39}Ar$ age dating.

The current economically significant mineral deposits in the Biga Peninsula were shaped by Cenozoic calc-alkaline magmatism, ranging between 52 to 18 Ma, and related to mainly collisional and post-collisional tectonic regime. Epithermal deposits including high-, low- and intermediate-sulfidation styles, porphyry Au-Cu-Mo and base-metal skarn systems associated with volcanic and subvolcanic rocks are economically the most important. Other deposit types include Carlin-like distal disseminated Au-Ag, orogenic Au, especially listwanite hosted, volcanogenic Mn and U, lateritic (ferricrete) Fe deposits, carbonate replacement and placers, though there are no economic examples of some of them yet. Intermittent metal production has come from several mines, e.g., Balya, Arapucandere and Koru. Base metal deposits have produced by-product gold-silver, but Kucukdere was the only Au-Ag mine in the Biga Peninsula. Current total gold endowment of the Biga Peninsula including reserves and/or resources is 9.18 Moz gold [284.2 tonnes] contained in twelve different deposits. Of these only 6 contain significant gold [>0.3 Moz or 10 tonnes]. Halilaga porphyry and Agi Dagi and Kirazli HS epithermal systems have ongoing feasibility studies, and Halilaga is a candidate to be one of the largest Cu-Au deposits not only in the Biga Peninsula, but in Turkey. Other newly discovered porphyries include Tepeoba and Tepekoy.

$^{40}Ar/^{39}Ar$ step-heating geochronological study, evaluated with the data from previous studies, indicates at least 3 phases of porphyry and 2 phases of HS epithermal mineralization in the Biga Peninsula. The most important mineralizing events range from 38 to 22 Ma, the Oligocene is especially important for economic Au-Cu systems. This temporal association is similar to deposits in the Oligo-Miocene Serbomacedonian-Rhodope metallogenic belt of the Balkan Peninsula in SE Europe. This field-based research and exploration project indicates that the Biga Peninsula forms a prime target for gold-copper exploration not only in Turkey but in the world.

Keywords: Tethyan Metallogeny; Geochronology; Porphyry Au-Cu-Mo; Epithermal Gold; Mineral Exploration; Ore deposits

Mineralogy and geology of zeolite-carbonate mineralization in basic igneous rocks of the Troodos Complex, Cyprus

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Zeolite carbonate mineralization in the extrusive sequence of the Troodos Ophiolite consists of various Ca-, Ca-Na- and Na zeolites associated in time and space with calcite and aragonite. Three different mineral associations have been established, each with a specific set of zeolites: (1) laumontite-stilbite/stellerite, (2) natrolite-thomsonite-heulandite, (3) analcime-gmelinite. The zeolite carbonate mineralization formed in the temperature range from 250°C to 20° C from seawater with variable amount of biogenic CO_2. Calcium-selective zeolites at depth and sodium-selective zeolites near the surface of the eruptive complex reflect a diminishing impact of seawater on the geothermal system with depth and an increase of biogenic CO_2 towards the seawater-rock interface. The mineralizing solutions may be characterized as near neutral to alkaline. Sulphides and oxidic ore minerals are associated with zeolites in metabasalts of the "Basal Group" . In this stockwork-like mineralization, Cu- and Fe sulphides precipitated subsequently to laumontite and stilbite which are representative of mineral association I. Sulphides of this mineralization may have contributed to the buildup of the massive sulphide deposits in the overlying "Pillow Lavas". Fault-related zeolite mineralization II is linked with Fe-Mn-oxide hydroxides and zeolite mineralization III may laterally grade into umber mineralization.

Keywords: zeolite-carbonate mineralization; Troodos Complex; Cyprus

Post-Miocene and bronze-age supergene Cu-Pb arsenate-humate/oxalate-carbonate mineralization at Mega Livadi– Serifos, Greece

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In the wake of the late Miocene skarn-type Fe mineralization at Mega Livadi on the Isle of Serifos, Greece, arsenical copper mineralization of hydrothermal origin formed in calcareous roof rocks of a granodioritic intrusion. The hypogene mineralization with pyrite, As-enriched fahlore and arsenopyrite suffered strong alteration during the Pliocene and Quaternary by descending meteoric waters. Geogenic and anthropogenic processes responsible for this alteration were subdivided into five mineralizing stages, differing from each other by their element budget, Eh and pH. The supergene stages I to III comprise a variegated mineral assemblage of oxide/hydroxides and arsenates: stage I (goethite, mixture of fine-grained Fe-As-Sb-Cu minerals, pharmacosiderite), stage II (Sb-bearing-beudantite, beudantite s.s., REE-bearing beudantite), stage III (arseniosiderite). The anthropogenic stages IV and V are characterized by a set of hitherto unknown K-Cu humates and oxalates (stage IV) and the common Cu carbonates malachite and azurite (stage V). Chemical weathering induced by the (sub)tropical climatic conditions during the Late Miocene and Pliocene was responsible for the supergene mineral associations of stages I through III at Mega Livadi, Greece. In the course of this supergene alteration the content of Fe decreased along with an increase in As. Anomalously high contents of LREE in beudantite were used as “minerostratigraphic” tracer to correlate the mineralization of stage II with a phase of pervasive lateritization in the Aegean region during the Pliocene. After a hiatus, a new anthropogenic mineralization was triggered by ancient mining activities during the early Bronze Age around 3325 to 2890 BC, when miners began exploiting the soft arsenical Fe and Cu ore at shallow depth. This anthropogenic mineralization evolved under more temperate climatic conditions as a result of ventilation during mining. Bronze-age K-Cu humate-oxalate aggregates and Cu carbonates precipitated from pedogenetic fluids as a function of variable redox conditions and a pH value fluctuating around neutral. This sequence of *per descensum* mineralization with arsenates, humates and carbonates at Serifos, Greece, is of importance in three ways. It offers an insight into the most recent weathering processes of base metal mineralization in the Aegean Sea region. It gives an overview of mining activities across Europe from Cyprus, the “Cradle of Cu mining”, to Great Britain during the Bronze Age. And the physico-chemical results obtained from the study of this multistage alteration may also be employed to explain the compositional variation under (sub)tropical through temperate climatic conditions in tailings derived from beneficiation of As-Cu ores elsewhere.

Neogene diagenetic and epigenetic strontium concentration in calcareous series from Tunisia, Cyprus and the Arabian Gulf

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During the Neogene, celestite deposits evolved in the Neo-Tethys basins, in what is today called the Mediterranean Sea and the Arabian Gulf. Two evaporite deposits, in Cyprus and in Qatar have been investigated from the sedimentological and mineralogical point of view with emphasis placed on Sr, S and Ca isotopes of carbonate, gypsum and celestite.
During the early Miocene shallow marine environments occurred in the Gulf region and in Cyprus both of which are abundant in syndiagenetic sulphate minerals. The calcareous environments had a strong impact on the fluid migration leading to the Sr mineralization. In the Gulf region algal biostromes favored the lateral migration of fluids but had a sealing effect so that any epigenetic mineralization based on vertical fluid flow was hampered. In contrast, the Cypriot depocentre overlying the Troodos ophiolite is dominated by patch and knoll reefs (bioherms) which provide enough porosity and permeability to be favorable for the circulation of fluids with a strong vertical component. Owing to these changes in the calcareous host series, epigenetic sulphate mineralization evolved in Cyprus during the late Miocene. This occurred as the Mediterranean Sea gradually became isolated from the open ocean and, as a precursor to the "Messinian salinity crisis" evaporitic brines circulated deep into the Meso-Cenozoic platform sediments and the underlying Troodos ophiolite where these fluids leached some base metals and sulfur for the celestite mineralization. The Red Sea Rifting was at full swing during the Late Miocene and its northern propagation into the Mediterranean Sea is assumed to have had a structural control on the positioning of the Sr deposits in Cyprus. In the Gulf area, the final closure of the Neo-Tethys and Zagros folding terminated deposition of marine calcareous rocks and alluvial-fluvial siliciclastic rocks were deposited across an unconformity. Missing circulation of highly saline brines was responsible for the absence of an epigenetic Sr mineralization of Cyprus-type in the Gulf area. Assemblages of light (e.g. zeolites) and heavy minerals (e.g. rutile, zoisite, clinopyroxene) and Ca isotope analyses support basic igneous rocks as the source for the detrital and dissolved matter in the depositional environments in Cyprus and the Arabian Gulf. The Ca isotope data imply formation of the sulphate and carbonate minerals in a marine environment without significant contributions of more radiogenic ^{40}Ca coming from old continental crust, e.g., the Kyrenia Range or Mamonia Complex, both of which containing rocks as old as Permian.
Cyprus-type (bioherm-type) and Gulf-type (biostrome-type) evaporites are potential progenitors of sediment-hosted mineral deposits (SHSCD) or base metal vein-type deposits. Syndiagenetic celestite-bearing evaporites of the Gulf-type are a model source and progenitor of base metal deposits of stratigraphically-controlled fixed or mobile reductants such as Kupferschiefer-type deposits. Is the Arabian Gulf a Kupferschiefer basin in the making? The epigenetic celestite-bearing mineralization of the Cyprus-type reflects an advanced stage of fluid migration relative to the celestite deposits along the Trucial coast but this brine mobilization failed to create a base metal deposit of its own mainly due to the absence of fixed or mobile reductants. These reductants were present in the western Mediterranean regions in Tunisia and Algeria, where evaporite-associated base metal deposits are going to be mined and in the Mesozoic through Cenozoic platform sediments in central Europe, where numerous suprasalt unconformity-related metal deposits were mined in the past. In the western Medtiterranean Region, strontium is contained in fluorite deposits in form of celesto-baryte.

Some medieval celsian-kalsilite-bearing iron slags from the Yahyalı area (Kayseri), Turkey

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While surveying the iron slags of the Develi-Yahyalı (Kayseri) area, one slag site, Hacılar Tepesi Mevkii, near Yahyalı, was found to be distinctly different from any other slag site encountered in our previous investigations. This particular site is notable due to the presence of abundant fired clay fragments; these fragments are considered to be the remains of tuyeres used during the smelting of iron at this site. Generally, in our survey of central Anatolian slags, slag sites were observed to be devoid of any materials other than slag fragments. This site also proved to be unique with respect to both age and composition.
Charcoal fragments found embedded in these slags yielded an age of 1035 yrs BP, with an expected standard deviation of 57 yrs. A graph of ^{14}C age versus calibrated calendar age gives an expected calendar age of 1000 CE; this is considerably earlier than the other slags of the Develi-Yahyalı area, which gave a calendar age of 1470, or the iron slags of Yapraklı (Çankırı), which gave a calendar age of 1412. The younger slags would correspond to early Ottoman times, while the Hacılar Tepesi slags would roughly correspond to the fall of Kayseri (1067) to Seljuk commander Afşin and his warriors.
Individual pieces of slag have the appearance of scoriaceous lava and are 8-10 cm in diameter. The slags, in roughly 'hand' size pieces, generally have the texture of a compact ceramic, typically with abundant vesicles. While some pieces are glass and some pieces have ropey surfaces, none of the pieces show any flow banding. Compositionally, these iron slags are sufficiently rich in both potash and barium that both kalsilite and celsian are present as crystalline phases. Examination of these slags also reveals the presence of modal kirschsteinite, fayalite, wüstite, hercynite, metallic iron, leucite and an unusual ferroglass. The interstitial glasses in the studied samples fall into two groups: those with high and those with low silica. If normative kalsilite and celsian are subtracted, the high-silica glasses are normative in hercynite-mullite-quartz while the low-silica glasses are normative in anorthite-fayalite/kirschsteinite-quartz or anorthite-fayalite/kirschsteinite-wüstite. The low silica interstitial glasses straddle the anorthite-fayalite join such that some are normative in quartz and others are normative in wüstite. The interstitial glasses probably formed at ~1100°C.
We do not yet understand the source of the barium in the slags, the unusually high potash content, or the nature of the ferroglass phase.

Keywords: ferroglass; metallic iron; wüstite; kirschsteinite; tuyeres; ^{14}C; mining history

Borates: An overview and future forecast

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As one of the 92 elements that make up the planet, it's not surprising that boron is all around us - in soil and water, plants and animals. Although the element boron does not exist by itself in nature, it occurs in combination with oxygen and other elements in salts, commonly called "borates". Over 150 boron-bearing minerals have been identified, the most common being sodium, calcium, or magnesium salts. Borax is the major commercial source of boron, with major supplies coming from Turkey, USA and Argentina. Colemanite, large-scale production of main calcium borate, is restricted to Turkey. Datolite and szaibelyite are confined to Russia and Chinese sources.

Although boron is a rare element (average content in the Earth's crust is 10 ppm), extraordinary concentrations can be found in certain places. The formation of borate deposits can be summarized as follows; (1) a skarn group associated with intrusives and consisting of silicates and iron oxides; (2) a magnesium oxide group hosted by marine evaporitic sediments; (3) a sodium– and calcium–borate hydrates group associated with lacustrine (playa lake) sediments and explosive volcanic activity.

The following conditions are essential for the formation of economically viable borate deposits in playa-lake volcano-sedimentary sediments: (1) formation of playa-lake environment; (2) concentration of boron in the playa lake, sourced from andesitic to rhyolitic volcanics, direct ash fall into the basin, or hydrothermal solutions along graben faults; (3) thermal springs near the area of volcanism; (4) arid to semi-arid climatic conditions; and (5) lake water with a pH of between 8.5 and 11.

A borate is defined as any compound that contains or supplies boric oxide (B2O3). A large number of minerals contain boric oxide, but the three that are most important from a worldwide commercial standpoint are borax, ulexite, and colemanite. These are produced in a limited number of countries.

Borate exploration consists of detailed prospecting of favorable areas followed by drilling, and uses all the tools available to the exploration geologist. In recent years, Turkey has improvements to be leader and to compete with USA in the world production. Turkey has largest borax, ulexite and colemanite reserves in the world. All the countries are dependent upon colemanite and ulexite reserves of Turkey.

Most of the world's commercial borate deposits are mined by open pit methods. Brines from Searles Lake, and presumably the Chinese sources, are recovered by either controlled evaporation or carbonation. Boric acid is one of the final products produced from most of the processes.

Very few modern industries can get by without borates, and very few people can get by without their products. When you consider the role boron plays in plant life, and by extension, all life, it's hard to imagine our world without it. Therefore, borates and their products could be one of the main topics for Sustainable Development in whole world.

Keywords: borates; geological setting; exploration; mining; trade

Biomineralization in lake Acıgöl, a hypersaline lake, SW Turkey

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Lake Acigol (Bitter Lake) is a hypersaline lake in southwestern Turkey at an elevation of 836 m above sea level. It is a perennial lake and closed drainage basin where a semiarid continental climate dominates. Extreme water chemistry ((mg/L) salinity,8-200; SO_4,112-15232; CI 290-35320; Mg, 82-3425; Ca 102-745) allow flourish of unique microorganisms in the lake. We studied microbial diversity of the Lake and further biomineralization by the culture isolated from the Lake, in which, until now, the type and role of microorganisms on carbonate precipitation had not been described. Biomineralization experiments were conducted at 4 and 30 ^oC using variable sulfate concentration and Mg^{2+}/Ca^{2+} molar ratio with solid and liquid medium. In addition, prolong biomineralization experiments were set up to monitor possible mineral transformations with time. The extent of the precipitation, and the mineralogy and morphology of the formed carbonate bioliths were investigated. Bacterial populations of sediments in the Lake Acigol and the saltern ponds are comprised mainly of moderately halophilic bacteria and uncultured species. We have confirmed that a high percentage of these bacteria are able to precipitate Mg rich carbonates . No precipitation was observed in the uninoculated controls or in those inoculated with a high concentration of dead bacteria that had no metabolic activity. Mineral precipitation monitored via petrographic microscope showed two types of precipitated minerals: Mg rich -carbonates,which have a morphology of spherical particles, and struvite, with a morphology of large polyhedral crystals. These minerals precipitate when the bacterial colonies have developed. It is suprising that we did not determine dolomite precipitation as suggested by previous studies. Our results also indicate that presence of sulfate does not affect mineralogy of the precipititates. Overall, our experimental results suggest that microorganims contribute to mineralization processes in the Lake by regulating C, N, P, Ca and Mg cycles.

Keywords: Lake Acıgol, biomineralization, salinity, halophilic microorganims

Low-sulfidation epithermal Au-Ag mineralization in the Sındırgı District, Balıkesir Province, Turkey

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The Sındırgı district (Balıkesir, western Turkey) lies within the Western Anatolian volcanic and extensional province, adjacent to the WNW-trending Simav graben, ~130 km NE of Izmir. The Sındırgı mining district is underlain mainly by Miocene volcanic rocks and hosts several low-sulfidation epithermal Au-Ag deposits and prospects located in the vicinity of the towns of Sındırgı and Bigadiç. The Kızıltepe low-sulfidation epithermal gold-silver deposit is located southeast of Yusufçam village (Sındırgı, Balıkesir), and other prospects including the Kepez, Kavaklıdüz and Karadüz prospects are located to the north east of Kızıltepe. Potentially economic grades occur at Kızıltepe which contains a measured and indicated resource of 1.754.790 Mt @3.0 g/t Au, 44 g/t Ag, hosted by quartz veins showing colloform/crustiform banding, quartz pseudomorphs after bladed calcite and multiphase brecciations, all typical textures noted in low-sulfidation epithermal deposits. Alteration minerals include mixed-layer illite/smectite, high-crystallinity illite and kandite group (dickite and nacrite). Precious metal minerals include traces of electrum, acanthite, Au-rich acanthite and Ag-Hg-Au-Te-Tl-Pb series, occurring mainly within quartz. Pyrite is the most common opaque mineral at Kızıltepe. $^{40}Ar/^{39}Ar$ dating of adularia from the quartz veins indicates an age of mineralization of 18.3 ± 0.2 Ma. The ore-mineralization is divided into three main phases. These comprise the deposition of: coarse-grained quartz, illite, pyrite and minor precious metals (Phase I), major gold-silver-bearing medium-grained quartz which commonly exhibits crustiform banding, carbonate replacement and hydrothermal breccia textures (Phase II), and fine-grained chalcedonic quartz with colloform/crustiform banding (Phase III). Phase II is economically most important in terms of precious metal content. Phase II quartz contains fluid inclusions which range from predominantly vapor-rich to predominantly liquid-rich with homogenization temperatures (T_h) varying from 157 to 330^{o}C, showing a cluster between 190^o to 300^{o}C; ice–melting temperatures (T_m) range from -0.2 to -2.9^{o}C (salinity from 0.5-4.8 wt.% NaCl equiv.). Moderate to strong positive correlations occur between Au-Ag (R=0.8) and Au-Cu (R=0.5), whereas there is no correlation between As and Au or Ag. Variations in Ag/Au ratios may indicate that chloride complexing was dominant in the early stage whereas sulfide complexing was dominant during the later stage of formation of the Kızıltepe epithermal system. The presence of liquid-rich to vapor inclusions with variable liquid-to-vapor ratios and relatively large ranges in homogenization temperatures at Kızıltepe deposit and prospects suggests that boiling was a predominating mechanism in precipitating gold.

Keywords: Gold; hydrothermal alteration; geochronology; fluid inclusions; Sındırgı.

Metallogenic borate provinces in the world

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Four main metallogenic borate provinces, with exogenous deposits of continental environments, were recognized in global scale. They are Anatolia (Turkey), American West (USA), Central Andes (South America) and Tibet-Qinghai plateau (Central Asia). These provinces have several common characteristics and some differences. Generally, the origin of borate deposits is related with Cenozoic volcanism, thermal spring activity, closed basins and arid climate. With the exception of Tibet, a collisional plateau, the other provinces were generated in a tectonic framework of non-collisional continental plateaus by plate subduction. Anatolia, Tibet and California are located in the northern hemisphere and the Andes in the southern hemisphere. The age of the borates is Cenozoic, principally, Miocene and Quaternary. Miocene borate deposits are present in Anatolia (ca. 18 Ma), California (ca. 22-6 Ma) and the Andes (ca. 7-5 Ma). Tibet has only Quaternary borate deposits and Anatolia only Miocene borate deposits. Four main borax deposits are present in the world: one in Anatolia (Kirka), another one in California (Boron), and two in the Andes (Tincalayu and Loma Blanca). Kirka, Boron and Loma Blanca have similarities in order to the chemical and mineralogical composition of the borate minerals with sequences Ca/CaNa/Na/CaNa/Ca (colemanite and/or inyoite//ulexite //tincal//ulexite //colemanite and/or inyoite). Borate minerals are included in greenish volcaniclastic lacustrine evaporatic sequences, with scarce tectonic deformation. On the other side, Tincalayu looks different, with evaporites included in red beds, with disharmonic deformation, and a lithologic sequence composed from base to top of halite/gypsum/tincal/ulexite. Tincal textures are different in the four main deposits: chemical fine varves (mm) in Kirka, chemical thick varves (cm) in Boron, massive (m) in Tincalayu, and disseminated evapocrystals (mm to cm) in Loma Blanca. Colemanite deposits with or without probertite and hydroboracite are present in Anatolia (e.g., Emet), Death Valley, Ca. (Furnace Creek Fm.), and Sijes (Argentina). Quaternary borates are present in salars (Andes) and playa-lakes and salt pans (USA-Tibet). California and Andes have calcium, calcium sodium and sodium borates, and Tibet (ulexite and Mg-borates). Thermal springs and geysers, with related borate deposits, are common in the Central Andes. The four metallogenic provinces here described contain the most important borate reserves in the world.

Keywords: Metallogenic province; borate; world

Coeval Acidic-Basic Magmatism and Related Mo-Cu, Fe Mineralizations, Karacaali Magmatic Complex, Central Anatolia, Turkey

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The Late Cretaceous calc-alkaline Karacaali Magmatic Complex (KMC) located in the northwest part of the Central Anatolian Crystalline Complex contains important Mo-Cu and Fe mineralizations. KMC represents a clear example of synchronous basic and acidic magmatic associations. The KMC plutonic rocks mainly consist of monzonite, granite, and gabbro, whereas the associated volcanic rocks are chiefly basalt and rhyolite in composition. The Mo-Cu mineralization is mainly hosted in monzonitic rocks and is related to N-S striking vertical quartz-calcite veins. The Fe mineralization, on the other hand, is hosted in gabbroic/basaltic rocks.
The monzonitic rock gives 73.1+2.2 Ma age on single zircons (U-Pb), while the rhyolitic, basaltic, and gabbroic samples yield well-defined $^{40}Ar/^{39}Ar$ plateau ages of 69.1 ± 1.3, 58 ± 10, and 66.4 ± 1 Ma, respectively. Furthermore, two molybdenite samples from Mo-Cu mineralization give Re–Os ages ranging from 73.7±0.4 to 76.2±0.4 Ma. The relatively overlapping ages between monzonite (73.1±2.2 Ma), rhyolitic rocks (69.1±1.3 Ma) and Mo mineralization (73.7±0.4 to 76.2±0.4 Ma) reflect a long lasting gradual crystallization within a zoned magma chamber. On the other hand, younger age data obtained from basaltic and gabbroic rocks indicate that a younger multiphase basic magma was injected into a partially crystallized zoned magma chamber. According to these data, older molybdenite age (76.2 Ma) in KMC probably represent the mineralization period related to crystallization–differentiation processes, whereas the younger molybdenite age (73.8 Ma) in the KMC may represent the prolongation of the life of magmatic–hydrothermal processes/cycles and/or the remobilization of molybdenum within the solidified granitic system by the intrusion of the basic magma. In addition to Mo-Cu mineralization in the KMC, the intrusions of basic magma into a semi-evolved acidic magma chamber have caused the sudden segregation of iron-rich melts and this process produced the Fe mineralizations in the region.
Our results indicate that basic intrusions into the acidic magma chamber and fractional crystallization processes played a decisive joint role enhancing the metal-enrichment processes in the KMC.

Keywords: Karacaali Magmatic Complex; Mo-Cu mineralization; Fe mineralization; coeval magmatism; Ar-Ar age determination; Re-Os age determination

Alteration mineralogy and geochemistry of Şamlı (Balıkesir) Fe-oxide Cu (±Au) deposit

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Şamlı (Balıkesir) Fe-oxide Cu (±Au) deposit, one of the several Fe-oxide (+Cu ±Au) deposits in western Turkey, is hosted by rocks of Şamlı pluton and metapelitic- metadiabasic rocks of Karakaya Complex, which underwent widespread calc-silicate alteration. Alteration associated with the Şamlı deposit is characterized by four distinct mineralogical assemblages. They are, in the (chronological) order of formation, are (1) plagioclase-early pyroxene (± scapolite), (2) garnet-late pyroxene, (3) chlorite-epidote, and (4) chalcedony-calcite alterations. Alteration and mineralization in Şamlı seem to be formed as a result of cooling, crystallization and emplacement processes of Şamlı pluton which is a multi-phase intrusion formed by mixing between felsic and relatively more mafic magmas. Geochemical and isotopic (Sr, Nd, O, S) data from alterations and magmatic rocks suggest a genetic link between the hydrothermal system(s) that controls the Fe-oxide-Cu (± Au) mineralization and multiphase Şamlı pluton. Regarding the chemical gains and losses of host rocks during the alteration, the features common to both protoliths depend on increasing intensity of alteration. The overall picture of chemical gains and losses shows the conformity with the mineral assemblages in the alterations, and host lithology of alteration. The most prominent chemical features of alteration is i) enrichment in the CaO for both metadiabasic and dioritic host, and the enrichment in MgO for metadiabases and ii) depletion in the precious element during early alteration (e.g plagioclase-early pyroxene ± scapolite) for both protoliths, but enrichment in late alteration for both protoliths.

Key words: Fe-oxide Cu (±Au); Şamlı pluton; mineralogy; geochemistry; Balıkesir; western Turkey

Gold mineralizations and their genetic relationships with post-collisional exhumation and extensional tectonics in central Anatolia

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Gold exploration works in central Anatolia were intensified during the last decade, and potentially important gold mineralizations were discovered. Important gold discoveries hosted by metamorphic and granitic rocks are in the western part Savcılı, Terziali, Sıddıklı (Kırşehir), in the middle part Himmetdede, Mahmatlar (Kayseri) and Akçataş (Nevşehir), and in the southeastern part Gümüşler (Niğde) mineralizations. In these mineralizations, only Sıddıklı prospect is placer type and all the others are vein-type gold enrichments. In these mineralizations gold is associated with Sb, Hg, As, W, U and Sn. The common opaque minerals are pyrite, arsenopyrite, marcasite, stibnite, galena, sphalerite, chalcopyrite, fahlore, pyrrhotite, scheelite and gold. The common gangue minerals are quartz, calcite, barite and fluorite. The host rocks of mineralizations generally display both hydrothermal and supergene alterations. Hydrothermal alteration is selectively vein controlled and limited to the nearest surroundings of the veins. The common alteration types are silicification, kaolinization, chloritization and propylitization. Weathering zones are common in Savcılı, Terziali, Akçataş and Gümüşler mineralizations. In weathering zones, mineralizations and their host rocks are characterized by their higher gold content, and brown colors, high limonite/hematite, kaolinitic clays content.

According to fluid inclusions data the temperature of ore forming fluids were between 80 and 420^{0}C and the salinities were between 2 and 33% NaCl equivalent. The origins of the ore forming solutions are interpreted by different authors as magmatic, metamorphic and meteoric.

Gold mineralizations have many similarities to orogenic gold deposits in terms of metal associations, wall-rock alteration assemblages, mineralogy, formation conditions and structural control. The spatial associations of gold occurrences with high-grade metamorphic rocks, granitoids and detachment fault zones suggest an origin related to exhumation and following thin-skinned extensional tectonics in central Anatolia.

The thermal characteristics of the regional crust in central Anatolia as indicated by Curie point depths suggest the presence of shallow hot zones (about 8 km) and a significant regional crustal uplift (more than 10 km). We attribute this to an asthenospheric upwelling that results from the post-Late Cretaceous extension of the crust in the region and leading to hydrothermal water circulation and gold mineralizations in the region.

Keywords: Kırşehir, Cappadocia, Curie point, mantle upwelling, exhumation, post-orogenic uplift.

Granitoid hosted vein-type Akçataş Sb-Au-As-U mineralization (Hacıbektaş-Nevşehir) in central Anatolia

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Akçataş mineralization is located at 6 km SW of Hacıbektaş, Nevşehir. The basement in Akçataş consists of metamorphic and granitic rocks. It is unconformably overlain by Lutetian red colored conglomerate, sandstone and mudstone, and also by Neogene detritic sediments and basaltic lava flows.
The Sb-Au-As-U mineralization is mainly located in NE-SW-oriented fault zone. The vein system has a maximum thickness about 100 m. and a length of 5 km. It consists of mainly brecciated- and stockwork-type quartz veins.
The common ore minerals are stibnite, antimony ochre, pyrite, marcasite, sphalerite, arsenopyrite, hematite/limonite, electrum, and also uranium minerals like zeunerite, torbernite and uraninite. The gangue minerals are quartz, calcite and barite.
The common alteration types restricted with the vein system are silicification and clay alteration. The main alteration minerals are quartz, kaolinite, sericite and calcite. The host granite is intensely altered to kaolinite close to the vein systems. Biotite is chloritized and hematite partly replaces biotite. Feldspars are replaced by kaolinite, sericite, quartz and calcite.
Akçataş prospect is the first and only known mineralization containing Sb, Au and U in the same vein system in central Anatolia. According to field work, mineral content, alteration and fluid inclusion studies, the mineralization is occurred in an extensional environment by a mixing of ascending brines with Sb, Au, As and U, and tertiary basinal sedimentary fluids with Cu and Zn contents. According to fluid inclusions data, the temperature of ore forming fluids were between 88°C and 350°C and the salinities were between 3,4 and 5,7% NaCl equivalent.

Keywords: Turkey, Kırşehir massif, Cappadocia, antimony, uranium, gold, basinal brines, fluid inclusion.

Genetic relationships between skarn ore deposits and magmatic activity in the Ahar region, Western Alborz, NW Iran: Evidence for metasomatism and copper mineralization

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Subduction and subsequent continental collision during the Paleocene to Oligocene in northwest Iran caused extensive I type calc-alkaline and alkaline igneous activity in the Ahar region. Numerous skarn deposits formed in the contact between Upper Cretaceous impure carbonate rocks and Oligocene–Miocene plutonic rocks. The calcic Fe-Cu-bearing skarn zone includes the Sungun, Anjerd and Mazraeh, Javan Shaykh, Ghranigh Deragh and Gowdul skarns in which the first three skarn deposits are more economical and importants. The skarns were classified into exoskarn, endoskarn and ore skarn. Andraditic garnet is the main skarn mineral; the pyroxene belongs to the diopside-hedenbergite series. The skarnification process occurred in five stages. The history of skarn formation starts with pluton emplacement and assimilation of limestone by the magma. The first stage involved prograde metasomatism and anhydrous minerals like garnet and pyroxene formed, followed by retrograde stages along with minralization. In addition to Fe, Si and Mg, substantial amounts of Cu, along with volatile components such as H2S and CO2 were added to the skarn system. Consequently considerable amounts of hydrous calc-silicates, sulfides, oxides and carbonates replaced the anhydrous calc-silicates in the host granodiorites. Endoskarn with magnetite, epidote, pyroxene, plagioclase, and exoskarn with garnet and epidote, such as found at Mazraeh and Sungun, indicate an island arc or subduction-related origin of the Fe-Cu skarn deposit. This study presents new field observations of skarns in the western Alborz range; describes the petrography and mineralogy of the important skarn deposits based on thin section, electron microprobe and presents the geochemistry of the host igneous rocks. These data are used to interpret the metasomatism during sequential skarn formation and the geotectonic setting of the skarns granitoide.

Key Words: genetic, granodiorite, magmatic, skarn, garnet, epidote, sulfide

Mobility of REE and other trace elements during hydrothermal alteration in Asarel porphyry copper deposit, Central Srednogorie, Bulgaria

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The Asarel porphyry copper deposit is located in Panagyurishte ore region, Central Srednogorie, part of the Late Cretaceous Apuseni-Banat-Timok-Srednogorie (ABTS) magmatic and metallogenic belt defined by intensive magmatic and volcanic activity and formation of porphyry and epithermal deposits. The volcanic and porphyritic rocks are strongly affected by intensive hydrothermal alterations of propylitic, argillic, sericitic and advanced argillic alteration (AAA) types.

Chondrite-normalized REE patterns of volcanic rocks are characteristic for island-arc subduction-related magmas with LREE enrichment and comparatively flat HREE patterns. REE patterns of propylitic, weak K-silicate, argillic and sericitic altered rocks are similar to those in fresh volcanics. Visible mobility of MREE and HREE is seen with increasing alteration degree in argillic and sericitic rocks. Important changes in the behaviour of REE are observed in AAA zones. REE patterns in pyrophyllite altered rocks show MREE and HREE fractionation, which is stronger in dickite, diaspore and alunitic rocks. LREE are relatively immobile due to the presence of alunite and APS minerals which contain small amounts of La, Ce and Nd. All REE are extracted from small silicic bodies.

MORB-normalized multi-element patterns of volcanic rocks are enriched in LILE and depleted in HFSE. Spidergrams of propylitic and weak K-silicate altered types are similar, only depletion of Sr and low mobility of Ba, P, Y, HREE is visible. Argillic rocks are characterizes by depletion of LILE, P, Y, HREE and enrichment of Pb, while in sericitic rocks Cs, Rb, Ba, K concentrate (or are immobile) and Pb, Sr, P, Y, HREE are strongly depleted. HFSE, Ti, LREE are comparatively inert during both alteration types. Significant mobility of most of trace elements is seen during AAA. Cs, Rb, MREE, Y, HREE are strongly depleted from all AAA types, while Th, U, K, Nb, Ta are depleted in smaller degree, especially in alunitic rocks. LREE, Zr, Ti are comparatively immobile, while enrichment is visible for Sr, Pb, sometimes for P, Zr, Ba. Silicic alteration is characterized by strong depletion of all trace elements except Nb, Ta, Zr, Ti.

REE and multi-element patterns of altered rocks show comparatively inert behaviour of most elements during the propylitization and starting of mobility with increasing the alteration degree in argillic and sericitic altered types. Significant mobilization and redistribution of REE and other trace elements are happened during AAA in the upper part of the Asarel porphyry copper system. It consists in leaching of Cs, Rb, MREE, Y, HREE and comparatively inert behaviour of LREE. This is due to the low pH of hydrothermal fluids, high water/rock ratios and abundant complexing ions (F^-, Cl^-, SO_4^{2-}). The presence of appropriate minerals which can accommodate LREE is of vital importance. These are alunite and APS minerals (svanbergite, woodhouseite, florencite) which are characteristic for AAA and determine the geochemistry of elements which concentrate or are immobile in these zones like Sr, P, Ba, Pb. Only Nb, Ta, Zr and Ti are immobile in extremely low-pH environment for silicic alteration.

Keywords: REE; trace elements; alunite; APS minerals; advanced argillic alteration; Asarel deposit

Geotectonic Setting and Structural Controls of Elmadağbeli, Menteş, Karaçat, Kartalkaya and Attepe Iron Deposits (Kayseri-Adana Region, Turkey)

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The aim of this study is to determine the geotectonic setting and structural controls of Elmadağbeli, Menteş, Karaçat, Kartalkaya and Attepe iron deposits, located on the western part of Eastern Taurides. The main lithostratigraphic units exposed in the study area are belonging to Geyikdağı allochthonous unit. They are Precambrian-Early Cambrian Emirgazi fm, Early Cambrian Zabuk fm, Middle-Late Cambrian Değirmentaş fm and Ordovisian Armutlu fm.
The primary ores are syn-sedimentary siderites comformable with bitumen-shale, continental to shallow marine clastic rocks with spilitic lavas and diabases of Precambrian-Early Cambrian aged Emirgazi fm. These ore deposits are structurally and tectonically controlled by fault systems and are related to volcanic rocks in the study area. New geochemical data show that spilitic lavas and diabase are sub-alkaline character. High Zr/Y and Th/Yb values, Nb/Y versus Ti/Y and chondrite-normalized REE values indicate that these volcanic rocks are of riftogenic signature and they are possibly produced in a mature arc setting.
Principal stres axes indicate that the NNW-SSE compressional regime caused current syn-and post-mineralised faults. The late-stage formation of iron deposits, such as hematite and goethite, are related to these fault systems (faults developed after primary siderite deposits) transporting Fe-bearing fluids from Precambrian-Early Cambrian aged primary siderite deposits in deep level. Fluid inclusion studies show that the meteoric fluids migrating in the post-mineralised fault zones, interacted with the ascending systems which transporting older metals occurences, and these faults give rise to ore bodies shaping in current positions.
Considering all data, primary siderite deposits may be related to Precambrian-Early Cambrian aged sub-marine volcanism possibly implying a shallow mantle source and back-arc extansional setting, and are closely associated with exhalative sedimantary or syn-sedimantary iron deposits. Iron oxides, meanwhile, are related to hydrothermal and meteoric fluids, mobilized primary iron-carbonates to the post-deposition fault systems.

Key Words: Eastern Taurid, back-arc, fault, rifting, iron deposits

The Geochronology of gold-copper deposition, temporal association with magmatic rocks and petrochemical controls in western Anatolia, Turkey

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The western Anatolia hosts a variety of porphyry (copper-gold and copper-molybdenum), low- and high-sulfidation epithermal (gold and gold-silver), mesothermal (lead, zinc, copper) and skarn (iron - copper, lead-zinc) type deposits. Most of these deposits/prospects are clustered within the Biga Peninsula where the mineralization events are temporarily and spatially associated with episodic magmatism since the middle Eocene to late Miocene-Pliocene. This work basically contributes to the tectonic setting and geochronology of magmatic episodes and timing of hydrothermal events in relation to major magmatic episodes within the western Anatolia. It also highlights some major points of Turkish Tethyan metallogeny along with the regional evolution of western Tethysides. A total of 52 prospects/deposits known to contain gold mineralization were sampled and examined, and petrochemical and geochronological data was presented.
The epithermal and porphyry deposits are commonly localized within or around porphyry intrusives, subvolcanic masses or in volcano-tectonic depressions, volcanoclastic sequences, meta-carbonates, calderas, and grabens, typically in faults and fissures related to block faulting and/or orogenic collapse. The Ar-Ar geochronology of the hydrothermal mineral separates hosting and/or associated with these deposits and fresh magmatic rocks are consistent with 6 major hydrothermal episodes, spatially and temporally associated with six magmatic episodes in the western Anatolia. These are; (1) a Late Cretaceous (81.9-70.37 Ma) calc-alkaline igneous complexes mainly to the northern promontory of Turkey (Thrace region, Strandja massif, northern Turkey) (Dereköy, Şükrüpaşa), (2) Middle Paleocene-Middle Eocene (57.3-36.9 Ma) magmatic associations (Muratdere, Tüfekçikonak, Kaymaz, Kuşçayır, Kartaldağ, Madendağ, Serçeler, Kirazlı, Pirentepe) exposed mainly within the Biga Peninsula and southern costs of Marmara sea, (3) Late Eocene-Early Miocene (28-22.7 Ma) calc-alkaline volcano-plutonic complexes (Tepeoba, Şamlı, Evciler, Küçükdere, Ağıdağ, Halilağa, Eğmir, Ayazmant), (4) Early Miocene (22.3-20.1 Ma) volcanic and plutonic calc-alkaline associations (Kepez and Baklan), and (5) Middle Miocene (20-15) calc-alkaline volcano-plutonic rocks mainly at Biga Peninsula, and (6) Middle-Late Miocene (14-11 Ma) alkaline rocks (Kışladağ, Sandıklı, İnlice) at the southern margin of the region. These hydrothermal and magmatic episodes are interpreted to be resulted from (1) the northward subduction and closure of the marginal Vardar-Izmir-Ankara ocean that was followed by Early-Middle Eocene post-collisional magmatism to the north and south of the Izmir-Ankara-Erzican suture zone (IASEZ), and (2) closure of the remnant of the NeoTethys ocean along Aegean and Cyprean subductions. This was followed by extensive extensional regime that produced voluminous calc-alkaline to alkaline even ultrapotassic magmatism starting from Oligocene to Late Miocene-Pliocene.

Key Words: Tethyan metallogeny; geochronology of magmatism; age of ore deposition; epithermal, porphyry deposits; western Anatolia

Geology and alteration mineralogy of the Çataltepe Pb-Zn±Cu±Ag deposit, NW Turkey

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The Biga Peninsula is a well known metallogenic province in Turkey that hosts many currently mined Pb-Zn±Cu±Ag deposits. These deposits are hosted by a variety of rocks that range from metamorphic to volcanic and there has been a long debate about the age and origin of these deposits. The present work contributes to the mineralogy and wall rock alteration of the Çataltepe Pb-Zn±Cu±Ag in Lapseki (Çanakkale) from the Biga Peninsula.
The Çataltepe Pb-Zn±Cu±Ag deposit is hosted by rocks that range in age from Mesozoic to Tertiary. Mesozoic rock units are generally characterized by Çamlıca metamorphic and Çetmi Melange units. Çamlıca metamorphics consist schists, quartzite, metasandstone, and phyllite with lens- and/or band shaped recrystallized limestone and/or marble intercalations in green schist facies. The Çamlıca metamorphics are tectonically overlain by Çetmi Melange that consists mainly of serpentinized harzburgite. Tertiary rock units are represented by Şevketiye granitoid (granodiorite) and Beyçayır volcanics (porphyritic andesite, augite-bearing andesite, dacitic andesite and dacite) Eocene in age.
The mineralization of the Çataltepe Pb-Zn±Cu±Ag deposit is lithologically controlled and hosted mostly along the marble-metasandstone/quartzite contact and within marble itself. Mineralization is rarely seen at the fractures and cracks of the other metamorphic rocks. Microscopic studies reveal a prograde stage characterized by calc-silicate associations of garnet and pyroxene; followed by a retrograde stage characterized by carbonate and epidote that partly replaced the prograde association. Ore minerals consists of brown sphalerite, honey coloured sphalerite, galena, chalcopyrite, pyrite, pyrrhotite, magnetite, valeriite, hematite, marcasite, arsenopyrite, limonite, and bixbyite. Some of these minerals are found in the fractures of garnet crystals. Electron microprobe analysis (EPMA) of garnets show middle compositions on the grossular-andradite solid solutions. Trace elements compositions of sphalerite obtained by EPMA show that brown sphalerite and galena associated with massive ore have significant compositional differences than honey coloured sphalerite and galena associated with disseminated ore represent two distinct stages in ore genesis.
Mineralization appears to be epigenetic formed under meso-epithermal (hydrothermal) conditions in more shallow depths relative to a distal Pb-Zn skarn deposit.

Keywords: Biga Peninsula; lead-zinc deposit; alteration mineralogy

The ancient black smoker vent chimneys from VMS deposits of NE Black Sea Region, Turkey

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The Eastern Black Sea Region of Turkey forms a specific metallogenic province characterized by thick Upper Cretaceous volcanic and sedimentary rock series hosted a number of volcanogenic massive sulfide (VMS) deposits and prospects. Discovery of sulfide chimney fragments was the first for these structures in the district. In this study, we focus on mineralogical and geochemical investigation of diverse Late Cretaceous vent chimney samples recently collected by the first author at VMS deposits of Çayeli, Lahanos, Killik, Kızılkaya and Kutlular.
The fossil chimney fragments in massive sulfide were defined in the clastic sulfide ores. Mineralized hydrothermal chimney fragments vary in diameter, from 2 to 8 cm. The components of sulfide fragments usually consist of pyrite, marcasite, chalcopyrite, bornite, covellite, sphalerite, galena, fahlore, pyrrhotite, quartz and barite. Electrum, gold, hessite, wittichenite, tellurobismuthite and silver-sulfosalts were also detected in minor amounts. The well-preserved chimney fragments typically have distinct concentric zones. The mineralogical zoning can be clearly observed in some samples.
LA-ICPMS was utilized to determine the distribution of trace elements within two well-preserved chimney samples from Çayeli deposit (ch1 and ch2). It was noticed that there was a roughly systematic trace elements distribution pattern throughout the horizontal section of the chimneys. Mn, Co, Ni, Au, Bi, U and Tl are enriched in pyrite and chalcopyrite in the outermost section (zone A) of the chimney walls of both chimney samples. As, Ag, Te and Mo are also enriched in pyrite and chalcopyrite of zone A in ch2. In ch1, higher values of As, Ag, Pb, Se and Sn in chalcopyrite and pyrite, and of As, Ag and Au in sphalerite within the zone B were detected. In the ch1, Te and Mo are enriched in zones of B and C whereas in ch2, Se is enriched in pyrite of zones B and C. Our mineralogical and geochemical data reveal that mineral contents and their trace elements distribution of sulfide chimneys are sensitive to variations of temperature and geochemical factors. The Mo, Sn, Se, Tl, As and Pb enrichments in transition and vent zones of chimneys can be interpreted as the sign of high- and low-temperature fluctuations and rapid changing of geochemical conditions during the chimney formation.
The sulfur isotope values were measured from chalcopyrite, pyrite, sphalerite, galena and bornite within concentric zones of chimney. $\delta^{34}S$ values for Çayeli chimney show range of 0,5 to 5,8 ‰ and are similar to those obtained from Matsuki deposit (Kuroko type). Killik, Kızılkaya, Lahanos ve Kutlular chimneys yielded values (-2,7 to +3,2 ‰), similar to those Yaman-Kasy (Ural type). According to their sulfur isotope composition and ore facies, Pontide VMS deposits show close similarities to Ural and Kuroko type deposits.
The chimneys fragments identified in the Pontides share similarities with those observed on the modern and paleo-districts in terms of their mineral contents, textural features, alteration styles, zonings, shapes and depositional environments. The basic differences between the modern and fossil chimneys are mainly due to ageing. These chimney fragments are important proofs of the hydrothermal vents in the Cretaceous seafloor in the Eastern Pontides. The presence of the mineralized chimney fragments in the massive sulfide deposits of the Eastern Pontides and their trace element contents also present considerable data for understanding of the physico-chemical environments and the depositional histories of the sulfide mineralizations on the seafloor.

Keywords: Pontide; black smokers; vent chimneys; VMS deposits; mineral chemistry; trace elements

Ore facies in volcanic-hosted massive sulfide deposits of Black Sea Region, NE Turkey

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Although volcanic-hosted massive sulfide deposits (VMS) of Eastern Black Sea Region have been studied extensively, ore facies processes remain poorly understood. Based on ore body structure and ore texture we recognize ore and ore-bearing facies in the massive sulfide deposits of the district. Discovery of some ore facies characteristics was the first for these structures in the district. Ore facies can be subdivided into hydrothermal-metasomatic, seafloor hydrothermal and biological facies.
Hydrothermal-metasomatic facies are indicative of sub-seafloor replacements and characterised by disseminated, stockwork, massive vein and massive ore lenses which formed below the sea floor. Sub-seafloor ores can be defined as sulfide mineral formation within pre-existing volcano-sedimantary rocks by infiltration and precipitation in open spaces and form an important component of some deposits (e.g. Murgul mine). Seafloor hydrothermal facies refer to sea-floor sulfide accumulation on the seafloor and characterised by hydrothermal sulfide chimney fragments and clastic ore facies. Clastic sulfide ore facies can be divided into proximal and distal facies. Sulfide clasts, reaching up to 5 cm, in proximal facies are chaotic and composed of coarse-grained fragments containing predominantly pyrite, chalcopyrite, sphalerite, galena and bornite. In distal facies, sulfide clasts are also chaotic and composed of sand-sized sulfide fragments. Graded bedding and soft-sediment deformation structures are widespread in distal ores. Numerous sulfide fragments display alteration rim, indicating submarine alteration. In Kutlular mine, a sulfide sandstone sample analysed by using LA-ICPMS contained elevated Au (up to 17 ppm), Ag (729 ppm), Cu (32%) and Te (1510 ppm). Biological facies represented by fossil vent fauna (tube worms) are also characteristic of sea-floor accumulation (Killik, Çayeli and Lahanos deposits).
Ore-bearing facies are characterised by exhalites providing diagnostic evidence that the sulfide deposit formed at the seafloor. They occur in the immediate hanging wall of massive stratiform ore and are recognized by its red color. They are discontinuous and have a variable thickness. These exhalites show elevated concentrations in trace elements relative to normal pelagic sediments overlying massive ore horizons. In Kutlular mine, Au (up to 10 ppm), Ag (up to 270 ppm), Se (up to 571 ppm) and Te (up to 344 ppm) values were detected from ferruginous chert by using LA-ICPMS.
The VMS ores of Eastern Black Sea Region have well-preserved facies characteristics in terms of texture and components. Some massive sulfide deposits were accumulated by molasse/mass flow on the seafloor, whereas some others formed by sub-seafloor replacement processes below the sea floor. Seafloor and sub-seafloor supergene processes led to destruction of sulfide mound and alteration of clastic sulfides on the bottom of the Tethys Sea. Clastic sulfide textures, sulfide chimney fragments, ferruginous cherts and fossil vent fauna (tube worms) defined in the Pontide deposits are diagnostic and can be used as typical evidences in support of a seafloor origin for VMS deposits. Ore facies method may be useful tool to classify the VMS deposits, especially for global comparison. Ore facies characteristics of Eastern Black Sea Region show close similarities to those in Ural district rather than Kuroko.

Keywords: Pontide, ore facies; sulfide sandstone; clastic ore; tube worm; sulfide chimney

Geochemistry, U-Pb zircon dating, Sr-Nd-O isotope and fluid inclusions studies in the Hassan-Abad Cu-Au prospect (SW of Neyshabour)

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The Hassan-Abad Cu-Au prospect in SW of Neyashabur is part of northeastern Iranian magmatic belt. The Old plutonic rocks in this region are calc-alkaline granite, granodiorite and tonalite with U-Pb zircon age of ~ 97 Ma; whereas adakitic monzodiorites, quartz syeno-monzonites and porphyritic monzonites (U-Pb zircon age of ~ 30 Ma) are younger intrusions. Andesitic to trachy-andesitic volcanic rocks are common in this region with U-Pb zircon age of ~ 45 Ma. Field and petrographical studies indicate various types of alteration in the region including potassic, phyllic, propelitic, sericitic, silicification and carbonation with two types of mineralization: 1) Cu mineralization associated with old, late Cretaceous intrusions and 2) Au (and Cu) mineralization related to the young, Oligo-Miocene porphyritic monzonites. Au mineralization in this prospect is normally found as Au-bearing quartz-calcite-adularia veins, deposited under epithermal (low-sulfide) conditions. Fluid inclusions in calcite and quartz veins (with Au mineralization) show different occurrences of inclusions including two phases, vapor-liquid, liquid mono-phase and vapor mono-phase. Nearly all fluid inclusions are represented as primary with blade-type, 3D volume, sphere-like and irregular shapes.
Homogenization temperature in quartz mineral is in the range of 180-390˚C (mean=279˚C), with salinity range of 0.88-7.31 (mean=3.2 eq. wt.% NaCl). The homogenization temperature for Calcite is in range of 165-295˚C (mean=202˚C) with salinity range of 0.18- 4.08 (mean=0.59 eq. wt.% NaCl). Oxygen isotopes studies reveal a magmatic origin with various degree of mixing with Formation waters for hydrothermal waters that are responsible for mineralization in the region.
Whole rock geochemistry and Sr-Nd-O isotope systematic show that older calc-alkaline granites are usually mantle-derived melts with various εNd while adakitic (high LREE/HREE ratio) rocks have similar εNd and $^{87}Sr/^{86}Sr$ values, showing similarity to subducted oceanic crust-derived adakites without significant assimilation with continental lithosphere. The geochemical signatures of adakites associated with their ages and geodynamics situation confirm post-collisional magmatism after closure of Sabzevar Tethyan basin in NE of Iran for formation of these rocks.

Keywords: Geochemistry; adakites; Sr-Nd Isotopes; U-Pb zircon dating; Fluid Inclusions; Hassan-Abad Cu-Au Prospect

Advanced argillic alterations ("Secondary Quartzites") from Rosen ore field (Eastern Srednogorie, Bulgaria) – relation to ore mineralizations.

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Rosen ore field belongs to the Eastern Srednogorie Zone, located on the Black Sea coast of Bulgaria. The Srednogorie Zone is accepted as the remains of a Late Cretaceous island-arc system, which prolongation to the east are the Eastern Pontides of Turkey. As a metallogenic unit, the Srednogorie has a dominantly Cu specialization being part of the Tethyan Eurasian metallogenic belt. Rosen ore field consists of several closely spaced deposits with more than 50 veins of economical value, mined in the past. The origin of the veins is suggested to be related to a central type volcano, presently found around a suggested ring-like Late Cretaceous intrusion (Rosen Pluton).

In the Rosen Ore Field several localities with advanced argillic lithocaps are known, but in most cases mineralizations have not been established in relation to them. The zones with advanced argillic rocks (secondary quartzites) are hosted in the wall rocks of the intrusion and are located with one exception in the internal (caldera) zone, thus suggesting a structural control and spatially are clearly not related to the known vein-type mineralization. Mineralogically and geochemically the secondary quartzites belong to three groups: 1. high-temperature, characterized by corundum + andalusite, andalusite + pyrophillite, diaspore + pyrophillite, quartz + sericite. 2. intermediate, related to a quartz-sericite paragenesis; 3. low-temperature, related to a sulfate group. A specific feature of the alunite facies is the broad occurrence of APS minerals. The chemical compositions of the alunites show their affiliation to the Na-containing varieties with a transition to the natroalunites. The alteration zones exhibit a metasomatic zonality. The presence of some higher temperature minerals like diaspore, andalusite and corundum overprinting alunite, kaolinite, as well as other minerals suggests a transitional volcano-plutonic environment or the presence of an intrusion at depth. The presence of propylites, argillizites as well as alunite-containing secondary quartzites suggests middle to low-temperatures of the hydrothermal solutions. The advanced argillic zones tend to show a zonal arrangement around the Rosen intrusive, the higher-temperature varieties being in the close vicinity of the contact zone. Despite the lack of spatial relation between the ore veins and the advanced argillic zones, they show similar structural features suggesting both to be formed during a single structural stage. At the present-day erosional level the advanced argillic rocks exhibit a vertical extend of the alterations of over 150 m. This may be due to primary reasons, but may well be caused by neotectonic displacement.

The imposed carbonitisation over the alunite-dickite secondary quartzites established in some localities is a very probable analogue to the carbonate assemblages imposed on the vein-type ore mineralization in Rosen ore field, thus suggesting a similar trend in the ore-forming processes from the inner and outer sides of the caldera. This, as well as the later baritisation and some gold content give ground to expect the presence of ore mineralizations beneath the present-day erosional level of the advanced argillic rocks.

Key words: Eastern Srednogorie Bulgaria; Rosen ore field; secondary quartzites, advanced argillization; alunite; APS

The first gold mineralization discovery in the middle north of Turkey (Middle Pontide): Şaphane Au±Cu Deposit (Oğuzlar/Çorum)

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Şaphane Au±Cu deposit is located 35 km northwest of Çorum, in the middle north of Turkey (Middle Pontide), between Sakarya and Kırşehir continental fragments separated by İzmir-Ankara-Erzincan ophiolitic suture zone. Middle Pontide province hosts several types of mineralizations such as volcanic-hosted massive sulfide type Cu-Pb-Zn, porphyry type Cu-Mo and vein type Pb-Zn-Ag±Cu, Cu-Pb-Zn±Au and Sb. Şaphane Au ± Cu prospect, which was discovered in 2009 by MTA, is the first known gold mineralization in this region. The discoveries of adits, shafts, shallow pits, processing waste, as well as the ancient mineral processing devices found in the surrounding area of the mineralization provide evidences that this gold mineralization is mined in the ancient times.

The basement rocks of the region consist of Middle-Upper Triassic Devecidağ and Upper Cretaceous Artova ophiolitic complexes. These basement rocks are unconformably overlain by Lower-Middle Eocene Alacahöyük sedimentary sequence. Middle-Upper Eocene Bayat formation, which conformably overlays the Alacahöyük formation, consists of volcanic, volcano-clastic and sedimentary rocks which are cut by medium to high-level intrusions and dykes of gabbro, syenodiorite, diorite porphyry, granite porphyry, aplite and quartz veins. These alkaline and subalkaline volcanic and plutonic rocks are related to the same magmatic system. All pre-Eocene and Eocene units are unconformably covered by sedimentary successions of Miocene age. The Şaphane gold mineralization is represented by NE-SW trending quartz-vein system hosted by partly silicified and extensively clay-altered subaerial volcanic rocks of Bayat formation (basaltic trachyandesite-basaltic andesite-trachyandesite-trachyte-dacite lava/pyroclastic rocks) and diorite porphyry of Middle-Late Eocene age. The gold mineralization consists of two major gold-quartz vein systems (S-1 and S-2) striking NE-SW and steeply dipping (85^o-90^o) to NW. Veins are 600 m long in strike direction and have a width up to 20 m on the surface. According to drill core data, mineralized veins extend down to 150-160 m from the surface. Gold-quartz veins display typical epithermal textures such as massive, vuggy, comb, crustiform and breccia textures.The pervasive quartz-kaolinite-illite-pyrite ± alunite ± amorph silica alteration zone encloses the main quartz veins. The ore mineral assemblages of the veins are native gold, magnetite, hematite, rutile, limonite, pyrite with trace amounts of chalcopyrite, galena, bornite, covellite and chalcocite. Native gold grain sizes change between 10 µm-0.25 mm. Gold content of the quartz veins changes between 40 ppb to 17.4 ppm.

Şaphane gold mineralization has many similarities to epithermal gold deposits in terms of metal associations, wall-rock alteration assemblages, mineralogy, textures and structural control. According to the geology, tectonics and the ancient mining activities in the region, it would appear that the middle north of Turkey is a new and favorable target for the discovery of epithermal gold deposits.

Keywords: gold; epithermal; kaolinite; illite; vuggy quartz

Fluid evolution of the Koru Pb-Zn deposit, Çanakkale (NW-Turkey)

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Koru Pb-Zn deposit is located 46 km northeast of Çanakkale in the Biga Peninsula, northwest Turkey. The Pb-Zn mineralization in Koru is hosted by Tertiary calc-alkaline volcanic rocks which are represented by Eocene andesitic lavas/tuffs, Oligocene-Miocene rhyolitic domes/lavas and tuffs. The ore minerals formed as disseminations and stockworks in the contact of rhyolite-tuff and as veins which are associated with NW-SE trending faults.Major ore minerals are galena, sphalerite, pyrite, chalcopyrite with lesser tetrahedrite-tennantite, chalcocite, covellite and marcasite. The gangue minerals are barite, quartz and calcite. Fluid inclusions were studied in sphalerite, barite and quartz within veins, breccias and stockwork from the Koru Pb-Zn deposit.

The main ore-forming fluids were $NaCI-CaCI_2-MgCI_2$ brines (First ice-melting temperatures range from -27 ºC to -54 ºC) with wide range of homogenization temperatures between 146 ºC and 359 ºC (without pressure corrections) and salinities between 0,2 and 11,1 equiv. wt. %NaCI.

The $\delta^{18}O_{fluid}$ and δD_{fluid} compositions in clays ($\delta^{18}O_{SMOW\text{-}clay}$ and $\delta D_{SMOW\text{-}clay}$ values ranging from +3,6‰ to +5,2‰ and from -68,4‰ to -88,2‰, respectively) suggest the mixed character of fluids between the fields of meteoric and magmatic water as a result of isotopic exchange between the deep circulated meteoric water and surrounding volcanic rocks.

Keywords: Fluid inclusions; oxygen and hydrogen isotopes; Koru Pb-Zn deposit; Biga Peninsula; Çanakkale

Ultra-High temperature K-silicate alteration in porphyry systems: Examples from the Çöpler (İliç) and Karakartal (Kemaliye) deposits in eastern Turkey

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The granitic stocks cropping out in a zone extending from Erzincan to Tunceli in the eastern part of the Anatolide-Touride Block contain many porphyritic intrusions, and are highly significant with regards to porphyry type mineral deposits, the examples of which include the Çöpler (İliç, Erzincan) Au- and Karakartal (Kemaliye, Erzincan) Cu-Au deposits. These deposits manifest typical examples of alteration zones related to porphyry systems. Potasic alteration occurs on the pre- and syn-mineral intrusive rocks at the center of the deposit and is characterised by quartz veins/veinlets, magnetite, secondary biotite, secondary K-feldspar and anhydtrite. Phyllic alteration is represented by mainly sericitisation of plagioglases on the outer zones of the potasic alteration. Argillic alteration occurs locally and is found near the surface. Propylytic alteration follows the contact between the intrusive rocks and the meta-sedimentary rocks, and also overprints the potasic alteration.

This study sums up the results obtained especially from the K-silicate alteration zones from these deposits. Quartz veins are highly enriched in fluid inclusions. Varying in size from <5 to 35 micron, the inclusions are divided into three distinct groups: Single phase, two-phase, and multi-phase. Single phase inclusions are further subdivided into liquid and gas types, and two phase ones into liquid-rich and gas-rich types. Composed of $H_2O+CO_2\pm CH_4\pm NH_3\pm N_2\pm SO_2$ the two-phase inclusions are enriched in $CaCl_2+FeCl_2+NaCl+KCl$, have 15-25 wt% NaCl eq. salinity and homogenise at 200-350^{o}C.

Multi-phase inclusions, which, based on electron microscope and Laser Raman analyses, are found to contain salt crystals, and/or Fe-oxide and sulphides, sulphates such as anhydrite and synjenite, and apatite, have rather low liquid and variable gas contents. Some inclusions are observed to contain only halite, some halite and sylvite, some Ca- and Fe-salts in addition to others, supported by eutectic temperatures as low as -55^{o}C. The homogenisation of gas in these inclusions takes place at 300-873^{o}C, with the presence of meta-stable inclusions (not homogenised even at temperatures exceeding 1000^{o}C). Salt phases homogenise at 125-425^{o}C and 400-680^{o}C, and opaque phases (Fe oxides and sulphides) at 850-1050^{o}C, resulting in salinity values of up to 80 wt % NaCl eq. Geothermometre calculations on biotites from the center and outer sections of the K-silicate alteration zone gives formation temperatures of 710-750^{o}C and 675-725^{o}C, respectively. The chlorites transformed from biotites obtained from the same zones produces respective temperatures of 310-370 and 250-310^{o}C, in accord with the microthermometric results of two-phase fluid inclusions.

These evidence shows that the studied porphyry systems are formed from salt-oversaturated fluids under ultra high to high temperature conditions at moderate to low pressures. The lower temperature fluids indicate repeated hydrothermal activities, probably causing alteration overprints.

Keywords: Karakartal, Çöpler, gold, Laser Raman, K-silicate alteration, geothermometre, porphyry deposits

Clay mineralogy of fossil and active hydrothermal systems around Sındırgı, Balıkesir, Turkey

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Miocene calc alkali volcanism hosts widespread hydrothermal alteration zones along Simav Graben in Western Anatolia. Sındırgı region is an example for this hydrothermal activity. There are several economically important ore deposits, hydrothermal mineralizations and geothermal fields near the area. The clay minerals subject of this study were formed by the effect of both fossil and active hydrothermal systems. The fossil hydrothermal alteration in Sındırgı region is related to the epithermal quartz veins and rhyolite dykes.
The mineralogical analysis of the clay samples were carried out by using x-ray diffraction (XRD) and scannining electron microscope (SEM). The clay mineral succession shift from kaolinite, illite to smectite with increasing distance from the quartz veins. The alteration related to rhyolite dykes occurred at two stage. At the first stage, dickite and alunite rich zones developed along faults and are related to acid-sulfate alteration. At the second stage, mixed layer clay minerals occurred and indicates a neutral type alteration. On the other hand, active hydrothermal system at Hisaralan geothermal field yields smectite while illite and chlorite are belong to the fossil hydrothermal system. The mineral saturation values of geothermal waters and activity diagrams are well compatible with clay minerals of active geothermal system.
Occurrence temperature of illite is between 230-320 °C and the transition for interlayered clays (illite/montmorillonite and chlorite/montmorillonite) occurs between 200-250 °C in hydrothermal environments. On the contrary to this, smectite (Ca-montmorillonite) formation occurs at <150 °C. It is therefore concluded that the temperature of the fossil hydrothermal fluids was > 200 °C in the region while it is well below from this temperature in active system. It is indicated that the system is cooling. The δD and $\delta^{18}O$ values show that the clay minerals in the field are hypogene in origin.

Keywords: Volcanism; hydrothermal alteration; geothermal system; dickite; illite; interlayered clays.

Petrographical and geochemical properties of the Paleocene aged and bordeaux - red colored marbles from Menderes Massif, SW -Turkey

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The Paleocene aged marbles from the southwestern Menderes Massif contains a calcite marble unit hosting a commercially exploited from bordeaux to red marble deposit, which underwent greenschist-facies. Major and trace element have been used to define geochemical differences between interbedded calcite and bordeaux - red marbles and to assess their post-depositional isotopic resetting.
The Aegean Bordeaux marbles are distinguished from other rocks by characteristic Bordeaux – red color related to their pigmentation by finely dispersed bauxite and hematite. They are commonly inequigranular rocks. Depending on the content and distribution of Al rich minerals, piemontite and accessory minerals, they are characterized by massive, spotted, or banded and ptigmatic structures.
This paper reports isotopic and sedimentological data from a calcite marble succession at southern Menderes Massif. The succession are all part of the marble group belonging to the southern Menderes Massif in Turkey.

Key words : Paleocene; Aegean bordeaux; ptigmatic; banded texture; REE elements

Genesis, Stable Isotope and Mineral Characterisation of Sarıbeyli – Sığırlı and Bodurlar Kaolin Deposits, Çanakkale, Turkey

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The Çanakkale-Çan area is situated on the Biga Peninsula of northwest Turkey. The NE-SW "*en-echelon*" faults, which constitute the western end segments of the North Anatolian Fault Zone (NAFZ) in the Biga Peninsula, are represented by; (1) the Manyas-Danışment fault, (2) the Yenice-Gönen fault and (3) the Sarıköy-Inova fault. The third fault is also known as the Çan-Bayramiç fault zone and forms the location of the many epithermal systems that have been studied along this zone. The Biga Peninsula host many economically significant epithermal mineral deposits that were shaped by mainly collisional and post-collisional tectonics regimes, ranging from 18 to 52 Ma. Mineralization took place during Cenozoic calc-alkaline magmatism and calc-alkaline volcanic rocks types that ranging from andesitic lavas to andesitic tuffs. These altered andesite tuffs are the host rocks for the epithermal deposits in the study area. The Sarıbeyli-Sığırlı and Bodurlar kaolin deposits are major epithermal deposits and contain high-(HS) sulfidation styles. The mineralization of these kaolin deposits was controlled by geothermal solutions ascending through the fault zones to the surface. The Sarıbeyli-Sığırlı kaolin deposits comprise different mineral associations with increasing distance from the fault zone; i) massive quartz, ii) quartz + alunite ± kaolinite, iii) kaolinite ± quartz, iv) kaolinite + illite + feldspar; and for the Bodurlar kaolin deposit; i) vuggy quartz ± Fe-oxides, ii) kaolin + jarosite ± alunite ± quartz, ii) kaolin + halloysite ± quartz ± feldspar. Alunite samples from the Sarıbeyli-Sığırlı deposits have $\delta^{34}S$ values of +2.4 to +4.1 ‰ that reflect its formation from magmatic-hydrothermal derived sulphur. Hypogene alunite deposits have high P_2O_5 contents, suggesting a deep magmatic origin. The range of $\delta^{18}O$ and δD stable isotopic values of kaolin samples from these deposits are +6.7 to +12.7 ‰ and –61 to –97 ‰, respectively, which are very close the values of primitive magmatic water. Hence, the isotope data suggest that original geothermal waters were a mixture of magmatic water and meteoric waters. $\delta^{18}O$ and δD values of kaolin samples of Bodurlar kaolin deposit are +6.7 to +12.7 ‰ and –61 to –97 ‰, respectively, which reflects a supergene origin and enrichment in the $\delta^{18}O$ values. Based on SEM studies, micro-morphologic features of kaolinite crystals show that kaolinite occurs as hexagonal blocky and book-shaped crystals, which can exist in both ordered and disordered forms. Halloysites rods exhibit parallel and randomly non-parallel, closed-hole morphology, and alunite crystals show rhombohedral shapes. According to paleo-temperature model calculations, which are dependent on kaolin-water oxygen isotope fractionation, the formation temperatures of the Sarıbeyli-Sığırlı deposits range from 104 to 179°C, and the formation temperature of the Bodurlar deposit ranges from 67 to 87°C. Hence, the Sarıbeyli-Sığırlı and Bodurlar kaolin deposits have similar origins which can best be described as steam-heated high-sulphidation epithermal systems in tectonically active regions.

Key Words: calk-alkaline magmatism; high-sulphidation; kaolin; alunite; jarosite; stable isotope.

Diagenetic processes and depositional environment of the Germik Formation evaporites (Siirt, SE Turkey)

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Depositional analysis of the Oligocene Germik Formation (Kurtalan-Siirt, SE Turkey) is carried out by determining sedimentary lithofacies as well as diagenetic processes in evaporites. The Germik Formation consists predominantly of carbonates with minor mudstone, marl, gypsum and anhydrite beds.
Gypsum and anhydrite lithofacies are determined based on stratigraphic relationships and sedimentological features. Gypsum is secondary after anhydrite. Massive, banded, laminated, nodular, chicken-wire, enherolitic and brecciatted gypsum lithofacies are identified in the Germik Formation. Anhydrite nodules, micritic limestones and bitumen- rich mudstones are also present.
According to sedimentary structures and lithofacies the evaporites of the Germik Formation-are assigned to a coastal sabkha-lagoon environment during sedimentary and early diagenesis, while alabastrine, porfiroblastic and satin-spar gypsum fabrics resulted from the late diagenetic cycle (burial anhydritization and rehydration during exhumation).

Keywords: Siirt, Germik Formation, evaporite, diagenesis.

Mineralogical, chemical and microstructural characterization of crude and expanded Industrial Perlite from Milos Island, Aegean region, Greece

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Milos Island in the southwestern Cyclades (Aegean Sea, Greece) belongs to the active southern Aegean volcanic arc and is well known for its mineral resources since ancient times. Trachilas complex at the central-north and Fyriplaka complex at the south-east part of the island comprise the two main volcanic centers. They exhibit the youngest volcanic activity of upper Pleistocene Age which is associated with extensive perlite deposits.

Perlite is a natural volcanic glass, commercially valuable due to its expansion ability from 4 to 20 times its original volume and its simultaneous reduction in bulk density by up to 90%. These characteristics make perlite an ideal industrial product for a plethora of traditional and new applications. Perlite is used in industry in two forms, as crude after crushing and screening of the raw perlite and as expanded after heating of the crude perlite to a critical point, nearly to its softening point.

Representative raw perlite samples were collected from the two main volcanic centers of the island. The present study examines the 1.18-2.5 mm industrial size fraction of these samples (crude perlite) and their expanded counterparts with the aim to determine and compare their mineralogical and chemical compositions and their microstructures.

X-ray diffraction (XRD) study indicated the presence of amorphous glassy matrix together with quartz, plagioclase, K-feldspar, biotite, muscovite and minor to rare zircon, ilmenite, chalcopyrite and apatite, for both Trachilas and Fyriplaka crude perlite samples. Differences in the mineralogical compositions of the crude samples and their representative expanded materials as well as between the expanded materials of the two crude samples are assigned to the unexpanded components that remained intact after the expansion.

Based on Inductively Coupled Plasma Mass Spectrometry (ICP-MS) chemical analyses, all samples are classified as rhyolites having a calc-alkaline character. Nevertheless, crude perlite samples from the two areas, exhibit differences in their chemical composition.

Crude and expanded perlite samples were observed using a Scanning Electron Microscope (SEM). Perlitic and pumiceous structures are apparent in crude perlite samples, whereas expanded perlite samples are characterized by the presence of open pores as small channels forming a thick network and closed pores as isolated cells and holes.

Keywords: Industrial Perlite; XRD; ICP-MS; SEM; Milos Island

Platinum-group element (PGE) abundances of chromitites in southwestern Lycian peridotites, Turkey

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Local PGE enrichments are previously reported in Turkish chromitites. The bulk-rock major and trace element compositions and PGE abundances of several podiform chromitite occurrences of Lycian Peridotites are studied in order to investigate such variations. To fulfill this aim, thirteen selected chromitites (Rozocak, Sinekli, Yolocak, İnbaşı, Elmaslar, Bülüşlü, Keserali, Harmancık, Dikmen, Sivan, Ilıkdere, Kaymakam, Kazandere) from Lycian Taurides are sampled and analyzed. The PGE abundances in all of the studied deposits are generally low (∑PGE=64-494 ppb, $\sum PGE_{av}$= 267.7 ppb, n= 38). Most of the sampled chromitites are enriched in IPGE (Ir-group PGE; Os, Ir, Ru) over PPGE (Pd-group PGE; Rh, Pt, Pd). Average PGE abundances are 8.5 ppb for Pt, 7.0 ppb for Pd, 8.4 ppb for Rh, 73.2 ppb for Ir, 90.0 ppb for Os and 80.7 ppb for Ru. Three of the sampled chromitites (Elmaslar, and nearby Topuk and Kadem to the north of this deposit) present higher average PGE abundances with 19.5 ppb Pt, 11.9 ppb Pd, 9.5 ppb Rh, 83.7 ppb Ir, 120.3 ppb Os and 81. 2 ppb Ru with an average ∑PGE content of 326 ppb (n=12). One sample from the Elmaslar chromitite present unusually enriched in PGE (4145 ppb ∑PGE), in favor of Pt and Pd, and high base-metal content (3330 ppm Ni, in massive chromitite).

Generally, Ir, Os and Ru content of the all sampled chromitites present positive correlations with Cr_2O_3 and ∑PGE, and negative correlations with SiO_2 suggesting that the PGM phases are concentrated mainly in chromium-spinel as Ir-Os-Ru species. Pt and Pd and Ir, Os and Ru contents show positive correlations with each other. Pd/Ir ratios are significantly positively correlated with SiO_2 and negatively correlated with Cr_2O_3, supporting the Pd- and Ir- group fractionation between interstitial silicates and/or matrix and the chromium-spinel.

The chondrite normalized PGE patterns of the sampled chromitites present slightly negative sloped patterns from IPGE to PPGE with positive Pd anomalies and some samples present slight Ru-positive peaks relative to Ir and Rh, which is compatible with the previous studies from the region. The PGE patterns from Elmaslar and Topuk chromitite also present similar negative sloped patterns however, with absence of the Pd anomaly due to the higher Pt_N values. Furthermore, the Elmaslar chromitite samples present variation in normalized PPGE and IPGE ratio vs. their near constant ∑PGE content. This suggests local fractionation of the PPGE and IPGE along the deposit during the formation of the chromitite pod.

The ΣPGE data indicates that studied chromitites are currently non-economic for PGE mining operations. There is only a slight elevation in the average PGE abundances and total PGE content of Elmaslar and nearby chromitites according to the general average; although it is also not economic.

Keywords: Peridotite; podiform chromitite; platinum-group element abundances; southwestern Turkey

Manganoan skarns: Important host of the hydrothermal ore mineralization in the base metal deposits in Central Rhodopes, Bulgaria

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The Rhodopean metamorphic massif outcrops in southern Bulgaria and northern Greece and is considered as the inner-most zone of the Alpine-Himalayan orogenic system in the Eastern Mediterranean. Large Tertiary (~30Ma) hydrothermal Pb-Zn deposits in the Central Rhodopes are hosted in the high grade metamorphic complex, consisting of various gneisses, amphibolites, mica schists, and certain marble layers, intruded by rare pre-ore rhyolitic dykes. Ore bodies are presented by: 1) steep ore veins and stockwork zones, controlled by six major NNW faults and 2) metasomatic skarn-ore bodies, formed at intersections with three marble horizons.

The metasomatic Pb-Zn ore bodies in Madan are preferably embedded by early manganoan skarns, which in turn are formed by vein-derived hydrothermal solutions, causing replacement of marble interbeds within high grade metamorphites. The reduced manganoan skarns in the Madan region host rich sulphide Pb-Zn mineralization.

The skarns have several characteristics, which distinguish them as a separate geochemical and petrological formation. The observed exoskarns are of infiltration type, distal, without visible links to magmatism and no direct link with intrusion. A possible local connection with the pre-ore rhyolitic dykes near the ore bodies could be suggested. Skarn ledges are entirely marble-hosted; showing variable morphology depending on the lithological contacts of the primary carbonate layers and screened by the other rock types. These skarns are clearly pre-ore, without any sulphides, although their retrograde alteration suites the deposition of rich sulphide ores. An important geochemical characteristic is their manganoan specialization. The radiate aggregates of the primary skarns are composed of high-manganoan pyroxenes from hedenbergite-johannsenite$_{ss}$ and lately overprinted manganoan pyroxenoids. The skarns exhibit well expressed zonation defined by the different Mn/Fe ratio across lateral and vertical direction. Manganoan skarns are formed at relatively lower temperatures, as compared to the other skarn types. Microthermometry on fluid inclusions in the pyroxenes revealed Th 420-400^{o}C.

The ore deposition in the metasomatic bodies is achieved as neutralization of metal-bearing acid fluids reacting with the alkaline pyroxene skarns. Their retrograde alteration leads to formation of manganoan silicate-carbonate association of pyroxenoids, amphiboles, manganilvaite, chamosites, andraditic garnets etc. The highly reactive in S-containing high-T fluids Mn-Fe clinopyroxenes favors the economic ore precipitation in the process of lowering temperature and pH of the hydrothermal solutions.

The complex history of replacement ores includes two main crystallization mechanisms: 1) metasomatic growth in solid medium realized by solid-state topotaxic ion exchange reactions or reconstructive dissolution/precipitation processes; and 2) crystallization in open space.

The metasomatic bodies concentrate an important part of the ore resources of the Madan district. Since they are perspective in all levels of the deposits they can be considered as a potential future resource for base metals in the region of Central Rhodopes.

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Keywords: manganoan skarns; Pb-Zn sulphide deposits; Rhodopes; Bulgaria

Systematic differences between prehistoric and modern metal provinces in Western Turkey as a result of supergene modification – implications for archaeological provenance studies

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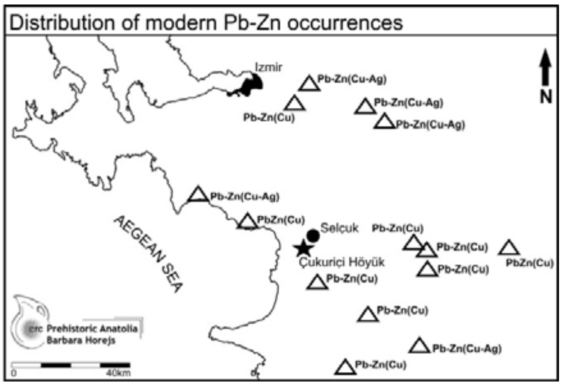
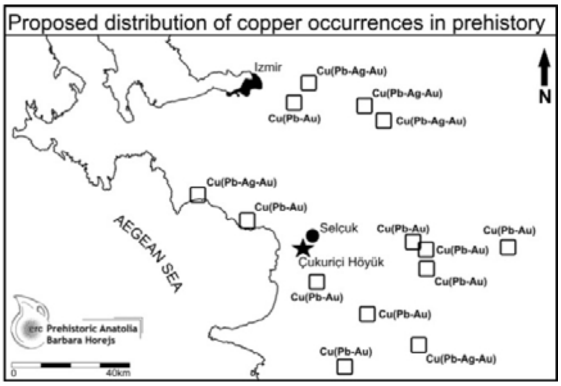
The prehistoric, Neolithic to Bronze Age settlement of Çukuriçi Höyük, situated adjacent to the antique town of Ephesos, has been the subject of recent archaeological excavations as well as of geological studies. Finds from the Early Bronze Age (excavation phases III and IV) include a relatively large number of furnaces, metallurgical tools, copper artifacts, and even a few fragments of low-grade copper ore. The settlement has apparently been an important metallurgical center, which required the complex logistics of sufficient raw materials supply, such as Cu-ore, and a exchange system of distributing metal products, as suggested by "standardized" molds for the production of arsenic copper ingots.

The environs and hinterland of Ephesus and Çukuriçi Höyük are geologically well-studied and documented and – according to modern metallogenic maps – represent a metal province dominated by polymetallic vein-type Pb-Zn-(Ag) as well as by meso- and epithermal Au occurrences. Thus it appeared rather surprising that Çukuriçi Höyük, as a substantial copper producing site, should be located far from the rich copper districts in northeastern and northwestern Turkey. Our preliminary study includes detailed field observations as well as general considerations on the influence of supergene modification of vein-type ore deposits. The differential solubility and mobility of base and precious metals in the surface and near-surface meteoric depth range suggests that modern distribution maps do not reflect the prehistoric situation adequately.

Modern maps generally document metal occurrences and deposits of current economic and geological interest at a tested depth; many of them having been explored, drilled, and (many of them) mined. As a consequence, these hypogene, typically polymetallic Pb-Zn-Ag (Cu-Au) sulphide vein systems make up the majority of the documented occurrences in publications and metallogenic maps of this region. However, supergene processes (including "weathering") by meteoric water will drastically modify the relative metal abundances and mineralogical compositions of the ores in this surface and near-surface depth range. Zn will, almost invariably, be remobilized and lost due to its highly soluble nature under oxidizing conditions. Pb will be mobilized and partly lost but will also be partly preserved as galena due to armoring by anglesite. Cu is typically oxidized and forms secondary non-sulphide minerals (e.g. malachite, azurite, and cuprite) or secondary Cu-sulphides such as chalcocite. These near-surface secondary copper minerals are particularly amenable to early smelting and "co-smelting" techniques.





As a consequence, a prehistoric mining landscape with the above mentioned endowment with polymetallic veins would have been characterized predominantly by near-surface Cu-(Pb-Ag-Au) deposits. This is in marked contrast to the impression from modern maps, which may not fully appreciate the metal districts available to and exploited by the earliest Anatolian miners.

Keywords: Çukuriçi Höyük; supergene processes, non-sulphide minerals; Early Bronze Age

Geology, mineralization and alteration of the Razi Abad porphyry Cu-Mo mineralized district, SE Iran

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Razi Abad copper ore deposit has located in the Uromieh-Dokhtar volcano-plutonic belt. The complex is associated with Oligo-Miocene age intrusives and Eocene volcano-sedimentary rocks. The area is situated in 25km northwest of Jiroft town. To access to the area is possible via Kerman-Jiroft towns. Geological rocks in the area comprise of dark shale, volcano-sedimentary units, Eocene andesitic lava and granular quartz diorite intrusive units. Mineralization host rocks are Oligo-Miocene subvolcanics ranges in micro diorite, micro quartz diorite, porphyritic quartz monzodiorite, and porphyritic granodiorite compositions. Acidic, intermediate, and basic dykes are intruded into intrusive rocks.
Razi Abad is a typical porphyry Cu-Mo mineralized district –in terms of its alteration and sulfide assemblage zonation, association with felsic to intermediate intrusions, and predominance of quartz vein-hosted copper mineralization. There is an intimate spatial and temporal association between all stages of mineralization and latest Oligocene to early Miocene felsic to intermediate intrusions at Razi Abad.
Most of the copper was emplaced during the late magmatic stage, contemporaneously with intrusion of the granodiorite porphyry stocks and intermediate to mafic dykes into a acidic and intermediate stock complex. Mineralization of the late magmatic stage is mainly hosted by a quartz-magnetite-dominated stockwork associated with potassic alteration in the granodiorite and micro diorite porphyry and minor propylitic alteration of the micro diorite porphyry and intermediate to mafic dykes. Minor copper-mineralized hydrothermal biotite-cemented breccias formed at this time. The late magmatic stage was followed by stage of phyllic alteration, during which thicker, Cu-rich veins were emplaced. Potassic-phyllic alteration formed during the late hydrothermal stage and appears to have destroyed a large amount of ore from some parts of mineralizations. Minor argillic alteration formed in the granular quartz diorite rocks limited to faulted zone.

Keywords: Razi Abad; porphyry; geology; mineralization; alteration; Kerman

Felsitic Magmatizm of the Greater Caucasus Kakheti Sector and Rare Elements Ore mineralization

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The Greater Caucasus is the northernmost fold system of the Caucasus collisional orogen, which is linked to the southern margin of the Eurasian continent, more than 1200 km, between the Black and Caspian Seas.

Kakheti sector is situated on the eastern part of the Greater Caucasus southern slope and is mainly formed of Lower-Jurassic clay-shales and small quantities of sandstones and volcanic-sedimentary rocks. This complex of sediments extends in the NW-SE direction and is intersected by gabbro-dioritic, dioritic and felsitic intrusives. According to modern geophysical data, the sediments of the southern slope of Greater Caucasus in Kakheti sector are located on oceanic type crust.

In the study area felsitic intrusives are represented by hypabyssal quartz-porphyric and granite-porphyric dykes, thickness of which varies from single meters to tents of meters, and they cause intensive hydrothermal alteration and sulfide mineralization of host rocks. According to geological data Upper Cretaceous age of these magmatites is defined. Four main occurrences of which in the region are represented by Speroza, Stori, Siptiskhevi and Lopota outcrops.

Hydrothermal alteration and ore mineralization is particularly intensive in the river Stori canyon. The canyon cuts the southern slope of the Greater Caucasus and at 3,5 km distance exposes the interaction zone of mentioned sedimentary and magmatic rocks. In this section clay-shales undergo intensive hydrothermal silicification, carbonatization and sulfide mineralization. This process is particularly intensively revealed in brecciaed shear zones, where sometimes thick sulphide ore lodes are formed. The studies showed, that during alteration, the complex of rocks was enriched by thorium, bismuth, lantanium and strontsium up to industrial concentration (Th=50-200g/t; Bi=200-900g/t; La=16000-17000g/t; Sr=3600-3770g/t; Chemical analyses of these elements have been performed in Vancouver "ACMELABS" laboratory, Canada, using the ICP-MS method). High concentration of lantanium and strontsium is fixed only in altered 7m thick clay-shales. And bismuth and thorium are related as to hydrothermally altered rocks so to quartz-pyrite-pyrrotite-copper pyrite veins.

Content of Th in the section of hydrothermally altered rocks varies between 50-200 g/t, Bi – 200-900 g/t, but these values are higher in quartz-pyrite-pyrrhotite-copper pyrite veins. The highest content of these elements is detected in one zone (Gelia zone, where visible thickness is 3-7 m, and is traced on 300 m), where the Th concentration reaches to 3842 g/t, and Bi – 4806 g/t. Also high concentrations of these elements are marked in Bendena zone (thickness – 7-15 m, traced on 550 m), where Th content reaches to 320 g/t, and Bi – 1050 g/t.

As it is known, Th is considered as primary energy resource of the third millennium, and Bi, La and Sr are used in modern high tech production. Because of that we think that the region is very interesting of rare elements ore mineralization, and it's necessary to carry out farther detail research.

Keywords: Great Caucasus, felsitic magma, intrusive, REE

The “chessboard” classification scheme of mineral deposits-With special reference to ultrabasic magmatic rocks

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Economic geology is a “*mixtum compositum*” of all geoscientific disciplines focused on one goal, finding new mineral deposits and enhancing their exploitation. The keystones of this “*mixtum compositum*” are geology and mineralogy whose studies are centered around the emplacement of the ore body and the development of its minerals and rocks. In the present study, mineralogy and geology act as x- and y-coordinates of a classification chart of mineral resources called the “chessboard” “ (or “spreadsheet”) classification scheme. Magmatic and sedimentary lithologies together with tectonic structures (1-D / pipes, 2-D/ veins) are plotted along the x-axis in the header of the diagram representing the columns in this chart diagram. 63 commodity groups, encompassing minerals and elements are plotted along the y-axis, forming the lines of the spreadsheet. These commodities are subjected to a tripartite subdivision into ore minerals, industrial minerals and gemstones/ ornamental stones. Further information on the various types of mineral deposits, as to the major ore and gangue minerals, current models and mode of formation or when and in which geodynamic setting these deposits mainly formed throughout the geological past may be obtained from the text by simply using the code of each deposit in the chart. This code can be created by combining the commodity (lines) shown by numbers plus lower caps with the host rocks or structure (columns) given by capital letters.
Each commodity has a small preface on the mineralogy and chemistry and ends up with an outlook into its final use and the supply situation of the raw material on a global basis, which may be updated by the user through a direct link to databases available on the internet, e.g., the database of the US Geological Survey. The internal subdivision of each commodity section corresponds to the common host rock lithologies (magmatic, sedimentary, metamorphic) and structures. Cross sections and images illustrate the common ore types of each commodity. Ore is given priority over the minerals. The minerals are listed by their chemical composition and may be viewed by the reader by clicking on-line the pertinent databases, where the “showroom” varieties, seldom found in a mine, are on display.
A metallogenetic-geodynamic overview is given at the bottom of each column in the spreadsheet. It is the “sum” and “ mean” of geodynamic models and ideas put forward by the various researchers for all the deposits pertaining to a certain clan of lithology or structure. This classical or conservative view of metallotects related to the common plate tectonic settings is supplemented by an approach taken for the first time for such a number of deposits, using the concepts of sequence stratigraphy. This paper, so as to say, is a “launch pad” for a new mindset in metallogenesis rather than the final result.
The relationship supergene-hypogene and syngenetic-epigenetic has been the topic of many studies for ages but to keep them as separate entities is often unworkable in practice, especially in so-called epithermal or near-surface/shallow deposits. Vein-type and stratiform ore bodies are generally handled also very differently. To get these different structural elements (space) and various mineralizing processes (time) together and to allow for a forward modeling in exploration, architectural elements of sequence stratigraphy are adapted to mineral resources. Deposits are geological bodies which need accommodation space created by the environment of formation and the tectonic/geodynamic setting through time. They are controlled by horizontal to subhorizontal reference planes and/or vertical structures. Prerequisites for the deposits to evolve are thermal and/or mechanical gradients. Thermal energy is for most of the settings under consideration deeply rooted in the mantle. elements
Table and order of contents: Chromium, nickel, cobalt, platinum group elements (PGE / platinum-palladium-osmium-iridium-rhodium-ruthenium),titanium, vanadium, iron manganese, copper, selenium-tellurium, molybdenum-rhenium, tin-tungsten, niobium-tantalum-scandium , beryllium, lithium-cesium-rubidium, lead-zinc-germanium-indium-cadmium, silver , bismuth, gold, antimony, arsenic, thallium, mercury , rare earth elements (REE/ lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium)-yttrium, uranium-radium , thorium, aluminum-gallium , magnesium calcium, boron, sulfur-calcium sulfate , fluorine, barium, strontium, potassium-sodium-chlorine-bromine, nitrogen-iodine sodium carbonate- sodium sulfate, phosphorus, zirconium-hafnium, silica, feldspars, feldspathoids, zeolites, amphibole-asbestos (asbestiform minerals), olivine-dunite pyroxene-inosilicates, garnet-group minerals, epidote-group minerals, sillimanite-group minerals, corundum-spinel, diamond, graphite, allophane-imogolite, halloysite, kaolinite-group minerals(kandites), talc-pyrophyllite group, smectite-group minerals, vermiculite, mica-group minerals, chlorite-group minerals, sepiolite-palygorskite (hormites), jet (lapidary coal), amber.

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WATER RESOURCES AND ENVIRONMENT

Conveners:
Alper Baba , Jochen Bundschuh and Avner Vengosh

Water Resources Management in Water-Scarce Regions regarding Impacts on Groundwater and the Environment

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In Israel the local trends of urban development, as well as increased adoption of water desalination and irrigation with wastewater, have combined to accelerate groundwater salinity. We will present a model for planning water supply from diverse sources integrating hydrological, technological and economic considerations, and estimates the economic and environmental impacts of alternative water management policies. This model was implemented in a case study in central Israel. The hydrological database includes groundwater data for each hydrological cell in the case study area, and we implemented hydrological model for planning the allocation of the water resources and forecasting the concentration of chlorides in the aquifer under alternative scenarios. These scenarios included a variety of threshold policies for water supply to the city, irrigation or to the aquifer, irrigation with and without wastewater, and various well water pumping policies. The economic model estimated the costs of various desalination processes under the regional conditions, and calculated the costs of the water supply to the region under these scenarios. The hydrological model produces annual forecasts of chloride concentration in groundwater in the short term and long term, while the economic model produces forecasts of the implementation costs. The economic cost of improving the quality of the supplied water and of the aquifer water should be considered in decision-making.

Keywords: water management; groundwater; desalination; environment; economics

Groundwater recharge and turnover in a coastal aquifer in Albania

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The Pleistocene river Mati coastal plain contains important aquifers supplying water to neighbouring towns. The sedimentary sequence contains at least three aquifers sandwiched between clay layers. The aquifers are confined except for a gravel cone at the entrance of the river into the plain. This is an important point of recharge. The lower aquifers are artesian with pressure heads up to 2 m above ground. While the upper aquifer contains fresh water the lower aquifers are slightly brackish and mostly of a Na-HCO_3-Cl type indicating flushing of former saline strata. The salinity may, as per □^{18}O analysis, be derived by diffusion from the clay layers rather than by mixing in of residual sea water. Thus, the flushing of the aquifers has reached a rather late stage. Five samples from the lower aquifers dated with ^{14}C showed ages between 2 000 to 6 000 years. It coincides with a sea water level that was about 5 m higher than the present one. The area is situated close to the seam between the African and the Eurasian plate which make the past sea water levels a complicated story. However, a shore line found in the plain has been defined as belonging to the Flandrian transgression. This in addition to the artesian character indicates limited offshore outlets.
The recharge from river Mati can be traced by the elevated sulphate content in the river water originating from sulphide mines upstream in terms of concentrations and sulphur isotope ratios. About 10 M ton of waste rock and tailings sand is present in the catchment of the rivers Mati and Fani. While the sulphide derived sulphate has δ^{34}S ratios slightly above or close to zero the ratio in sea water and sea spray is in the order of 15-21 per mille. The main well field in the plain seems to be completely fed by the river via the alluvial cone as per sulphur isotopes in the sulphate. The leaching from mining wastes does not seem to pose a threat to the water quality as the river water is well buffered with a pH ranging from about 7,5 to above 8. A speciation of the metals in the river water shows that copper is present mainly in suspended and colloidal form while zinc, cadmium and nickel are more mobile. No elevated concentrations of heavy metal were found in the groundwater. Two wells had an arsenic content just above the permissible limit of 10 μg/l. A more serious threat to the aquifers is the extensive gravel extraction taking place in the gravel cone. This may decrease the hydraulic conductivity and decrease the hydraulic gradient from the gravel cone to the main well field in the plain serving as water source for more than 225 000 people.

Keywords: groundwater; coastal; recharge; sulphur isotopes; carbon-14 dating;

Defining protection zones of the Egirdir Lake based on regional geology and groundwater flow fields

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The freshwater of Isparta and Egirdir is supplied from the Egirdir Lake which is the second largest freshwater freshwater lake of the Lakes District. the Egirdir Lake is studied within the frame of "Basin Protection Plan of the Egirdir Lake and Assigning Special Provisions Project" of Ministry of Environment and Forestry. For this purpose, groundwater flow fields were prominently used in defining protection zones as well as surface runoff. This lake is vastly recharged by groundwater from karstic carbonate rocks and alluvium deposits.
The inner protection zone which is defined as the 50-day travel time and the outer protection zone defined by 400-day travel time were estimated by infiltrometer tests in alluvium, and pumping tests results for the determination of hydraulic conductivity, and the groundwater levels for the determination of hydraulic gradient.

Keywords: Eğirdir Lake; protection zones; travel time

Evalution of hydrogeochemical properties of Merzifon (Amasya) aquıfer

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The most important requirements of the regenerates is water in the world. Groundwater is the most strategic value among other water resources. Unfortunately quality of the surface and groundwater are polluted with physical, chemical and biological factors.

Alluvial groundwater, surface and spring water of Merzifon Aquifer were investigated from point of drinking and agricultural activities in this study. The water analyses from 20 water samples, taken over in rainy season, were used to determine hydrogeochemistry and contamination of groundwater and surface water.

Recharge area of the Merzifon-Gümüşhacıköy Basin is covered of 1060 km^2. Merzifon Aquifer that presents phreatic aquifer characteristics is covered 40 km^2. Recharge of the aquifer is occurred from rivers and surface runoff; discharge from the groundwater is eventuated from the springs and the wells. Totally 36 water wells are used for drinking, irrigating and industrial purposes in the catchment area. Yields of wells are 10-60 l/sec and depths are 40-235 m. Groundwater flow is occurred from north to south in the basin. Aquifer material is composed of Pliocene-Quaternary aged permeable sandstone, conglomerate, sand and gravel.

The chemical analysis results of the well waters drilled in Merzifon Aquifer, surface waters and spring water have been evaluated. EC of the water samples are between 41-137x10^6 (25 ^{0}C) and pH values are between 7-8,4. Total hardness of the water samples are 14-64 FH. The surface water samples were classified as high quality waters in terms of Ph, EC, TDS and BOD and the second quality to DO, BOD and Turbidity. The groundwater samples were determined as the second quality in terms of color, DO and TDS.

Groundwater and surface water samples are of the Ca-HCO3 water type according to the Piper Diagram. Dominated cation trends of the water samples are $Ca^{++}>Na^{+}>Mg^{++}>K^{+}$ and anion trends are $HCO_3^{-}>SO_4^{--}>Cl^{-}$. According to the Schoeller Diagram groundwater and surface water samples have the same origin but the surface water samples have lesser ion contents. Anion and cation contents of the groundwater are increased from north to south.

The groundwater and surface water in the Merzifon Aquifer were classified as high quality in terms of Cr, Mn, Cu, Cd, Co, Ni, Al, B, Pb and Zn according to the Water Pollution Control Regulation. But partly polluted in terms of Mn and As. On the other hand Ba values in the waters are higher than other elements. Groundwater samples are suitable for drinking according to the Water Standard for Human Consumption (TS-266, 2005).

Mapping studies in the Geographical Information Systems were made in order to determine the quality of ground and surface waters according to the physical and chemical parameters. Major anion-cation, physical parameters and trace elements distribution maps were created by using ArcGIS 9 Geographical Information Systems program. Water quality maps marks that element concentrations of the surface and groundwaters in the aquifer are increased in the direction of water flow.

Keywords: Groundwater; Surface water; Hydrogeochemistry; Merzifon Aquifer

Environmental – Hydrogeological investigations in the broad area of Lemnian earth, Limnos Island, Greece

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An environmental study took place in the broader area of Lemnian earth at Northeast part of Limnos Island aiming at the investigations of a) the hydrochemical conditions and the groundwater quality of the area and b) the properties and the quality of the Lemnian earth. The wider area of Romanou – Kotsinas has been affected in high grade of groundwater salinization due to seawater intrusion caused by the overexploitation of the volcanic aquifer. Ion exchange is the dominant hydrochemical process; however the enrichment of groundwater in various metals, especially in potassium and magnesium is attributed to rock and mineral weathering and dissolution. In the Ancient Greek period, the Lemnian Earth (mud material) extracted in Kostinas region of Limnos Island, was used for medicinal uses (e.g. as antiseptic cataplasms, to cure skin afflictions, as cicatrisers, as a cure for snake bites). In order to determine the quality of Lemnian Earth, its suitability and efficiency for medicinal uses a series of samples were collected and studied by various techniques. The mineralogical composition of the material was determined using XRD and SEM and it was found to be rich in smectite and specifically in Ca-montmorillonite. The chemical analyses of major, trace elements and REE show that the material was suitable and effective for therapeutic purposes but prolonged use of the material could cause serial health problems.

Keywords: Hydrochemistry, groundwater quality, Lemnian Earth

The influence of geothermal fluid on groundwater quality in Alaşehir region, Manisa, Turkey

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Geothermal energy is generally accepted as being an environmentally benign energy source. Geothermal development has shown that it is not completely free of impacts on the environment. In essence, with its high dissolved constituents and thermal content, geothermal fluid is known to have significant impacts on environment when disposed in an uncontrolled manner. In parallel to developing geothermal energy applications in Turkey, many sites are now experiencing problems associated with not only waste geothermal fluid disposal but also uncontrolled surface eruptions during drilling operations. Being one of these sites, Alasehir Geothermal Area is studied in this study and problems associated with waste geothermal fluid discharge on groundwater resources are assessed. The waste geothermal fluid originating from Alan where geothermal drill was collapsed in the area is found to cause significant thermal and chemical contamination. Particularly, the uncontrolled discharge of geothermal fluid contained high levels of arsenic and boron. The result shows that uncontrolled geothermal fluid eruptions influence groundwater resources of the area where water resources are commonly used for agricultural irrigation.

Keywords: Geothermal fluid, groundwater, water quality, arsenic, boron.

Arsenic concentration in the groundwater of Taft, Central Iran

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This study investigate the concentration, distribution and origin of arsenic in ground waters in the Taft area (15 km South West of Yazd). Sixty-one water samples were collected from canals, wells and springs in the study area from October 2008 to May 2009. Heavy metals were analyzed by ICP-MS. The concentration map of the arsenic was done and Frequency diagrams were plotted. All date were compared with EPA and WHO standards. The results show that arsenic levels in the water samples range from 5.72mg/l to 18.37 mg/l. Some of these samples concentration exceed the EPA (10 mg / l) and WHO (10 mg / l) limit. The results show that arsenic (As) have a positive correlation with pH, iron and manganese whereas aluminum is a weak inverse correlation. Local people have been used these contaminated water which is risk for human health such as nervous system disorders, skin cancer, lung and bladder and venous disease. Therefore, contaminated water sources need to be monitored and treated.

Keyword: Arsenic, Taft, WHO, EPA

Environmental effects of Hasangazi (Pülümür-Tunceli) Chromite Mine

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The mined chromite ore around Pülümür area (Tunceli) is present in serpentinized mafic-ultramafics of the Upper Cretaceous ophiolites. One of the abandoned mines is Hasangazi chromite pit at east of Pülümür, the water circulating through which flows into the Turnadere creek feeding the Pülümür stream. Water quality of the stream is important regarding the ecosystem in the Tunceli area. The previous studies on the sediment and soil samples from the stream implied enrichment in heavy metals including Cr and Ni due to country rocks croping out in the area. Beside these, open pit operations in the chromite deposits could be efficient in toxic element enrichment. To understand the affects of pits, samples from waste material, soil and water were collected from Hasangazi mine and its surrounding area.

Samples are mineralogically and geochemically analysed by XRD, ICP-OES and ICP-MS methods. Mineralogical analyses display existence of chyrosotile and plagioclase in the soil. Geochemical analyses on the soil samples show enrichments in toxic elements, i.e. Cr, Ni, Co. Especially, Cr and Ni concentrations exceed the limits in soil pollution regulation of Turkey. On the other hand, water samples have Zn concentrations in toxic values.

Soil samples with high Cr, Ni and chyrosotile contents indicate influence of ophiolitic units with chromite. The toxic element enrichment is higher in the samples taken from the mine area compared to its surroundings. This enrichment points out impact of the abandoned mine on the stream and water quality. Environmental remediation efforts are strongly recommended in this inactive mine.

Key Words: Pülümür (Tunceli); chromite mine; waste material; toxic elements; water quality; remediation.

The Impact of Mining Activity on Dam Basin in Biga Peninsula, Northwest of Turkey

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A study was conducted to evaluate water resources problems related to lead and zinc mines in Umurbey dam basin in Biga Peninsula, NW Turkey. Past mining activities have caused changes in the geohydrology of the area. Many abandoned galleries have been found in this basin. These abandoned galleries are typically filled with water that contains high concentrations of lead and zinc. Physical properties (temperature, pH, redox potential, salinity and electrical conductivity), major anion and cation (sodium, potassium, calcium, magnesium, chloride, bicarbonate and sulfate), and heavy metals (lead and zinc) were determined on water samples taken from surface, spring, groundwater and wastewaters during 2010-2011 period in the region. The physical analyses of water show that pH ranged between 5.71 and 7.07 in springs, ranged between 6.5 and 8.47 in groundwater and ranged between 6.47 and 7.8 in surface water. Anion order is Ca> Mg> Na> K and cation order is HCO_3> SO_4> Cl. The chemical analyses revealed that lead and zinc concentrations reached to 3881 and 42380 ppb, respectively. The levels of these elements are found to exceed the maximum allowable limits depicted in national and international standards for drinking water quality in groundwater and surface water. The result shows that lateral migration of water from the mines site to surface water and dam site in the region. Effects of abandoned lead and zinc mines on tributaries of the Koru River in the area are most severe at the dam site. Drainage from tailings causes large concentrations of zinc and lead in in Koru creek. This contamination is enhanced during heavy-rainfall events that cause high runoff.

Keywords: Groundwater; mining; lead; zinc; dam site

Data mining application on Magnetic susceptibility of the soil

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The focus of our study is to predict the magnetic susceptibility of the soil . Magnetic susceptibility (MS) values depend on the composition, grain size of magnetic minerals and their source, such as lithogenic, pedogenic and anthropogenic origins. In this paper, we applied a data mining classification algorithm which is called C4.5 for predicting MS class and the degree of pollution along the Izmit area in Turkey. In this study, the sampling stations were considered to pursue the project which covers the Izmit area. In our study, possible MS values are obtained, according to the heavy metal concentration (PB, Cu, Zn, Co, Cd, Ni) values related to MS. It is shown that, test values and the measurement values are compatible with each other

Keywords: Data mining; magnetic susceptibility; heavy metal contamination

Water balance of Eğirdir Lake and the influence of budget components, Isparta,Turkey

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Lake Eğirdir is an inland closed basin and located within the Lake District of Turkey. The Lake is extensively used for different aims such as drinking, irrigation tourism and fishing. Therefore, Eğirdir Lake is indispensable water source for region, but it is under severe environmental pressure. One of the major problems in the management of lakes is the estimation of all water budget components. The lack of measured data as regularly is the biggest problem for calculation of hydrological balance of the lake. A lake water budget is computed by measuring or estimating all of the lake's water gains and losses and measuring the corresponding change in the lake volume over the same time period.
Recharge of the Lake Eğirdir is supplied from especially precipitation, surface and subsurface water inflow. Taking into consideration of the hydrogeological properties of the Eğirdir lake catchment area, the presence of groundwater inflow into the lake is determined. The groundwater comes from the immediate vicinity of the lake which drains agricultural lands and limestones from catchments areas directly into the lake. But, there have been no direct measurements of groundwater inflow into the lake. Groundwater inflow to a lake is one of the most difficult components of the water balance to measure. It is calculated by subtracting annual measured volume difference from annual total discharge. Unmeasured groundwater inflow represents 18% of the annual mean rainfall falling to the Eğirdir lake catchment area. In addition, the co-precipitation maps were prepared separately for each year in order to determination of recharge from precipitation. Using this data, the mean rainfall for Lake Eğirdir catchment area and surface area are estimated as 558.66 mm and 593.88 mm, respectively. The cumulative deviation from annual precipitation curve was plotted using the mean annual rainfall data for meteorological stations in the Eğirdir lake catchment area. The lake level variations (1970-2010) were investigated at monthly time steps and made a preliminary sensitivity analysis of lake level and rainfall changes. The dry period was observed between 1981 and 1994 years according to precipitation data measured in the meteorological stations. In this period, the lake water level decreased approximately 2 m, although discharge components of the lake did not changed.
The discharge components of the lake are evaporation and water abstracted for the purposes irrigation, drinking and energy. Evaporation from lakes is often the largest percentage component of the water budget, so its accurate determination is crucial for a reasonable estimate of the water budget. The mean evaporation amount is calculated 484.7 hm^3 for the lake surface area. The amount of evaporation in the Eğirdir Lake partly increased between 1962 and 1974 years, but it decreased approximately 560 mm from 1974 until 2008. A preliminary analysis of level and outflow of the lake suggests that they are controlled more by variation in rainfall than by basin-scale forcing induced by human activities. However, evaporation is not as effective as rainfall at variation of the lake water level.

Keywords: Eğirdir Lake; water balance; lake level; rainfall

Meteorological drought severity assessment in the Eğirdir Lake basin (Turkey) using remote sensing and GIS

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Drought is one of the most important natural disasters threatening the future of humanity. Globally there are four known categories of drought i.e. meteorological, agricultural, hydrological and socio-economic. The main objective of the study is to determine the meteorological drought severity in the Eğirdir Lake basin from past to present and to investigate the relationship between meteorological drought severity, drought indices (Normalized Difference Vegetation Index (NDVI) and the Vegetation Condition Index (VCI) which are based on satellite images. Meteorological drought is defined as a situation when there is significant decrease from normal precipitation over an area (i.e., more than 25%).

In this study, meteorological drought analysis was performed using the Standardized Precipitation Index (SPI) method in the Eğirdir Lake basin during 12 month period. SPI is a probability index which is negative for drought, and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive. For this analysis, precipitation data which are measured at meteorological stations in Eğirdir, Kovada, Gençali, Taşköprü, Yalvaç, Isparta, Burdur, Senirkent, Uluborlu, Şuhut, Koçbeyli, Çeltek, Baladız, Cankurtaran, Dinar regions is used. The precipitation data belongs to years from 1975 to 2009. Meteorological drought maps were prepared by using SPI index data measuring in meteorological stations. These data were interpolated by kriging method in ArcGIS software. Extremely drought value (SPI = -2.5482) is computed in 1977 year at Senirkent region which is the driest period. In 1978, extremely Wet value (SPI = 2.7340) is also computed in Eğirdir region.

In addition, to determine of vegetation density in the basin, NDVI and VCI maps were created using ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) satellite images belongs to 2006. According to NDVI and VCI maps, bare rocks contain very little vegetation are collected in the 66% of the Eğirdir Lake basin. Also, the correlation and regression analyzes were performed to determine the statistical relationship between NDVI index values and SPI index values belongs to same years. Statistical analyses show that, NDVI index and SPI index values have a high positive correlation. Finally drought severity maps were generated by integrating the meteorological and agricultural drought severity maps. The maps can be extremely helpful to the planners to reveal the situation in the area.

Keywords: Meteorological Drought; Standardized Precipitation Index (SPI); Normalized Difference Vegetation Index (NDVI); Vegetation Condition Index (VCI)

Microbiological pollution of surface and groundwaters in the Eğirdir Lake basin (SW-Turkey)

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Different types of groundwater contamination sources can pose different threats to human health and different problems in health risk assessment. The most important causes of microbiological pollution for water sources are discharge of sewage and land application of natural fertilizers (manure) which are contained numerous pollutants such as nutrients, organic matter, pathogens, heavy metals, hormones and antibiotics. Manure and sewage contain high level of pathogens (disease-causing microorganisms), and the impact of these pathogens is severe for human health. According to Water Pollution Control Regulation of the Turkey, drinking water shouldn't contain disease-causing micro-organisms and harmful chemical substances. For this reason, microbiological quality of water sources should be checked frequently. The microbiological quality of waters can be determined by measure of indicator organism contents. The most common indicator organism is coliform bacteria such as total coliform, or a subset of this group, fecal coliforms, which are found in the intestinal tracts of warm blooded animals. Escherichia coli is a member of the fecal coliform group and its presence correlates well with illnesses that result from exposure to fouled water.
The Eğirdir Lake catchment area is located in the southwest of the Turkey and covers an area of 3390 km^2. The agricultural activities have been made intensively in the lake basin and also natural fertilizers have been used densely. In the study area, only Yalvaç-Gelendost domestic water treatment plant existed. But, this plant is not worked on a regular basis. Waste water of other small settlement areas in the lake basin are also discharged to streams and septic tanks. In this study, the microbiological pollution of surface and groundwaters were evaluated within the Eğirdir Lake catchment area. The water samples (total 27 numbers) were collected from lake, stream and groundwater in May-2010 and total coliform bacteria and E. coli analyses were made using membrane filtration system at the Environmental Engineering Department of Süleyman Demirel University, Laboratory of Microbiology and Moleculerbiology. According to the analyses results, the number of Total coliform bacteria and E. coli were found between 1.18-6.3 CFU/100 ml and 0-8.48 CFU/100 ml in lake water; 2.7-6.7 CFU/100 ml and 1.7-6.81 CFU/100 ml in stream waters and 3.9-12.6 CFU/100 ml and 2.7-14.24 CFU/100 ml in groundwaters, respectively. Hence, it is shown that groundwater samples have more bacteriological contamination than surface waters. According to classifications which are given at the Water Pollution Control Regulation of Turkey, surface and groundwaters in the study area are class I-II type water and existed bacteriological contamination.

Keywords: Eğirdir; microbiological pollution; groundwater; surface water

Stream water quality in the Eğirdir Lake catchment area, Isparta,Turkey

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Eğirdir Lake is the second largest fresh water lake of Turkey. The most important surface waters flowing through the basin are Pupa, Hoyran, Yalvaç and Çay streams. Generally, the point pollutant sources (industrial-domestic wastewater, landfills etc.) and nonpoint pollutant sources (agricultural activities) in the lake basin negatively affected to water quality of the lake. Pollutants from point and nonpoint sources are transported into the lake via these four main streams. Pupa Stream is the main stream in the Uluborlu-Senirkent basin, west of the lake and transports to the lake wastewaters of the Senirkent, Uluborlu, Büyük Kabaca, Küçük Kabaca, Uluğbey, Yassıören, Dereköy, and Ortayazı settlements. In the Yalvaç- Gelendost basin, the main stream is Yalvaç stream and transports wastewater of the Yalvaç, Gelendost, other neighboring settlements and also waters of Yalvaç treatment plant. The wastewater of Kumdanlı and other neighboring settlements is discharge into Hoyran Stream and discharge to the lake in the north of the Eğirdir lake. Also, Çay Stream transport wastewater of settlements located in the south of the basin.
The objective of the study is to determine water quality of streams in the Eğirdir Lake catchment area. Thus, hydrogeochemical properties and water quality parameters were determined in samples obtained from Pupa, Yalvaç, Hoyran, Çay streams and also discharge points to the lake in May (wet period) and October (dry period) - 2010. The pH, temperature, electrical conductivity and dissolved oxygen values of waters were measured in situ. The major cation and trace metal amounts were determined by inductively coupled plasma mass spectrometry (ICP-MS) within group 2C-MS in ACME Laboratory, Canada. The major anion and pollution parameters were analyzed in the Eğirdir Fisheries Research Institute Laboratory (Isparta/Turkey). According to the Piper classification diagram, the stream waters have Ca–Mg–HCO_3 facies. In general, the concentrations of all parameters were higher in dry periods than wet period. Temperature, pH and electrical conductivity values of the waters are between 15.6-26.9 ^{o}C, 7.3 - 8.9, and 285-570 µS/cm, respectively in wet period. When analyses results of the water are compared with standard values of the Water Pollution Control Regulation of the Turkish Republic, all surface waters are classified as high quality water considering to the most of the parameters. However, the waters of Pupa, Yalvaç, Hoyran and Çay Stream are classified as highly polluted and polluted considering to the values of dissolved oxygen, NH_4^+, NO_2^-, BOD, total phosphor, total organic carbon, sulfur, Fe and Mn. Additionally, Pupa and Yalvaç Streams have more pollution load than Hoyran and Çay Streams. It is concluded that the high pollution loads in the Pupa and Yalvaç Streams have been originated from agricultural activities, municipal wastes and waste waters of treatment plant.

Keywords: Eğirdir Lake; pollution; stream; water quality

Assessing availability of the Tefenni plain (Burdur) groundwater

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The Tefenni (Burdur) plain is an important closed plain in the Eastern Mediterranean Region. This plain is one of the rare regions which are not observed of groundwater scarcity in the Turkey. But, groundwaters in the plain are densely used for different purposes such as drinking, domestic, irrigation and industrial without taking into account availability. In addition, Karataş Lake which has important water potential is also used for irrigation. The aim of this study is to investigate the availability of the groundwaters in the Tefenni plain. For this purpose, 28 water samples representing Tefenni plain were taken from the surface water, spring and wells in dry (July-2009) and wet periods (May-2010). These results of chemical analyses were evaluated using different standards and diagrams.

Primarily drinking water quality of waters was evaluated in the Tefenni plain. The Turkish Drinking Water and the World Health Organization standards were used for assessment of drinkable. In addition, Schoeller drinkable diagrams were prepared for the dry and wet periods. According to these standarts, generally, groundwater is suitable for drinking water. But, the sample of Kozluca well is "Middle-poor quality waters" class in the Schoeller diagram due to high Na and Cl contents. The microbiological content of water is also an important parameter for usage as drinking water. 20 water samples were taken from springs and wells for the determination of microbiological contamination in March-2010. The Total Coliform and E. Coli analyses were made by Burdur Public Health Laboratory. According to the results, except Karamusa, Başpınar and Seydiler regions microbiological contamination was not observed in spring water. The cause of microbiological contamination is related to animal husbandry activities in these regions. U.S. Salinity Laboratory and Wilcox diagrams were used for evaluation as irrigation water. According to the U.S. Salinity Laboratory diagram, water samples taken from Kozluca well in dry period and Boğaziçi well in wet period are in C_4S_1 water class due to high electrical conductivity. These waters are not suitable for use as irrigation water. All other waters in the study area were in C_3S_1 water class. According to Wilcox diagram, samples from Kozluca and Boğaziçi wells are also not suitable for irrigation purposes. In addition, the values of residual sodium carbonate of groundwater and surface waters were changed as seasonal. The industrial usage properties were investigated as decaying, calcifying, foaming effects and usage production of concrete. To determine the decaying and calcifying properties of waters was used Calcium Balance Diagram, and it is observed changing carbonate balance of the waters as periodically. The foaming characteristics of the water are also changed between dry and rainy period. The sulfate content of waters controls availability at concrete. The waters taken from Kozluca and Boğaziçi wells are negatively affected to concrete.

Generally, groundwaters in the Kozluca and Boğaziçi regions are not suitable for usage different purposes. These wells drilled within Çameli formation which is composed of conglomerate, sandstone, claystone and marl and this region is old river bed. Water-rock interaction is quite effective in this region.

Key Words: Tefenni; availability; drinking water; irrigation water

Heavy metals detection in sediments of Anzali Wetland, northern Iran

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The Anzali wetland that located in southern margin of the Caspian Sea is subdivided into four subbasins (Sheyjan (eastern), Hendkhaleh (central), Abkenar (western) and siakishem). In this study, it was selected 21 stations for sampling in the wetland. An each site a core, 60cm long was taken and analyzed for physico-chemical parameters such as pH, %LOI, %CaCO3 and heavy metals (Zn, Cu, Pb and Cd). The concentrations for two parts of cores (0-30cm and 30-60cm) were measured after acid digestion by AAS method. The results show that the wetland sediments have fine grain texture (sandy silt) and grain size decreases to the west as well as from top to the bottom of the cores, changing to silty-clayey and clay. These sediments with pH>7 contain %LOI ringing from 0.5-11% that changes from east to the west of the wetland. Concentration of Zn and Pb in these sediments is lower but Cu and Cd concentration are higher when compared with standard values. The highest value of Cd and Cu elements has been measured in Sheyjan (eastern) subbasin. Due to high mobility, Cd value is high in the deeper sediments of the cores. The results of heavy metal enrichment factor (EF) value and cluster analysis show that the high values of Cu are correlated to natural and geological sources and there are two possible sources of Cd anthropogenic and industrial activities in this area.

Keywords: Heavy metal; Anzali Wetland; Sediment; Enrichment Factor (EF); Iran

Necessity Performance Synchronic Dam Constructions and Watershed's Planning for Stability of Quality and Quantitative Water Resource

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According to drought continuation in Iran, comprehensive planning in optimum exploitation at groundwater resources, replacing with surface water as much as 55 percent and modern exploitation (rainy and artesian irrigation) thus positional aquifer protection in unconfined aquifer and during critical condition in suspended aquifer and karst region resources utilization was important in Zanjan province.
To pay attention to geology structure and Stratigraphy towards get better run off in filtration suggested. Performance synchronic watershed and range management projects to cause increase infiltration in aquifers and reduce run of velocity, planning and performance reservoir dams, artificial recharge and flood control necessary. Because in additional to carry up quantity and quality of ground water resource.

Keywords: Modern irrigation; aquifer; reservoir dam; watershed and range management.

Evaluation of Groundwater Catchment of Khararud Basin (Iran)

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Due to reduced rainfall in recent years, qualitative and quantitative of groundwater resources have been changed within the Khararud study area. In this study, meteorological data have been evaluated with geological structure and the condition of the alluvial aquifer in the Khararud Region. Based on the hydrological conditions physiography of the basin and river's gradient have evaluated. In addition to discharge of water resources have estimated according to field study. Also, geophysical investigations, exploratory excavations, pumping tests were done in this region. According these data water samples were selected for analysis. Considering the aquifer conditions, thickness and alluvium composition, composition and structure of the bedrock, depth fluctuation, level and direction of flow, gradient of water table and feeding and evacuation sections ground water aquifer was quantitatively analyzed. Hydrogeochemical data were evaluated for defining the affective factors on the quality of water resources such as EC, T.D.S and S.A.R and relationship between these physical parameters with Cl changes. Type and visage of the groundwater and changes in the aquifer quality, the consumption type, from the perspective of agriculture and drinking was defined. Also, recharge rate, evacuation term, and the general water balance was calculated. Obtained results of the general balance's calculations are 10.32 and 10.57 million cube meters. According to respectable lack in the alluvial and a reduction in the underground water storage quality, it is suggested that by conducting supervision system (preventing unauthorized removals and forbidden utilization improvements) and performing curative plan (artificial feeding plans, water shed managements and flowage distribution) to protect water resources. It is important to try to balance the underground water table behavior. Also to achieve this goal, water removals for agricultural usages must be forbidden in the quadruplet zone of Khararud area.

Keywords: Zanjan; Groundwater; Khararud; Aquifer

The effect of asbestos exposure on the Mesothelioma disease: A case study on Dumanlı Village-Lapseki-Çanakkale

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This interdisciplinary study has been carried in Dumanlı village (Çanakkale-Turkey) in the Biga Peninsula NW Turkey. Upon detection of 4 cases of mesothelioma by the Çanakkale Provincial Health Directorate in 2011, a working group established and started to research by the geologists of Çanakkale Onsekiz Mart University (ÇOMÜ), Department of Geological Engineering, the experts of ÇOMÜ School of Medicine Department of Pulmonary Diseases and Public Health, the experts of Çanakkale Province Health Directorate. Studies has been carried out in earth sciences and the health sciences simultaneously. Earth science studies starts with geological mapping around Dumanlı village in order to determine the asbestos deposits. The Asbestos outcrops are mapped and sampled. Petrographic determinations of samples were followed by XRD and SEM analysis. The asbestiform minerals around Dumanlı village are within the units that mapped as Denizgören Ophiolite by MTA. The Denizgören Ophiolite composed mainly of highly sheared serpentinites. The Serpantinites occur as tectonic slices and lenses within Çamlıca metamorphites consisting mainly of micaschist and marble intercalations. These tectonic slices and lenses bounded by strike-slip faults and probably get their recent positions by transpressional tectonics during Late Cretaceous-Early Eocene time. Asbestiform minerals occurred within these stretching-shear zones in these strike-slip systems. Petrographic and mineralogic indications show that these minerals are clinokrizotile, lizardite, antigorite and actinolite. In parallel with earth sciences studies verbal autopsy studies were carried out in order to determine the actual causes of death in the village. Accordingly, today in the village that have 216 population (116 male, 100 female) encountered 9 deaths in last 5 years. Two of the deaths depend on lung cancer, one of them depends on laryngeal cancer and one of them depends on the mesothelioma. Other five deaths depend on different diseases. Currently, pulmonary function tests and radiological examinations of 139 people living in the village were done and evaluated. According to this, pleura calcification was appointed in 30 of living 139 people and thickening of pleura in 4 of living 139 people. A significant correlation between asbestos exposure and radiographic pathology was identified and understood that the duration of exposure in these cases changes between 23-80 years. In summary, asbestiform minerals occur as deposits in the region, which are used widely and unrestrainedly for various purposes. There is a correlation between asbestos exposure and radiographic pathology.

Keywords: Medical geology, Asbestos, Mesotheliama, Public health, Çanakkale

Engineering performance of clayey weak rocks as a geological barrier for a landfill: a case study

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With the principal purpose of averting the possible contamination of adjacent media such as groundwater and surface waters, the safe and reliable long-term disposal of solid waste is a significant component of integrated waste management system considering some leachate moving out of the landfill. Thus, the protection of the water and soil in storage of municipal waste must be performed using engineering clay liner and/or natural geological barrier that are essential for reducing the hydraulic conductivity of natural environment under landfill sites. In this paper, landfill site requirements of clayey weak-rock environments were discussed; geotechnical properties of the clays in weak-rocks were investigated in Trabzon city (NE Turkey). The main issues considered while investigating the suitability of convening the disposal site to a landfill included the effect of clays behaving, and the effect of leachate escape on the surface water system in the study. Thus, borehole applications, in-situ permeability testing and laboratory tests were conducted to determine vertical and horizontal homogeneity of clay bearing rocks units in the site. The geological barrier rocks under the proposed landfill site contain high plasticity and active clay materials, especially montmorillonite. Due to the swelling response of montmorillonite clay and corresponding development of swelling pressure on discontinuities in weak rocks in the site, rock mass permeability can be reduced. Considering to the geotechnical properties of impermeable clayey weak-rock barriers providing low hydraulic conductivity values with 10^{-8} m/sec, it is concluded that the proposed Düzyurt landfill site is the most suitable landfill site in Trabzon.

Key words: clay, geological barrier, geotechnical, landfill, weak-rock

The Holocene environmental scenario of southern Skhira coast and its evolution to actual sebkhas. A micropalaeontologic approach

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A micropalaeontologic study covering descriptive and statistical analysis (specific diagnose, calculation of biocenotic parameters supported by correspondence analysis), palaeoecolgy (ostracods) and isotopic dating (^{14}C) has been carried out on four long cores retrieved from the sebkhas Dreîaa and El Guettiate. The interpretation of the whole data set allowed the establishment of an evolutionary model for the southern part of the Skhira coast during the late Holocene This model includes five principal stages. It starts with a continental environment, replaced at > cal. 7711– 7195 yr BP by an open lagoon rich in marine ostracods. It coincides with the first Holocene marine transgression following the deposition of the continental Holocene series. This open lagoon is followed by an estuarine one (cal. 7711– 7195 – 6847 - 6411yr BP) characterized by the richness of brackish ostracods and low energy. Towards (cal. 5361 – 5575 yr BP) littoral drift currents are responsible for the genesis of sand spit, the closure of environment and the dominance of brackish ostracods. This lagoon includes an unstable period with washover deposits resulting from an extreme climatic event. During the third stage (cal. 3350-3752 yr BP), the enrichment of marine ostracods indicates a marine environment which evolve toward the closing. The settlement of the restricted lagoonal environments is linked to the second phase of building-up of sandy spit. At cal. 2839-3057 yr BP, the dominance of coastal ostracods, associated with coarse sands, show an open lagoon and the second marine transgression evidenced by the progressive modification in the ostracode assemblages. The last stage, cal. 515-777 yr BP, is marked by a strong marine influence with transport of marine Bivalvia, Gastropoda and ostracods towards the inner lagoon by means of storms. The rupture of sandy spits induced the introduction of marine macrofauna and microfauna which were accumulated and associated with charcoals and coarse sands.

Keywords: Sebkha, South - Eastern Tunisia, Holocene; sea level change; ostracods.

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PETROGRAPHY & GEOCHEMISTRY

Conveners:
Osman Candan and Mümtaz Çolak

Sarcophagus of Assos - meat eater or innocent?

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The ancient harbor city Assos located to the South of Troia. After Lelegians lost their power, Aeolian immigrants came from Methymna (Lesvos island), settled in Assos and made it their harbour (1000 B.C). Assos was also a well-known meeting place for philosophers such as Theoprastos, Dioskurides, Aristotle, who was one of the greatest philosophers of the world, worked and lived in the town for three years in the gymnasium at Assos. It is also said that sarcophagus (?) or otherwise called "Asian Stone" (?) to have been found at Assos and to be widely traded from its harbour reaching as far as Rome and Egypt The stone was believed to decompose the corpes placed in the sarcophagus within a short period of time, therefore the word itself meant "flesh eater" Σαρξ (σαρκοσ) in greek, thus also indicating that the name sarcophagus for the tombs originated in Assos. Religiously it was important since it was thought that one can reach heaven easier and faster. The description found in ancient documents concerning "Asian Stone" was contradictory from that of the physical qualities of the stone itself, therefore, for many centuries the issue of what was traded from the harbour of Assos remained under debate by scholars.
According to many ancient philosophers "Asian Stone" (?) to be a good medicine to dry out wounds or cure such inflammation as gout, is not hard and easy to break, tasting like a salt and with a white powder on a surface. All these characteristics indicate "Asian Stone" to be alunite, which mineral was important export material from Uşak and Foça (Anatolia) and also from Chios Island during the ancient period and also continued by the trade people of the Ottoman Empire. In contrast to "Asian Stone" of Assos, sarcophagus is made from trachyte, which is hard and resistant without any alteration or weathering and still well preserved up to this time. So, the question is why did they use another name for the alunite mineral and why the tombs of Assos are meat eater?
Assos is located on the hard trachyte rocks, which are not affected by weathering and alteration and also without any alunite veins. But after further investigations we discovered unknown ancient mining areas in three villages situated to North and North West of Assos. The main composition of the mines was alunite, which was impregnated within the alterated tuffs and other magmatic rocks. Our approximate evaluation for this area was based on the results of alterated alunite bearing tuffs taken from more than ten different open pits of such sizes as 200000 and 300000 m^3.
Perhaps it might be interesting to know that the turkish names of those three villages are Sap Köy, Sapkebir and Kızıltepe that respectively mean "Alunite Village", "Great Alunite Village" and "Red Hill". It might mean that alunite production from the area continued until the Ottoman period. We found out some relict, hard and fresh parts of alterated tuffs within the sarcophagus, too, originated from the above mentioned alunite mines. It means "Asian Stone" (alunite bearing tuffs) was additionally put into sarcophagus for the faster decomposition of flesh.

Keywords: Assos; archeomineralogy; aluma; sarcophagus

Mineral chemistry of gneisses and amphibolites from the Daday-Devrekani (Kastamonu) massif, N Turkey

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The Daday-Devrekani (Kastamonu, N Turkey) massif, located at the Sakarya zone in the central Pontides, contains various metamorphic rocks. The rocks consist of a wide spread gneisses and lesser extend amphibolites. Petrographically, gneisses exhibit paragneissic and ortogneissic characteristics, and are defined as hornblende, biotite-hornblend, cordierite-biotite, sillimanite-biotite, garnet-biotite, sillimanite-cordierite-mica, sillimanite-garnet-mica, sillimanite-cordierite-garnet-mica, microcline-biotite, muscovite-microcline-biotite, sillimanite-garnet-cordierite-microcline-biotite and quartz-feldspathic gneisses. They contain quartz, K-feldspar (orthoclase, microcline), plagioclase, biotite, sillimanite, cordierite, garnet, hornblend, sericite, Fe-Ti oxide, ±apatite, ±hematite, ±zircon and ±hercynite. In some gneiss, there are pre-kinematic and syn-kinematic mineral growths. Besides, cordierite porphyroblasts include sillimanite and hercynite minerals. The amphibolites contain hornblende, oligoclase-andesine, Fe-Ti oxides and ilmenite. The rocks exhibit grano-, lepidograno-, fibrolepidograno-, nemato-, nematograno-, lepidonemato- and porphyro- blastic textures.
Based on mineral chemistry data, amphibole chemistry in orthogneisses varies from tschermakite and ferro-tschermakite to magnesio-hornblende with $Mg^{\#}$=0.50- 0.68, whereas in amphibolites from magnesio-hastingsite and magnesio-hornblende to tschermakite and ferro- tschermakite with $Mg^{\#}$=048-076. Rare pyroxenes in amphibolites are diopsidic in composition ($Wo_{49-52}En_{36-38}Fs_{11-13}$). Biotite composition varies from annite ($Mg^{\#}$=0.12-0.14) and lepidomelane in paragneisses, lepidomelane ($Mg^{\#}$=0.43-0.50) in orthogneisses to phlogopite ($Mg^{\#}$=0.66-0.70) in amphibolites.
Garnets in paragneissic rocks have compositions of $Alm+Prb_{34-60}Grs_{3-33}Sps_{8-33}And_{4-10}$ for porphyroblastic garnets and are $Alm+Prb_{73-85}Grs_{1-4}Sps_{10-24}And0._{1-2}$ for fine grained garnets. Feldspar composition in paragneisses and orthogneisses ranges from orthoclase-microcline ($An_{0.6-1.1}$) composition to andesine-oligoclase (An_{12-30}). Plagioclases in amphibolites have labradorite (An_{48-61}), bytownite(An_{88-90}) and anorthite (An_{91-98}) compositions. Fe-Ti oxides in all rocks are dominantly titanite-ilmenite and some magnetite with hercynite (especially in paragneisses). Petrographical and mineral chemistry data on gneisses and amphibolites of the Daday-Devrekani massif reveal various protoliths from pelitic-psammitic sedimentary to igneous origin which had undergone amphibolite facies metamorphism.

Keywords: Daday-Devrekani massif, gneisses, amphibolites, mineral chemistry, Central Pontides

Petrology and geochemistry of the Late Paleozoic granites in the central Sakarya Zone

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In Anatolia, there are, mainly, six continental blocks which are separated by ophiolitic suture zones (Sengör & Yılmaz 1981; Okay & Tüysüz 1999). The Sakarya Zone is one of these blocks, ~1500 km long and 120 km wide, and located to the north of the Izmir-Ankara-Erzincan Suture Zone (Okay 2004). The basement of the Sakarya Zone is intruded by numerous Late Paleozoic granites, of which the Sarıcakaya plutonic rocks in the central Sakarya (Eskisehir) region, is the least-studied. The oldest units in the central Sakarya zone contain lower Paleozoic metamorphic rocks of the Karakaya Formation (Bingöl et al. 1973), which are cut by the Carboniferous Sögüt pluton (Cogulu 1967). The Sarıcakaya intrusive rocks are part of the Sögüt pluton (Altinli, 1973).
The Sarıcakaya plutonic rocks are quartzdiorite-granodiorite, granodiorite and granite. The quartzdiorite-granodiorites are dark-colored and fine-grained. In these rocks, plagioclase, K-feldspar, quartz, biotite and hornblende are the main minerals, whereas titanite, zircon, apatite and opaque minerals are found as accessory minerals. The granites are grey and medium- to coarse-grained with pink K-feldspar crystals. They contain quartz, K-feldspar, plagioclase, lesser amounts of biotite, muscovite and apatite. On the other hand, the granodiorites have transitional characteristics between quartz diorite-granodiorite and granite. The former rocks are cut by pegmatitic and aplitic dykes.
These geological divisions can be also observed in their geochemical characteristics. For example, in the K_2O-SiO_2 diagram, the quartzdiorite-granodiorite and granodiorite plot in the gabbrodiorite and diorite fields, whereas the granites fall in the granite field. In the K_2O-SiO_2 diagram, the diorites plot in medium-K, whereas the granites have high-K to shoshonite fields. The former is mainly peraluminous however the latter is metaluminous, and having I- to S-type granite features. In the chondrite-normalized REE pattern, all samples have small to moderately fractionated REE patterns and small negative Eu anomalies. The diorites have relatively flat HREE patterns compared to the granites, which have slightly more depleted HREE. In the primitive mantle-normalized trace element diagrams, the Sarıcakaya intrusive samples are characterized by enrichment in LILE relative to LREE and HFSE. The geochemical characteristics of the intrusive rocks indicate that they could have originated from partial melting of hybrid lower crustal sources.

Keywords: Sakarya Zone; Late Paleozoic; Saricakaya; granite; lower crust; melting

Evidences of mixing/mingling between mafic and felsic calc-alkaline magmas: An example from gabbroic rocks around the Bafra (Samsun) area, NE Turkey

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In the eastern Pontides, post-collisional Tertiary aged calc-alkaline felsic intrusive bodies are widespread in varying compositions with mixing/mingling features in their petrogenetic evolution, whereas mafic intrusives are very limited. Miocene mafic host intrusions and felsic enclaves around the Bafra (Samsun) area were described here for the first time within Tertiary aged volcanic and sedimentary units at western edge of the eastern Pontides. The studied rocks comprise coarse-grained host monzogabbro and felsic microgranular enclaves ranging from a few centimeters to one meter in size and from 5 to 20 centimeters in diameter. The elongated spherical to ellipsoidal and/or round felsic enclaves are always medium to medium fine-grained and monzosyenite in composition. Most enclaves show sharp contacts with the host monzogabbro and distinct chilled margins in the small enclaves indicate rapid cooling after entering the mafic host magma. Additionally, the contacts between the enclaves and host rocks are also gradational and show no reaction or cooling zones. The host mozogabbro contains plagioclase, clinopyroxene, olivine, amphibole, biotite, apatite and Fe-Ti oxides, whereas the felsic enclaves include alkali feldspar, plagioclase, amphibole, biotite, clinopyroxene and Fe-Ti oxides. In these rocks, disequilibrium textures indicating mingling/mixing of mafic and felsic magmas are common such as poikilitic and antirapakivi textures in feldspar phenocrysts, sieve textured-patchy-rounded and corroded plagioclases, small lath-shaped plagioclase in larger tabular plagioclase, clinopyroxene megacrysts mantled by bladed biotites, clinopyroxene rimmed by green hornblendes, dissolution in clinopyroxene, bladed biotite and acicular apatite. Petrochemically, the rocks are calc-alkaline in character with slightly Na-rich felsic enclaves and K-rich the host monzogabbro. On primitive-mantle normalized patterns, the felsic enclaves are characterized by enrichments in large-ion lithophile elements (LILEs; Rb, Th, K_2O) and pronounced negative anomalies in high field strength elements (HFSEs; TiO_2, Nb, P_2O_5) relative to their mafic host rocks. The chondrite-normalized rare-earth element patterns of the felsic enclaves show enrichment in light rare-earth elements (LREEs) and pronounced negative Eu anomalies relative to the mafic host rocks. The REE distributions for the felsic enclaves have spoon-shaped patterns with LREEs enriched in comparison to those of the HREE and negative Eu anomalies, suggesting a significant role of hornblende, clinopyroxene and plagioclase fractionations. The petrographical and petrochemical contrasts between the felsic enclaves and host gabbros may be in part a consequence of extended interactions between the felsic and co-existing mafic magmas by mixing/mingling and diffusion. Fractionation of both enclaves and host rocks from the same melt cannot explain these petrographical and petrochemical differences. Instead, enclaves and host rocks more likely originated from two separate magmas, which subsequently mingled and mixed. Obtained data suggest that the mafic host rocks are products of modified mantle-derived melts while the felsic enclaves are partial melts of crust. Moreover, the felsic magma was at near liquidus conditions when injected into the mafic host melt, and the mafic intrusion reflects a hybrid product from mingling and partial (incomplete) mixing of these two melts.

Keywords: magma mixing/mingling; disequilibrium textures; mantle and crustal melts, Bafra (Samsun); eastern Pontides

Mineral chemistry and termobarometric implications on Tertiary alkaline volcanics in the northern part of Eastern Pontides, NE Turkey

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Tertiary alkaline volcanics in the northern part of the Eastern Pontides (NE Turkey) outcrop widely with a narrow extend parallel to Black sea cost as a part of Eastern Pontide Tertiary Volcanic Province (EPTVP). In the light of chemostratigraphical and geochronological data, the studied Tertiary volcanics are separated in three suites: Middle Eocene aged (1) basalt, trachy-basalt and basaltic trachy-andesite (BTB) and (2) trachyte and trachy-andesite (TT) suites, and Upper Miocene aged (3) basanite-tephrite (BT) suite. Petrographic studies reveal that Eocene suites contain clinopyroxene, plagioclase, hornblende, biotite and Fe-Ti oxides, whereas Miocene suite consists of analcime, clinopyroxene, plagioclase, hornblende, biotite and Fe-Ti oxides. Generally, the suites also exhibit some textural evidences of disequilibrium crystallization such as oscillatory zoning, sieve texture and corrosion in plagioclase phenocrysts, zoning and inclusions in clinopyroxene phenocrysts. Mineral chemistry studies show that clinopyroxenes in all suites are augite and diopsite in composition, varying from $Wo_{39}En_{44}Fs_{20}$ to $Wo_{44}En_{47}Fs_{9}$ with Mg-number 0.59-0.81and from $Wo_{45}En_{33}Fs_{22}$ to $Wo_{50}En_{37}Fs_{13}$ with Mg-number 0.60-0.91, respectively. Feldspars generally exhibit wide range of compositions from sanidine to albite and anorthite. Phenocrysts of plagioclase generally show weak normal and reverse compositional zoning. Olivines observed only in the BTB and BT suites have a compositional range from Fo_{68} to Fo_{92}. Hornblendes observed in all suite rocks are pargasite with their higher $Al^{(VI)}$ atomic ratio than Fe^{3+} and Mg-number ranging from 0.92 to 0.96. Biotites (except for TT suites) are phlogopite in composition with Mg-number 0.45–0.79. The foid minerals in the BT suite rocks are analcime, possibly derived from leucite. Fe-Ti oxides in all suites are generally magnetite and titanomagnetite in compositions. Mineral thermobarometric estimations in all suites were tested on clinopyroxene, feldspar and hornblende compositions taking account approaches of different authors. Clinopyroxene thermometry varies from 858-1188°C for BTB, 1133-1180°C for TT (Eocene suites) to 1091-1178°C for BT (Miocene suite). The clinopyroxene barometry ranges from 0.78-9.69 kbar for BTB, 0.2-5.06 kbar for TT to 3.12-5.85 kbar for BT suite. The feldspar thermobarometric results are controversial as 1140-1284°C for BTB, 936-1163°C for TT, 3.7-16.9 kbar for BTB and 6.9-12.3 kbar for TT suites. The hornblende barometry calculations yielded 6.3-8.5 kbar for BTB and 5.6-7.0 kbar for BT suites. These obtained results show that the suitable thermobarometric estimations for the studied rocks can be derived from clinopyroxene compositions since the rocks of all suites show common disequilibrium crystallization conditions. Therefore, the pre-eruptive physicochemical conditions of the parental magma(s) may imply shallow (<~1 km, upper crust) to deep (~25 km, lower crust) seated magma chamber processes, taking account clinopyroxene thermobarometry.

Key words: mineral chemistry, thermobarometry, Tertiary volcanics, eastern Pontides, Turkey

Multi-proxy records of Mid-Brunhes Event from Central Anatolia, Turkey

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After Mid-Pleistocene revolution (MPR), the second major event during the Pleistocene is known as Mid-Brunhes Event (MBE) which is a climatic transition that separates moderate warmth period (Early Middle Pleistocene interglacials during 780-450 ka) from greater warmth (Middle and Late Pleistocene interglacials after 450 ka). Many recent paleoclimate studies from Turkey have shown the records from the Late Pleistocene to the Holocene. But, very few of them has proxy data lasting for Early – Middle Pleistocene period. Quaternary calcretes from Ankara were studied by their mineralogical, geochemical and stable isotopic compositions. Calculated Electron Spin Resonance (ESR) ages of the calcretes from Ankara, Central Anatolia ages are from 761±120 to 419±69ka falling in the range of Middle Pleistocene. The stable isotope values of the studied samples indicate the formation from percolating soil-solutions under predominantly C4 to C3:C4 association type vegetation. The estimated soil depositional temperature for the formation of calcretes is calculated as approximately 25°C favouring the formation of calcretes in the region of semi-arid and seasonally dry with pluvial alternations. All of these proxies are relevant for MBE which changed the climatic control over the European continent. Therefore, it can be suggested that the formation of the studied Quaternary calcretes in the study area might possibly triggered by the warming by Mid-Brunhes Event (MBE) like the other many Mediterranean Quaternary calcretes.

Keywords: Mid-Brunhes Event; calcrete; Quaternary; Ankara; Turkey

Origin of the Quaternary alkaline volcanic rocks in Ahar, NW Iran

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Quaternary alkaline volcanic rocks are widely developed in NW of Ahar, NW Iran. The volcanic sequences in the Ahar area are correlatable with the eastern part of Turkey. The volcanic rocks in this area are characterized by the LILE and LREE enrichments and negative HFSE anomalies. The Sr and Nd isotopic ratios vary from 0.704463 to 0.704921and from 0.512649 to 0.512774, respectively. CaO/Al_2O_3 ratios versus MgO, La/Sm ratios versus Rb and Ba and Zr versus Th suggest that fractional crystallization was a major process during the evolution of magmas. AFC modeling and isotopic data as well as microscopic evidence, clearly indicate that crustal contamination accompanied by the fractional crystallization played an important role in petrogenesis of the trachyandesites. Also, geochemical and isotopic compositions indicate that magma mixing was not essential process in the evolution of Ahar magmas. Alkali basalts with high $^{143}Nd/^{144}Nd$ ratio, low 87Sr/86Sr ratio and high MgO, Ni and Cr contents indicate that they crystallized from relatively primitive magmas. REE modelling and Trace element ratios indicate that the alkali baslats were derived by small degrees (~2-5%) of partial melting from the spinel lherzolite. We suggest that late Miocene to Quaternary post-collisional volcanism occurred by slab breakoff and rollback processes after Neo-Tethys subduction. Slab breakoff after subduction lock-up caused mantle upwelling that provided the necessary heat and melt to produce the first phases of post-collisional magmatism in these young orogenic belts.

Keywords: alkaline volcanism, partial melting, AFC modeling, slab breakoff, Quaternary

Eocene arc-type andesitic dyke swarms in the Araç-Boyalı flysch basin, N Anatolia: A geochemical evaluation

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The Araç-Boyalı Flysch Basin is a foreland basin formed following the closure of the Intra-Pontide Ocean during the Late Cretaceous-Late Paleocene on the platform of the Sakarya Composite Terrane. Within the basin a large number of dykes and sills have been found. The dykes, 30 to 260 cm thick, intrude the deformed flysch sediments and also the olistolits. They are covered by the volcano-sedimentary rocks of Mid-Eocene age. Majority of the dykes contain chilled margins and flow structures characterized by large plagioclase phenocrystals and amigdules filled with calcite and zeolite. Among the flysch sediments, lava flows up to 50 m thickness include massive and pillow lavas, lava and pillow breccias. Pillow lavas within the olistostromes were formed by submarine volcanism and accumulated by gravitational sliding.
Petrographically, the lavas are dominantly plagioclase and pyroxene phyric and a few include biotite. Lavas as well as the dykes are variably altered, most of them showing chloritization, epidotization and carbonatization. Dykes are dominantly andesitic, and range from sub alkaline to alkaline basalts. Majority of lava and dyke samples are of calc alkaline character. In Harker diagrams FeO, MgO, MnO and TiO_2 values are negatively correlated against increasing SiO_2 both in dykes and lavas. Major element data plotted on SiO_2 is in accordance with plagioclase, pyroxene and biotite fractionation, as well as f of Fe-Ti oxides (possibly titanomagnetite). Tectono-magnetic discrimination diagrams of lavas as well as the dykes are indicative for destructive plate margin volcanism.
Regional geological constraints together with geochemical characteristics of the volcanic rocks are in favour of continental arc magmatism within the Sakarya Composite Terrane above the N-ward subducting Izmir-Ankara oceanic lithosphere of Neotethys.

Keywords: Eocene; arc volcanism; Sakarya Continent; dykes

Petrography and petrology of nokeh granitoidc pluton of northeast semnan

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The studied area is located in the 10-12 Km of the N-NE of Semnan in the end of central Alborz structural zone. Igneous outcrops include gabbros and granitoids. Nokeh granitoides contain mainly granodiorite and alkali feldspar granite. Igneous plutons of Attari area have gabbro and monzogabbroic compositions. Plotted geochemical diagrams on the base of major and trace elements of the studied rocks indicate that there is no a magmatic and genetic relation between gabbros and granites and also they originated from the same magma source regions. With attention to field, petrography and geochemistry investigation, gabbros originated from melting of an enriched mantle and the granitic rocks originated from melting of lower crustal igneous rocks. Granites rocks have metaluminous to weak peraluminous nature and belong to I-type granitioids. Metasomatism process along the contact of granitoids rocks with host rocks is resulted to form iron skarn. Contact metamorphism progressed to pyroxene hornfels facies and maximum P-T condition is : 500-600 º C temperatures and about 2 Kbar.

Keywords: **:** petrology, Geochemistry, nokeh granitoidc pluton, Back arc basin, Semnan

Petrography and geochemistry of Buldan metamorphic rocks, SW Turkey

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Buldan area includes metamorphic rocks belonging to the core and cover lithologies of Menderes Massif. Buldan Metamorphic Rocks are subdivided into two groups as the Precambrian Çine Group and the Paleozoic Ortaköy Formation. Çine Group is composed of augen gneisses at the bottom, spotted gneisses, banded gneisses and fine grained biotite gneisses at the top. Ortaköy Formation includes quartzite, marble, amphibolite bands and lenses. The gneisses contain quartz, plagioclase, K-feldspar, biotite, muscovite, garnet, turmaline and apatite. Gneisses formed in the different submassifs within the Menderes Massif represent high grade metamorphic rocks. They are calc alkaline and of magmatic origin. The Paleozoic Ortaköy Formation is in tectonic contact with the gneisses of the Çine Group. Our results suggest that the orthogneisses in Buldan metamorphic rocks have sub-alkaline character and were derived from peraluminous magma. Overall they represent metamorphosed S-type, syn and/or post-tectonic granites and granodiorites.

Keywords; Menderes Massif; Buldan Metamorphic Rocks; orthogneiss; metamorphism; S-type granite

Petrographic and morphometric characteristics of Upper Cretaceous aged pillow lavas (Yüksekova Complex) in the Elazığ and Malatya areas, E Turkey

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Late Cretaceous pillow lavas of the Yüksekova Complex are widely distributed in the vicinity of Elazığ and Malatya along the Southeast Anatolian Suture Zone. The pillow lavas are intercalated with deep sea volcanoclastics, radiolarite, chert, micritic limestone and pelagic mudstone.

Petrographically, they consist of microlites and phenocrysts of plagioclase and pyroxene, and rare olivine pseudomorphes. The rocks are mostly spilitized and display variolitic, intergranular, intersertal, poikilitic, subophitic, cumulophyric, hyalomicrolitic, microlitic porphyric, amygdaloidal and vesicular textures. The voids and vesicles were partly filled by carbonate, chlorite and/or silica. In some places, spaces between pillows were filled by radiolarian cherts, mudstones and/or micritic limestone.

The pillow lavas are generally claret reddish or wine reddish, partly greenish in color. Their pillow shapes vary from ellipsoidal, spheroidal to elongated lobs in forms, varying from centimetres to meters in dimension. Crust of the pillow lavas have a thickness ranging from several mm to 1 cm. Most of the pillow lavas are closely packed. Chlorite envelopes in the form of flakes between pillows were also developed as a result of reaction of lava with sea water and fragmentation of its crust during placement of the lavas.

The pillow lavas have a density of 2.69 g/cm^3 and a porosity of about 5%. The pillows have a height between 59.60 and 106 cm and a width between 36.5 and 106 cm. The ratio of the pillow height/width is between 1.59 and 2.07, indicating that the pillows show elongation rather than rounding. In the studied areas, presence of both elongated and ellipsoidal/spheroidal shaped pillows in the same localities may be related by irregularity in the paleotopography of the basin floor and change in the flow rate of lava. In addition, elongated pillows may be related to low viscosity of lava, and locally brecciated appearance of pillows related to fragmentation and disintegration of pillows during emplacement.

Conclusively, the studied pillow lavas around Elazığ and Malatya areas show similar physical properties, revealing that the lavas are product of the same volcanic system and derived from magmas having similar physical properties.

Keywords: Elazığ, pillow lava, morphometric properties, alteration

Skarnization and metasomatism in the northeast of Semnan (Nokeh area)

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The Nokeh granitoid intrusion with compositional rang of granodiorite, monzonite, granite and alkali-feldspar granite, located in the northeast semnan intruded in cretaceous limestones and Eocene volcaosedimenties and tafeceous limestones and resulted to formeations of calcslicates such as Garnte(andradite), diopside, epidot, scapolite. Formation skarn had associated with iron ore occuration. Iron ore mainly magnetite and hematite. Also, pyrite and chalcopyrite there are with less aboundance. Second minerals suchas goethite, limonite, malachite, azurite, gypsum, chlorite and quartz have been foun with iron ore deposite. Based on the minerals paragensis North semnan Fe-skarn deposite, is produced under following P-T condition: P=1-2 Kbar, TMax=600 °C. The cited episode has been done in the late Eocene to early Oligocene. In skarns and metasomatites of Zartul area the following mineral assemblages have been found: andradite (or grossular)- diopside, andradite – magnetite, diopside- scapolite and ….

Keywords: Skarnization, metasomatism, granitoid, semnan.

Singular granite RMG: El Bema-Est (Hoggar)

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El Bema granite appears to be an outlier in the family of Pan-African granites of Hoggar, it consists of a small dome and belongs to the province granites Taourirt defined Boissonnas, 1973 and alaskites similar with GIIb case (Azzouni et al 2003).
It differs from other granites of group-Silet Taourirt by the fact that it is associated with vein mineralization in cassiterite. It presents an annular arrangement with three facies outcropping in a centripetal organization of the periphery to the center:
-A coarse-grained leucogranite to biotite
-Biotite fine granite
and alaskite alkaline granite medium grain
The snow ball texture and aluminous character without the appearance of topaz seems closer to the magmatic topaz albite. Its location at the intersection of two major accidents on 4 ° 50 shearzone and one of its major branch of the 4 ° 30
The mineralization is associated mainly tin as cassiterite in quartz veins. But it also appears in releases in pegmatites in clusters. Depending on the design of Pollard and Raimbault.
The existence of an ilmenite pushes to classify in the group of rare metal granite GMR
This ilmenite Mn-rich until more than 10% as MnO shows a characteristic presence of Nb 0.24 0.05% Ta and SnO_2.
The El Bema granite by its various characters approaches the GMR granites of Hoggar (Chalal and Marignac, 2004) but it's not strictly part. The presence of Mn-ilmenite suggests a particular RMG group , this group and its significance remains to be defined

Keywords: RMG, granite, ilmenite, Hoggar, cassiterite

Trace element and Sr-Nd-Pb isotopic evidence for subduction recycling of sediments in the genesis of Western Anatolia post-collisional orogenic mafic potassic magmas: A case study from Isparta Angle

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Twenty five sedimentary rock samples, collected from i) Triassic radiolarite, chert, marl and sandstones associated with Mesozoic ophiolites, ii) Mesozoic carbonates and iii) Tertiary carbonated-terrigenous sandstones within the selected geographical locations of the Isparta Angle (SW Turkey), have been analysed for trace element (for all samples) and Sr-Nd-Pb isotopic compositions (for 6 samples). Obtained data compared with those of i) GLOSS (Global Subducting Sediments), and ii) post-collisional mafic potassic volcanics with orogenic geochemical signatures in Western Anatolia Extensional Province. Obtained data from the analysed sediments revealed that there is a strike geochemical and isotopic similarity between sediments and Western Anatolia orogenic mafic potassic rocks. These results also suggest that subduction recycling of sediments played a significant role in the genesis of orogenic potassic magmas from Western Anatolia.

Keywords: isotope; Isparta Angle; Western Anatolia; trace element

Geochemical, geochronologic and Sr/Nd isotopic characteristics of the late Paleocene-middle Eocene granitoids in the Tavşanlı zone, NW Turkey

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The Tavşanlı zone extending 280 km E-W from south of Mustafakemalpaşa to the Mihaliççık-Yunak line is composed of late Paleocene-middle Eocene (58-45 Ma) pre- and post-collisional intrusive masses extending in WNW-ESE direction. These granitoids in Günyüzü, Sivrihisar, Kaymaz, Topkaya and Yürükkaracaören regions display similar geochemical and age patterns. K-Ar (hornblende) age data indicate that intrusive bodies become younger from east to the west and K-Ar ages from hornblende, biotite and feldspar are discordant. Quartz, K-feldspar, (orthoclase, microcline), plagioclase, hornblende and biotite are the main minerals whilst apatite, sphene, magnetite and zircon comprise the accessory phases. Sericitization, epidotization and chloritization are the major alteration products.
These plutons in different texture and structure are represented by I-type affinity and have compositions of granite/granodiorite/monzonite with moderate peraluminous and metaluminous melt character. Based on K_2O (1.5-6%) content, Sivrihisar and Kaymaz granitoid samples are in shoshonitic affinity whilst other granitoids are of potassic-ultrapotassic calk-alkaline type. Oxygen isotope ratios measured in different minerals yielded in the range of mantle to mixed compositions (3.8-13.0‰). $\delta^{18}O$ values of Kaymaz granitoid (10.0-13.0‰) are consistent with high-$\delta^{18}O$ granites (7-10‰) and those of other plutons are comparable to I-type granites. This indicates that the source of magma forming the Kaymaz granitoid is derived from metagraywackes whilst Günyüzü and Sivrihisar intrusive are originated from amphibolites. $^{87}Sr/^{86}Sr$ values of Günyüzü and Sivrihisar granitoids are 0.706264-0.706929 and those of Kaymaz granitoid are 0.714255-0.714863. $^{147}Nd/^{144}Nd$ values of all granitoids range from 0.512266 to 0.512543. Sr-Nd isotopic systematics show that Tavşanlı zone granitoids are originated from an enriched mantle source. $^{87}Sr/^{86}Sr_{(i)}$ vs. increasing SiO_2 (wt.%) contents indicate that an arc-related mantle source with contribution from a crust component and also fractional crystallization and crustal contamination processes exerted primary control on the crystallization of magmatic rocks. In the $^{143}Nd/^{144}Nd_{(i)}$ vs. $^{87}Sr/^{86}Sr_{(i)}$ diagram Sr-Nd isotopic compositions of the Tavşanlı zone granitoids seem to overlap with those of western and central Anatolian granitoids.

Key Words: Sr-Nd isotopes, K-Ar age data, geochemistry, Tavşanlı Zone, NW Turkey.

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GEOTHERMAL SYSTEMS & ENERGY RESOURCES OF THE AEGEAN REGİONS

Conveners:
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Impacts of Paleotectonic and Neotectonic Periods on the Formation of Geothermal Systems in Turkey

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Different geological systems developed in paleotectonic and neotectonic periods in Anatolia where is located in the center of Alpine-Himalayan belt. Many geothermal systems have been seen on this belt. A geothermal system requires some features such as high porosity, high permeability, the appropriate size, high temperature and fluid. . The sustainability of the activity of the system, nominately, periodic faulting and / or fracturing events should continue in region for the protection of permeability.
When geothermal systems are examined in our country, while low enthalpy systems are observed in The Arabian Plate, the Central Anatolian Crystalline Complex and the Eastern Pontides, the Afyon Zone, Tavşanlı Zone and the Menderes Massif have high enthalpy systems forming the western part of Tauride.
It is inevitable that the paleotectonic and neotectonic periods have regional and local impacts on such geothermal systems which have many similarities in terms of both intrusion rocks and reservoir.
This reality is clearly observed when evaluate together temperature distribution maps and geothermal resource distribution maps with tectonic structure maps of Anatolia in paleotectonic and neotectonic period.

Keywords: Geothermal system; paleotectonic; neotectonic

Geothermal fields and thermal waters of Greece: an overview

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This chapter aims to present the thermal and mineral waters of Greece as they constitute a significant energy resource. Based on their geological setting the geothermal fields were distinguished into backarc fields, volcanic arc fields and fault-induced fields of Western Greece. High-enthalpy fields are distributed along the volcanic arc, whereas low- and medium-enthalpy fields in the backarc basins. The geothermal fields of Western Greece are also of low-enthalpy. Representative major and trace element concentrations along with radon concentrations are quoted for every geothermal field, with the backarc fields, dominated by crystalline rocks being enriched in radon compared to the rest. The backrac geothermal fields display Na^{+}-HCO_3^{-} water type; however in most of the cases this type is concealed by fresh and seawater influence. In both volcanic arc fields and fields from Western Greece, seawater effect is also significant. Trace element concentrations are more or less typical for similar type of water. Mainly As but also B, Li, Mn and Rb displayed relatively high values in many samples.

Keywords: radon; trace elements; hydrochemistry; volcanic arc

The Presence of Geothermal Energy in the Aegean Sea

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The existing geothermal fields in Turkey is occured due to Anatolian tectonic activities (Ercan, 1997). According to the intersection hypothesis of Ercan (1997), hot regions are situated at junction points of faults or grabens, which extend in N-S, NNE-SSW and E-W. The West Anatolia is one of the most important areas with respect to geothermal and hydrothermal activities because of having horst-graben structures and active volcanism. Geothermal areas are also known in many coastal regions and islands around the edge of the Aegean (Dando et al., 2000). Therefore, the Aegean Sea and its surrounding area have a significant potential in terms of geothermal activity. The geothermal fields in the coastal zones such as Çeşme-Ilıca-Şifne, Dikili-Bademli-Hayıtlı, Aliağa, Foça, Aydın-Kuşadası-Davutlar, Didim, Bodrum and Seferihisar-Doğanbey Bay have been known the presence of hot water flows in Turkey. In a result of marine geophysical, geological, sedimantology, radioactivity researches by Pekçetinöz (2010), have found significant geothermal sources in the Gülbahçe Gulf and its surroundings. Of single channel, 70 km, and 900 km of multi-channel seismic reflection data show that Izmir Gulf and surrounding regions are widely deformed by N–S to NE–SW trending active transpressional strike-slip faults, reverse faults and some E–W normal faults. (Ocakoğlu and Demirbağ, 2005). İzmir and its surrounding are located on the weakness zone with a dominant strike-slip fault as the İzmir-Balıkesir Transfer Zone (Sözbilir et.al., 2009). Last activity of this zone have proven with occured earthquakes in Sığacık Gulf in 17-20 October 2005.
A detailed investigation does not present about geothermal potential of Sığacık Gulf in current literature. For that reason, geothermal potential of Sığacık Gulf is investigated by using geophysical, geological and physical studies as seismic, magnetic, heat flow, sea-floor topography and ROV (Remotely Operated Vehicles) for monitoring of sea-floor.

Keywords: Aegean sea; geothermal fields; hot water flows

Temperature distribution and estimation of heat flow density on the thermal water complexes in Absheron Peninsula

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The variation of the geothermal gradient and distribution of heat flow within the depths of the development of complexes Absheron stage (upper Pliocene) and productive strata (middle Pliocene) layers was studied.. As thermal water complexes of this territory are confined about these sediments. The data from many oil wells show that, thermal waters with the temperature of above 20°C, have regional evolution within depths more than 110-180 meters.
On basis of above explanations, it is possible to determine the variation of heat flow for each complex separately. It can be calculated density of heat flow using equation $q = \lambda\overline{G}$.
$\overline{G}$ – determined on basis of the graphs shown on picture. On this basis, geothermal gradient for Absheronian complex is 0.0247 mK/m, for productive strata is 0.0166 mK/m.
λ – have determined on basis of the data polling book. Here, the heat conductivity for Absheronian stage deposits equals to 1.1 Vt/(m·K), for productive strata deposits equals to 1.35 Vt/(m·K).
On basis of the noted above parameters, if it calculate the density of the conduction heat flow, results q=27.7 mVt/m^2 for Absheronian stage and q=22.4 mVt/m^2 for productive strata.
Heat flow in the productive strata is less than heat flow in the Absheron stage. It is possible to connect with heat transfer convection on the lateral direction.
In last decades, in countries of Western Europe is used from the model of the gathering of heat volume in porous collectors. Geothermal resources H_1 (by Joule) are valued from formula shown below:

$$H_1 = H_0 \cdot R_0$$

there, H_1 – is the heat gathering in rocks. Matrix heat of rocks (m) and heat gathering in the water (w) filling the porosities have been included to this resource and it is valued so:

$$H_0 = \left[(1-P)\cdot \rho_m \cdot c_m + P\rho_w c_w\right]\cdot\left[T_t - T_0\right]\cdot A\cdot\Delta z$$

there, ρ_m, ρ_w – is corresponding to the density of the water and rock cage, kq/m^3; c_m, c_w – special heat capacity of water and of rock cage, J/(kg·K); P – measureless effective porosity; T_t – temperature in the top of the layer keeping water, °C; T_0 – , temperature of layer surface, °C; A – area considered surface, m^2; Δz – effective thickness of layer keeping water, m. R_0 – is the coefficient of to be restoring and it organizes the part of heat which taking out. It may defined as

$$R_0 = \frac{0.33(T_t - T_r)}{(T_t - T_0)}$$

there, T_r – is temperature of to be striking to the well, °C.
The geothermal energy resources of productive strata sediments for Absheron peninsula have been calculated by this method.
Results show that this district includes enough geothermal energy resources for heating systems and agriculture. There are different technological systems for using this energy. One of these is heat pumps, which usage has been developed last time. These technologies will be able to give impetus to using geothermal energy in Azerbaijan.

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Keywords: Absheron Peninsula; geothermal energy; heat pumps; temperature

Hydrogeochemical properties of Simav (Kütahya) geothermal site, Turkey

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Simav Geothermal Site is situated near the district of Simav in Kutahya Province, Western Anatolia, Turkey and demonstrates unique characteristics with regards to geothermal resources. The site has three geothermal fields (i.e., Eynal (162°C), Nasa (81°C), and Citgol (97°C)), which are used for domestic heating, greenhouse heating and thermal tourism activities. The hot waters reach to the surface through a fault zone that forms the eastern boundary of Simav graben, which is a E-W trending depression from Pliocene to Quaternary age that developed on the older NE-SW trending Miocene basins of Western Anatolia. Five major geological units outcrop in the study. The Paleozoic-aged Menderes Metamorphics form the base rock, which is overlaid in sequence by Paleocene-aged Egrigoz granite; Neogene-aged complex Kizilbuk formation that contains claystone, conglomerate, sandstone, agglomerate and tuff. Finally, the lower Quaternary basalt and Quaternary alluvium overlay these units with non-uniformity and forms the uppermost unit of Simav graben plain.

Water samples were taken during 2009-2012 period for analyzing the hydrogeochemical and isotopic characteristics of the three geothermal fields in the graben plain. The results showed that the thermal waters of the region was found to be rich in terms of sodium (Na^+), bicarbonate ($HCO_3^=$) and sulfate (SO_4^{2-}). The dominant water composition was found to be Na-HCO_3-SO_4 and Na-SO_4-HCO_3. It was also shown that the geothermal waters of the area also influence the quality of local cold groundwater. Isotope analyses (δ18O and δD) of thermal waters show that Simav Geothermal Site waters stay between the Global and Marmara meteoric water lines. Tritium isotope values demonstrate a minimum circulation age of 40-50 year. According to the conceptual models developed for this region, circulation of meteoric waters in the ground transfers heat from deep layers to the surface. Moreover, results also show that the Simav Geothermal waters are rich in arsenic and have an average arsenic concentration of 406 ppb. These values were found to be several orders of magnitude higher than the national (ITASHY, 2005) and international (EPA, 2006) standard limit of 10 ppb.

Keywords: Hydrogeochemisty, Simav Geothermal Site, arsenic.

Investigation of reservoir characteristics of high enthalpy geothermal fields on Büyük Menderes Graben and sulphate variations of geothermal fluids in the graben

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Extensional structures clarify to occurrence of extensive geothermal systems and Neogene volcanism in the Western Anatolia and Aegean Sea. Western Anatolian Graben has both good reservoir potential and fluid carrier properties by tectonic activities for geothermal systems. Low and medium enthalpy geothermal springs are located along the graben. Geothermal fluids have been discovered at northern flank of the graben and their temperatures can be reaching to 245°C in Germencik, Salavatlı, Pamukören and Kızıldere fields which are suitable for power generation. There are 10 more high enthalpy fields have been discovered and required studies are started to power productions in the graben.
Geological settings show continuity along Büyük Menderes Graben. The major stratigraphic units of the graben consist of Paleozoic aged Menderes Massive Metamorphites which is composed of marble, quartzite, various schist and Cenozoic (Tertiary) aged terrestrial-lacustrine sediments deposited on metamorphites. Tertiary deposits represent Kızılburun Formation with conglomera, claystone, sandstone, Sazak Formation with marl, limestone, Kolonkaya and Tosunlar Formations; sandstone, siltstone, conglomerate and Quaternary aged alluvial sedimentary units. Iğdecik Formation is indicated as a separate member of Menderes Metamorphites due to containing thick marble levels.
Geothermal reservoir and cap rocks of Germencik and Salavatlı fields are similar. In these fields, faulted Miocene sediments represent first reservoir, which consist of mainly conglomerate and sandstone, and overlay Pliocene Sediments, which consist of claystone, sandstone, conglomerate, and known as cap rock. Iğdecik formation and overlaid gneiss in fault zones are known second reservoir in the region. One reservoir is determined at the first studies in Pamukören field and the reservoir rocks are belong to İğdecik formation. In Kızıldere geothermal field, three reservoirs are identified in the graben. The first reservoir is Sazak formation, which consists of limestone, marl and, is not observed in other three fields. İğdecik formation is the second reservoir in Kızıldere. The third and the hottest reservoir of the geothermal system are assumed at abundant alteration zones of Menderes Metamorphic rocks. Quartz, pyrite, chlorite, calcite, pyrhotite, hematite and epidote are common alteration minerals at Germencik, Salavatlı, Pamukören and Kızıldere Fields in the Büyük Menderes Graben.
According to chemical, stable isotopes and noncondensable gas results, hydrogeochemical characterizations of geothermal fluids can change from west to east part along the graben. In Germecik field, which is located the west part of the graben, geothermal fluids contain low sulphate (20-80 mg/l) and high chloride (1400-2100 mg/l) values. Middle of the graben, sulphate values is increase up to 200 mg/l and chloride values decrease up to 230 ppm in Salavatlı and Pamukören fields. The east part of the graben, in Kızıldere, sulphate values increase to 600 in shallow reservoir and over than 700 mg/l in deep reservoir in fluids. Conversely, chloride values decrease to 80-110 mg/l in Kızıldere geothermal field. The highest boron (45-55 mg/l) and lithium values (8-8,5 mg/l) in Germencik field. Pamukören and Kızıldere geothermal fluids have less boron concentrations in the graben. These variations control that possible sea intrusion effects in west part of the graben and water-rock interaction effects in reservoirs. Although Kızıldere and Germencik reservoir temperatures are close each other, $\delta^{18}O$ values indicate highest water-rock interaction in Germencik field. According to noncondensable gas results, CO_2 is dominant gas in the reservoirs in Büyük Menderes Graben. Meanwhile H_2S gas values show differences along graben.

Keywords: Büyük Menderes Graben; Kızıldere; Salavatlı; Germencik; Pamukören; sulphate; geothermal

Hydrogeochemical properties of Gulbahce (Urla-Izmir) Geothermal System, Karaburun Peninsula, western Turkey

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Chemical and isotopic compositions of geothermal spring and cold water around Gulbahce Geothermal field which is located in eastern parts of the Karaburun Peninsula and is about 45 km away from the city of Izmir in the western Turkey, were monitored from 1989 and 2012. The Neogene stratigraphy around the Gülbahçe Geothermal system is represented by a volcano-sedimentary succession, including several sedimentary and volcanic units. These units rest on a basement comprising non-metamorphic and intensely sheared Paleozoic to Mesozoic rocks of the Karaburun Peninsula. An association of N-S and NW-SE trending active faults accommodating deep circulation of hydrothermal fluids of sea water origin are the primary control mechanisms of geothermal systems in this region. The physico-chemical characteristics of the hot springs are: average discharge 0.4-2L/s, surface temperature 31-37°C, pH 6.38-7.57, and electrical conductivity (EC) 34390-58400 µS/cm. The cold spring has a temperature of 14-20°C, pH 6.68-8.25, and EC 223-5320 µS/cm. The hot waters and some cold water springs such as İçmeler Karst spring are Na-Cl type, whereas the other cold water is $Ca\text{-}HCO_3$ type. The isotopic data (oxygen-18, deuterium and tritium) indicate that the thermal waters are formed by local recharge and deep circulation of sea waters. The origin of the other cold groundwater is meteoric waters.

Key words: Geothermal; hydrogeochemistry; isotope; Gulbahce; Turkey

Investigation of the spatial variations of the V_P/V_S ratios and seismic b-values beneath the West Anatolian Extensional Province in Turkey

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The spatial variations of V_P/V_S ratios and seismic b-values beneath the West Anatolian Extensional Province, WAEP (37˚-40˚N, 26˚-30˚E) are investigated to understand the physical properties of the crust. For this purpose, TURDEP (Multi-Disciplinary Earthquake Researches in High Risk Regions of Turkey Representing Different Tectonic Regimes Project) micro seismicity catalogue (July, 2007-February, 2011; $M_L \leq 5.1$) including 23335 events monitored by 53 stations is used.
For the estimation of V_P/V_S ratios of each station, data selection criteria are based on rms error ≤ 0.5 s (99.7%), epicenter error ≤ 20 km (98.8%), mostly ranging from 0 to 5 km (90.7%), depth error ≤ 30 km (95.9%), mostly ranging from 0 to 10 km (88.4%), azimuthal gap ≤ 300˚ (97.4%) and P- and S-wave residuals $\leq \mp$ 2.5 s (99.2%). As a result of the data selection criteria, the data from 35 stations is used for the estimation of the V_P/V_S ratios.
The V_P/V_S ratio is estimated from the slope of the Wadati diagram, which is a plot of S-P (t_S-t_P) versus P (t_P) travel-times fitting a straight line for a medium of constant velocity. In the study area, the V_P/V_S ratios vary from 1.63 to 1.78 with an average value of 1.74 ($t_S - t_P < 30$ s). Low V_P/V_S ratios (1.63, for $t_S - t_P < 9$ s) are observed around Denizli Basin and related to the geothermal systems controlled by the faults in the area. Relatively high V_P/V_S ratios (1.72-1.77, for $t_S - t_P < 30$ s) are observed around faults bounding graben systems in the WEAP.
The seismic b-value is a measure of the size distribution of earthquakes in the specific volume and estimated from the slope of Gutenberg-Richter formula. The spatial distribution of b-values within the crust beneath the WAEP is investigated along two cross sections aligning on NW-SE (from Buldan to Honaz in Denizli Basin) and E-W (from Aydın to offshore of Kuşadası) directions. The b values along the cross section of NW-SE direction are relatively high (~1.5) appearing as a concave shape beneath the basin. On the other hand, low b-values (0.8) are estimated at shallow parts of the inner basin. The b-values along the cross section of E-W direction are relatively low to normal (0.8-1.0) in the upper crust (10 km) and match the results obtained from the previous studies in the study area.

Keywords: seismicity, b-value, V_P/V_S ratio, geothermal, West Anatolian Extensional Province

Occurence of heat source to form geothermal systems at Anatolian crustle plate

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The heat source is one of the important parameters for geothermal systems. Major heat source is the mantle plume or the volcanism both occur principally on the plate boundaries.
Convergence of Eurasia and African-Arabian Plates has caused mainly to compressional regime in Anatolian Crustal Plate.
Compressional regime has been dominant at the eastern part of Anatolia because of pushing effect of Arabian Plate and this has been met by folding and faulting structure causing crustal thickening at the eastern part. Accordingly mantle has deepened at this region.
Due to tectonic regime characterized by basin formation and continuous deposition, relatively crustal thickening and mantle deepening has occurred at the central part of Anatolia. Volcanic activities were widespread at northern and western part of this basin while, at southeastern part they developed parallel to regional tectonic There are also some sporadic volcanic activities through the (North Anatolian Fault Zone) NAFZ.
At the western part of Anatolia, graben structures and thin crust have formed due to barrier effect of NAFZ, orientated to west-southwest in Aegean Sea, or to mantle plume and/or corner convection cell in mantle because of subduction of African Plate. On the otherhand, several volcanic activities have occupied extensive areas at the north of Western Anatolia. Accordingly an important heat source has occurred in the area.
Curie point temperature-dept estimation study has revealed that depth of this temperature is around 7 km. and 30 km at western and eastern Anatolia respectively. However, it reaches up to 25 km. depth at Central Anatolia. This phenomenon is quite compatible with structural components mentioned above.
Geothermal systems generally form around thin, volcanically and tectonically active parts of crust. Based on this general structure, presumably corner convection caused by subduction, or doming effect of mantle plume has caused the occurrence of graben structure and thinning of crust at Western Anatolia and development of volcanism at northern part of this area. Hence relatively shallow heat source has caused the formation of high enthalpy geothermal systems.
However, thick crust caused mantle deepening, but folding a faulting structure can permit settling of magma intrusion fringes and scattered volcanic activities at the Eastern Anatolia. So, geothermal systems having moderate enthalpy have formed in these areas.
Important geothermal systems have not developed at Central Anatolia due to weak tectonic and volcanic activities, and additionally deposition which resulted in thick crust, and accordingly deep heat source in the region. Available ones are around preexisting volcanic areas. Although the NAFZ is an active fault, there is no important geothermal field along this fault due to compressional effect caused to mantle deepening and inactive volcanism.
While the temperatures of geothermal reservoirs located Western Anatolia reach up to 285 ^{o}C, it is lower at East and Central Anatolia and lowest at other parts as 50-70 ^{o}C.
As a conclusion, tectonic structure, Curie point temperature – depth and heat flow map patterns and location of geothermal systems coincide with each other.

Keywords: Anatolian Plate, tectonic, mantle, heat source, volcanism, geothermal

Influence of fluids for potential reservoirs modeling

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This study focus on Albania and more particularly the diagenetic evolution of the Triassic-Liassic's carbonate reservoirs in the Ionian zone.
The results of thermal modeling GENEX-GenTect and Thrustpack were compared with the microthermometric data in order to clarify if the mineralizing fluid was in thermal equilibrium with the surrounding material (heat transfers remaining essentially conductive), or if the circulation of a deep fluid along fractures was sufficient to maintain a sustainable thermal balance with the host rocks (heat supply by advection of hot fluids).
One of the fundamental problems in the studies of diagenesis is the flow of the event(s) related to the geological phenomenon that affected the basin or the foothills in a larger geological scale.
By making calculations with the Thustpack software, It was noticed that the Upper Triassic autochthonous deposits stayed at temperatures between 120°C and 145°C during the later geodynamical stages such as the Plio-Quaternary, assuming a surface temperature = 16°C, flow = 30 mW/m2, and replacing the Permo-Triassic anhydrite with clay.
This result shows that high temperature fluids have circulated in the autochthonous and could possibly lead to a late dolomitization of Mesozoic carbonate reservoirs during the later geodynamic stages.
It is basically used to study the thermal evolution of the basin, the transfer of the fluids and their respective roles in the fluid-rock interactions affecting the major carbonate reservoirs.
This results show that there are several stages of dolomitization, with strong control of the paleo-environment. It has not observed any hydrothermal sign or dolomite of high temperature in the unit of Mali i Gjërë, which has indeed never been brought to high temperature due to an early tectonic setting, from the Upper Oligocene (maximum temperature reached by the Triassic is only 80°C).The results obtained in petrography show the following sequence of events:

- Sedimentation of a carbonate mud in a shallow and open environment with algae and precipitation of evaporates;
- Consolidation of sediments with the dissolution of aragonite and evaporates;
- Brecciation;
- Early dolomitization of the matrix;
- Calcareous-dolomite cementation with silica input (presence of quartz and chalcedony, pseudomorphosis of anhydrite);
- Fracturing and dissolution;
- Cementation of dolomite and calcite in fractures, veins and cavities;
- Karstification and late filling of cavities by the dissolution of a clayey mud.

The results obtained by the study of fluid inclusions and stable isotopes of oxygen and carbon show a paleo-maximum temperature reached by the Triassic reservoirs, presently at the outcrop, which remained low (<80°C), and low salinity of the waters related to the burial diagenesis, which unfortunately could not be measured accurately.

Keywords: dolomitization; modeling; GENEX-GenTect; software; diagenetic evolution; secondary porosity

The Comparison of Hydrogeochemical Properties in Ömer-Gecek and Heybeli (Afyonkarahisar) Geothermal Waters

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In Turkey, high entaply geothermal fields are located in Western Anatolia especially in the Aegean region. Apart from Denizli, Aydın, Kütahya, İzmir and Manisa, Afyonkarahisar has also several geothermal fields. Among these Ömer-Gecek and Heybeli geothermal fields located in Akarçay basin are leading geothermal areas in Afyonkarahisar. In the region, there are NW- trending normal faults related to Akşehir-Simav fault system (ASFS) developed in neotectonic period and secondary oblique faults cutting across them.
Meteoric waters percolating through the permeable rocks in the recharge area are heated by geothermal gradiant and ascend to the surface along these major faults. In the Omer-Gecek geothermal area, primary and secondary reservoir rocks are composed of Paleozoic marbles and Miocene andezites and conglomerates, respectively. The Miocene sedimentary sequence serve as a cap rock. The water temperatures in Omer-Gecek area vary between 51–90°C. On the other hand, the Heybeli area of which reservoir rock is formed of Paleozoic limestones. The cap rock is Miocene sedimentary succession like in Ömer-Gecek aera. In the Heybeli geothermal field water temperatures range from 27 to 50°C. The EC values of the thermal waters are 468 to 7820 µS/cm at Omer-Gecek, and 618 to 3600 µS/cm at Heybeli. The water types of Omer-Gecek and Heybeli areas are Na-Cl-HCO_3 and Na-Ca-HCO_3, respectively. The silica geothermometer models, suggest a reservoir temperature between 62-142°C for Omer-Gecek and 44 -112°C for Heybeli area. The F, Cl, B and As contents of the Ömer-Gecek waters are considerably high than those of the Heybeli area and it is thought that the residence time of the Ömer-Gecek waters are longer. Hot and mineralized waters in the region are used for purposes of district heating, greenhouse and thermal tourism.

Key Words: Afyonkarahisar, Ömer-Gecek, Heybeli, geothermal, hydrogeochemistry.

Geothermal drilling operation in Omer-Gecek (Afyonkarahisar) area, Turkey

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The study area (Omer-Gecek) is a town in the vicinity of Afyonkarahisar and is located 15 km on the Afyonkarahisar highway. Geotermal drilling in the area of Omer-Gecek was performed by rotary drilling machine according to the properties of formation (alluvium, schist, marble). Geotermal water in the operated wellbore was found in Afyonkarahisar metamorphic rocks (marble and schist). Drilling was performed by using 26" drill up to 38 m. depth, secondly 20" isolation pipes were placed in this hole then the gap between wellbore hole and 20" pipe was filled with cement with a density. After hardening the filled cement, drilling up to 337 m depth was done using 17 ½ " drill. 13 3/8" production tubing was installed for the depth of borehole (0-337 m). Again the gap between wellbore wall and 13 3/8" production pipe was filled with 1,83 gr/cm3 density. Next the borehole depth was deep and by using 12 1/4" drill up to 683 m for the section 337-495 m 9 5/8" and for the section were installed 495-676 m 6 5/8" plane casing pipes. The thermal water in Omer-Gecek, found to be rich in Na>K>Ca>Mg and Cl>HCO3>SO4 as a result of the chemical analysis. The water flow rate of approximately 90 lt/sec. Geothermal hot water appears starting from 550 m depth. Maximum temperature of the water is 118 0C which is the highest level of temperature in the region. The properties of water are suitable for residential heating.

Keywords: geothermal drilling, geothermal energy; renewable energy; Omer-Gecek, Afyonkarahisar

Hydrogeological and hydrogeochemical properties of the Buldan geothermal fields (Denizli, Turkey)

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Hydrogeological and hydrogeochemical properties of thermal waters are investigated in the Buldan-Denizli geothermal area where is located in the west of the Aegean region. This geothermal field is geographically divided into two main groups; Yenicekent and Gölemezli geothermal fields. In the study area, temperatures of the thermal waters range between 35 and 88°C, and their discharges are range from 15 to 140 l/s in springs and the depths of wells vary between 54 and250 m. Geothermal reservoir waters reflect the water types of Na-Ca-HCO_3-SO_4. Cold waters are mainly dominated by the HCO_3 and SO_4 anions and Na, Ca, and Mg cations. All the waters are of meteoric origin according to the ^{8}O, ^{2}H and ^{3}H contents. The geothermal waters results show that ^{8}O shift and have hardly any tritium corresponding to deep circulation and at least 50 years age.

Scaling, which can be seen in production wells and surface equipments sourced thermal waters, is the important problem in this site. Mineral saturations at measured sampling temperature by using PhreeqCi code suggest that mostly calcite, aragonite and dolomite and partly amorphous silica are the most likely to be precipitated as scales. To be avoided or minimized the scaling problems, determinations of the safety re-injection temperatures are the important part of this study.

Keywords: Geothermal field; Buldan; hydrogeology; hydrogeochemistry, scaling

Electricity Generation in Turkey by Geothermal Energy Resources

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Electricity generation generally is made in thermal, hydro, geothermal power plants and windfarms/windparks. Because of some advantages such as renewability, low-cost, clean, safe and naturality geothermal and wind energy will have been electricity generation source in the near future. Turkey has hot water springs suitable for electricity generation between 130 °C-242 °C with natural vapor and hydrothermal alterations in connection with grabens limited to active faults and diffuse young volcanism in Western Anatolia Region. Other renewable energy and electricity generation resource is wind energy. In Turkey electricity generation is made by windfarms/windparks. These parks/farms are generated 1414.55 MW electricity. The year 2010 electricity general total installed capacity in Turkey is about 49524.1 MW. According to the total installed capacity, thermal power plants have 65.18%, hydro power plants have 31.97%, geothermal power plants and wind farms have 2.85%. Electricity generation generally was obtained from 15 thermal power plants. In this study high temperature geothermal fields and windparks/windfarms in Turkey which are suitable for electricity generation potential were investigated.

Keywords: Geothermal energy, electricity production, alternative energy.

Environmental state-of-art in the oil fields and refineries of oil, gas and their by-products in Albania

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There are several centres for oil and gas production as well as two oil refineries that since many years exercise their activity in oil industry. The technology of oil production and decantation is old one, the technical state of the equipments is much deteriorated and the level of corrosion is high. Consequently, the environment contamination by the gases released in atmosphere and the waters discharged in the open channels, is high. The sources of contamination begin from the well, continue to the groups of oil accumulation, decantation impiants up to the Oil Refinery. The contamination occurs in gaseous, solute and solid state.
Last decade, several studies on the estimation of the contamination state in oil industry and its effect in the contamination level of the environment in the areas of all the known oil and gas deposits where this industry operates as well as in the territory of the whole country, have been completed. The real consideration and estimation of the grade of the effect of the environment contamination by oil industry in the whole environment contamination and aiming the institutional reaction for the environment protection and remediation from the structures of the Ministry that covers the hydrocarbons activity, last years, several organizative and technical – professional measurements on the stabilization and function of the related research and technical structures near the institutions and companies of the hydrocarbons sector, have been undertaken.

Keywords: oil; gas; field; pollution; environment; waters; discharged

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ENERGY PRODUCTION AND THE EFFECT ON THE ENVIRONMENT

Conveners:
Avner Vengosh and Alper Baba

An outlook of Turkish Coals; their properties, formations, utilizations and environmental concerns.

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Coal is the most important indigenous energy resource in the nation and scattered evenly all over the territory. There are three types of coals; poor quality lignites, sub-bituminous coals, and high volatile bituminous coals. The biggest coal reserve is lignite and located in Elbistan region with Pliocene age, higher rank coals are essentially confined to western part of the country. Soma, Tunçbilek, Çan, Yatağan, Aydın, Bursa and Balıkesir regions comprise of sub-bituminous coal deposits and have older ages as Miocene and Eocene. The oldest (Carboniferous) and highest rank coal is located in Zonguldak region (NW of Turkey).
According to the petrographical properties, associated rock assemblages and fossil remnants, Turkish coals tend to have deposited in limnic depositonal environments. The coal swamps are thought to develop within intermontane lake occurrences, developed mostly in Tertiary period.
Turkey owns about12.4 billion tons of brown (lignite + sub bituminous) and 1.3 billion tones of bituminous coal deposits. Turkish coals are mostly low quality (calorific value less than 2000 Kcal/kg). Poor quality coals have been consumed in electricity production mostly. Turkey uses more than 100 million tons of coals each year to substantiate her energy needs. Turkey has no choice to consume these resources much more in near future for energy demand. Power generation plants are mostly pulverized ("PC") type. Recently fluidized bed type plants are favorable types. One of the newest fluidized bed power generation plants is also located in the western region, in Çan area. Lately, the nation's energy policy is bound to utilize coal much more for her energy needs. New projects and investments of coal consumptions are expected to take place, since the country has an inevitable dependence of energy imports.
With consumption of these coals, huge amounts of ashes are generated every day. The environmental concerns of the ashes and emissions are not negligible at all. Controlling of particulates from emissions may be handled with electrostatic filters, but gas emissions, trace element impacts are invisible and always potential treats. Their impacts may seem negligible but the country's increasing scheme and the increasing change of world climate reveal, unfortunately, unpleasant figures. New actions and projects such as storage and capturing of the green house gasses should be taken into considerations soon, to handle the adverse impacts. Turkey should utilize coal for her energy needs but should absolutely take precautions the environmental impacts and the dirt of them, as well.

Key Words: Turkish Coal Types; Utilization of Turkish Coals; Turkish Coal Reserves.

The Hüsamlar lignite deposit: preliminary results of a coal-petrology study

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The coal-bearing Muğla Basin is located close to the eastern coast of the Aegean Sea, in southwest Anatolia, Turkey. The basement consists of rocks of Menderes Massif and Lycian Nappes. The sedimentary filling of the Basin consists of Early Miocene lagoonal to shallow marine sediments (Akçay Group) overlain discordantly by Middle Miocene to Pliocene terrestrial sediments (Muğla Group). Both Groups host coal layers. Talus and alluvial sediments of Quaternary age constitute the top of the stratigraphic column.
The western part of the Muğla Basin, namely the Milas sub-basin, hosts the lignite deposits of Ekizköy, Sekköy, Karacahisar, Hüsamlar, Çakıralan and Alatepe. The lignite of Akçay Group is exploited at Alatepe mine by both underground and surface mining. The Muğla-Group lignite is exploited at Karacahisar by underground mining, and at all the other sites by surface mining.
The Hüsamlar lignite deposit includes 51 Mt reserves. The lignite is exploited by surface mining for supplying the Kemerköy Thermal Power Plant (630 MW installed capacity). The aim of the study is to determine the conditions of the lignite formation.
About 23 lignite samples were collected from one site in the Hüsamlar Open Pit applying channel sampling. The lignite seam consists of alternating benches of matrix coal (20 cm to 1.5 m thick) and inorganic intercalations (2 cm to 3 m thick). Macroscopically, the lignite belongs to the light to medium gelified matrix lithotype. Molluscs occur frequently; plant remnants can rarely recognised. Some coal layers contain limonite and haematite, mostly occurring in cleats. About 17 lignite samples were examined under the coal-petrography microscope under white light and blue-light excitation. Macerals of huminite group are the most abundant. Inertinite is rare, while liptinite content strongly varies. The random reflectance of huminite is about 0.25%. On average, total moisture is 20.50 wt.% (on dry basis), ash yield 20.73 wt.% (on dry basis), volatile matter and fixed carbon contents 60.71 wt.% and 39.29 wt.% (on dry, ash-free basis), respectively. The elemental composition of lignite proved to be as follows: C 61.1 wt.%, H 7.7 wt.%, N 1.9 wt.%, S 9.7 wt.% and O 19.6 wt.% (on dry, ash-free basis). The gross calorific value is around 19.6 MJ/kg (on moist, ash-free basis). The lignite proved to contain calcite, aragonite, quartz, pyrite, feldspar and clay minerals.
On the basis of all the above results the palaeoenvironmental conditions during peat accumulation in the Hüsamlar palaeomire are reconstructed.

Keywords: lignite; coal petrology; depositional environment; Hüsamlar; Muğla Group; Turkey.

Petrological-mineralogical study of the Kryani lignite (Prefecture of Fthiotida, Central Greece)

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This study aims to determine the features of the Kryani lignite deposit (Prefecture of Fthiotida, Central Greece) in order to assess the palaeoenvironmental conditions during peat deposition and to test the potential of certain lignite beds for soil improvement.

The Neogene Zeli-Agnanti Basin is part of the Sub-Pelagonian zone. The margins and the basement of the basin consist of Upper Triassic dolomites and Upper Triassic and Jurassic limestones, overlain by shale and chert strata alternating with ophiolites. Palaeogene rocks are lacking maybe due to erosion. The lignite deposit is hosted in sediments deposited from Miocene to Early Pleistocene and distinguished into three formations: the lignite-underlying, the lignite-bearing and the upper ones. The lignite-underlying (lower) and the upper formations consist mainly of clastic, relatively coarse-grained rocks, whereas the lignite-bearing formation includes lignite beds alternating with fine-grained clastic and calcareous rocks. At the sampling site, except of lignite layers, Neogene sediments such as humic clay, siltstone, sandstone and sand were encountered. The basin includes several smaller deposits, namely Kryani, Agnanti, Golemi.

Thirty four lignite samples were collected applying channel sampling, from the upper seam exposed at the Kryani open pit mine. Inorganic intercalations were additionally sampled. The total thickness of the sampled profile is 17.5 m and the cumulative lignite thickness is 9.8 m. The matrix lithotype is dominant with the mineral-rich lithotype being less common. Xylite- and charcoal-rich lithotypes are seldom encountered. The intercalations mainly consist of siltstones, claystones, as well as of sandstone lenses or layers, sometimes including pebbles.

Proximate and ultimate analyses, along with maceral and mineralogical analyses provide evidence for the depositional environment of the Kryani lignite deposit. Additionally, the extraction and the separation of humic substances (humic and fulvic acids, humines) constitute criteria for the adequacy of certain layers as soil-improvement media.

Petrology, mineralogy and depositional environment of the Karapınar-Ayrancı lignite (Konya, Central Turkey)

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Low-rank coal is an important indigenous energy resource for Turkey. The Karapınar-Ayrancı Basin (Konya, Central Turkey) hosts the most significant deposit (1.8 Gt lignite) recently explored by the Turkish General Directorate of Mineral Research and Exploration (MTA). The lignite deposit will be exploited for power generation. The bedrock of the basin consists of Jurassic-Cretaceous marine limestone. The basinal filling consists of Upper Miocene lacustrine and Pliocene lignite-bearing sediments, uncomformably overlain the bedrock. The sedimentary sequence comprises alternations of lignite, claystone, sandstone and mudstone, and is overlain by Upper Pliocene-Quaternary lacustrine and fluvial sediments. Lignite and inorganic samples picked out from one drill core at the eastern part of the basin were studied in order to determine the environmental conditions during peat deposition in the Karapınar-Ayrancı palaeomire. For this purpose lithological, coal-petrography and mineralogical data along with these from proximate and ultimate analyses are used. Macroscopically the lignite has a black colour and contains at sites gastropod shells. Alternation of matrix and mineral-rich lithotypes is common, while the char-rich lithotype is also abandoned. The studied samples display high ash yield (range 23.29-59.78%; on dry basis), high volatile matter content (range 43.15-87.77%; on dry; ash-free basis) and relatively high H/C ratio (up to 2.43). The gross calorific value reaches 21 MJ/kg (on moist, ash-free basis). Huminite proved the dominant maceral group consisting mostly of detrohuminite. Liptinite and intertinite display low values. Quartz, clay minerals (illite-kaolinite-smectite group), feldspar, halite, pyrite, calcite, bassanite, rarely siderite, are contained in the bulk lignite samples.
Low to moderate Gelification Index (GI) and low Tissue Preservation Index (TPI) values, as well as the occurrence of framboidal pyrite crystals and the high S values are also related to wet (mesotrophic) and anoxic conditions during peat deposition. Thus gastropod shells remain preserved. Hence, ash yield and volatile matter content are high and not related with the topogenic setting. However, the palaeomire was never dried out, although the water table was not stable as the presence of dirt bands and the low Groundwater Influence Index (GWI < 0.5) indicate. The peat-forming vegetation was dominated by herbaceous plants. Even though, the Vegetation Index (VI) values are very low, there could be woody plants in the peat accumulation area as the occurrence of fluorescent eu-ulminite indicates. These fluorescent macerals are related with relatively high H/C ratio indicating anoxic conditions too. However, the presence of halite and bassanite, as well as the high sulphur values could be an indicator of marine influence in the palaeomire. Being the latter impossible in the Karapınar-Ayrancı Basin, halite and bassanite could form epigenetically by inter-basinal brines that forming salty and brakish lakes in the Closed Konya Basin. This data assumes that the studied lignite cores derived from peat accumulated in the Karapinar-Ayranci Basin under anoxic limnotelmatic conditions, which favoured bacterial activity.

Keywords: lignite, peat-forming environment, coal petrology, Karapınar-Ayrancı Basin, Turkey

Petrography of soil organic matter from the surroundings of lignite-fired power plants in Muğla Basin, SW Turkey

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The present study attempts to shed light, by means of organic petrography, on the composition of soil organic matter (SOM) and to estimate the degree of human-induced disturbance in Muğla Basin, which hosts lignite-fired power generation facilities with an installed capacity exceeding 1.5 GW. Ten topsoil samples around the power plants of Yatağan, Kemerköy and Yeniköy were collected for this purpose. They were subjected to density separation in order to concentrate the organic-rich fraction and studied under the coal-petrography microscope. In order to assess the origin of coal and fly ash particles in the studied soil organic matter, the characteristics of the local lignite, fly- and bottom ash were also determined in samples obtained from the Yatağan, Kemerköy and Yeniköy power plants. The organic matter content in the soils of Muğla Basin is moderate, with the Milas soils being slightly enriched compared to the Yatağan ones. The quantitative petrographic analysis carried out applying point counting, involved the classification of organic particles into coal-derived, carbonized and modern organic matter. Modern organic matter dominates, with its content exceeding 50% in most of the soil samples. This can be attributed to high vegetation density in the sampled areas. Structured and fragmented parts of higher plants are the major petrographic components of modern organic matter with spores, resin, roots and fungi summing slightly higher than 20% of this particle group. Coal constitutes between <25% and 75% of the total organic particles. Local lignite is the major coal type; however, medium to high-rank coal particles were also observed, possibly indicating periods of blending the feed coal. Lignite particles are huminite-dominated (>90%) reflecting the composition of the feed lignite in the stockpiles of the power plants. The carbonized particles content is unexpectedly low (<25% of the total organic matter) compared to other areas with similar industrial facilities. This can be explained by the fact that fly ash and to a lesser extent bottom ash, contain very low quantities of unburnt organic matter due to a good combustion efficiency. Char particles (products of incomplete lignite combustion) are the major components in this group; however, coke and diesel soot are also observed indicating industrial sources other than lignite mining and combustion close to the study area. The mineral matter in the light fraction concentrates is composed of both geogenic and anthropogenic minerals. Clay minerals are dominant in the former group and amorphous glassy particles in the latter. Both inorganic constituents tend to form aggregates and therefore, become enriched in the light fraction due to their relatively low densities.

Key words: lignite, density separation, char petrography, fly ash, Muğla Basin, Turkey

The geological setting and origin of the natural gas seeps in the Kemer-Cıralı area, Antalya, SW-Turkey

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The giant natural gas deposits in marine Neogene basins in Eastern Mediterranean region have been discovered in the last decades. So, the importance of Tertiary basins in Eastern Mediterranean region has been increased. The geological setting of the natural gas seeps and the stratigraphic features of the main Neogene basins in SW-Anatolia and their natural gas potentials will be described within this study.
The marine Neogene basins located in southern part of Anatolia and named as Adana-Iskendurun, Mut, Manavgat, Aksu and Finike-Kasaba basins in ascending from east to west. Generally, these basins controlled by N, NE and NW trending fault systems and are separated each other by Paleozoic and Mesozoic basement rocks. The organic substance rich turbiditic sediments that fill these basins have source-rock properties that are considered to be good for hydrocarbon compounds. The thick reefal limestone levels (Early and Middle Miocene) are found in these basins (Oymapinar, Mut, Karaisali and Karabayır Formations), are excellent reservoir units in terms of natural gas due to their porous textures and their stratigraphic setting.
The thickness of the Aquitanian reefal limestones in Finike-Kasaba basin on the west of the Gulf of Antalya reach up to 500 meters. These marine carbonates that usually contain coral, algae and bivalvia fossil components are made of the limestones with high porosity (% 25-35).The Burdigalian turbiditic sediments dominantly are comprised of claystones, mudstones and sandstones which overlie on the Aquitanian reefal limestones with a conformably contact. On the other hand, in the Kasaba and Finike basins, the Lutetian (Eocene) turbiditic sedimentary sequence overlain by the Aquitanian reefal limestones with unconformably contact. The Eocene and Burdigalian turbiditic sediments in Kas-Kasaba basin have moderately and good source-rock properties (% 0.51-3.47 TOC) due to their organic substance content. The stratigraphic properties of Kasaba and Finike basin show that the Aquitanian reefal limestones can be perfect reservoir rocks for natural gas.
The continuously burning natural gas seeps since Antic eras in Yanartas area in Antalya are the most important natural gas seeps in the region. The natural gas seeps in Cirali area are found in serpantinites of Antalya nappes. The serpantinites in this area are known to have overthrusted on the Early Miocene autochthonous units belong to sedimentary sequence of the Kasaba-Finike Neogene basin. Therefore, it can be stated that the natural gas seeps in serpantinites were derived from the lower autochthonous Aquitanian reefal limestones.
On the other hand, the mud volcanoes in the south offshore of Cirali are very important since they quite likely show that there are natural gas seeps also under the sea. The fact that these mud volcanoes are found in similar locations and in the same zone with the gas seeps in Cirali region shows that they quite likely developed due to the gas seeps on the sea ground. The natural gas seeps in Cirali area can be considered as the data supporting the probability of the natural gas existence especially in the bay of Antalya and in Finike basins.

Keywords: Natural gas seeps; Neogene basin; Kemer-Çırali area; Antalya, SW-Turkey

Dispersed organic matter in Jurassic Bituminous Shales from the Ionian Zone (Epirus Region, NW Greece)

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This study aims to determine the maturity of dispersed organic matter (DOM) from the bituminous shales at the region of Epirus in NW Greece. The sedimentary facies of the shales are distinguished in the Lower and the Upper *Posidonomya* beds respectively. The Lower beds started depositing during Toarcian times, isochronous to the facies of the red marl ammonite limestone, known as *Ammonitico rosso*. The upper shale facies continued to deposit until Late Jurassic (Tithonian).

Coal-petrography techniques, namely the measurement of huminite/vitrinite reflectance, as well as the determination of the macerals under the microscope, are applied. The mineralogical and chemical compositions of the shales are also determined applying X-Ray Diffraction analysis (XRD) and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS).

The Upper Jurassic samples reveal low reflectance values (Rr_{oil}<0.40%), setting the Upper shales outside the oil window (0.6-1.3%). By the examination under fluorescence mode, abundant macerals of the liptinite group being appropriate for hydrocarbon generation, were observed. The organic matter of the Upper Jurassic samples is low for H/C generation, ranging from 0.3% to 1.0%. The variability in organic matter content can be explained through the palaeotectonic evolution of the Ionian Basin, in which during Jurassic times the mid part of the Ionian zone began to change, resulting in the interchanging deposition of chert, marl limestone and colored shales.

On the other hand, the Early Jurassic shales are thought to have a higher hydrocarbon potential. The first results are promising with 0.49% Rr_{oil} and 1.4% TOC.

Quartz, anatase, illite, crypto-alite, montmorillonite and haematite are the major minerals contained in the upper bituminous shale strata. Titanium concentrations are relatively high, with the highest value exceeding 2700 ppm.

Rock-Eval pyrolysis is expected to provide further information regarding the maturity of the organic matter, as well as the kerogen type of the studied shales.

Keywords: Dispersed organic matter, Bituminous shales, Ionian zone, Organic petrology

Influence of geological parameters on production and planning under difficult working conditions in Zonguldak Hard Coal Basin

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Underground coal mining is getting to operate at deeper seams as shallow seams are finishing. In general, longwall mining is used to produce coal in underground mining. The basic principle of longwall mining is simple. A coalbed is selected and blocked out into a panel averaging nearly 30-300 m in width (face length), 100-2000 m in length (panel length), and 0.5 m-9 m in height (thickness of seam), by excavating main gate and tailgate around its perimeter. Face and panel length should be selected longer in order to decrease development operations. Geologic conditions, rock and coal conditions affect face and panel lengths. If coalbed contains faults, discontinuities, joints, cracks, anticlinal, synclinal, dirt band and methane gas, panel and face length can not be selected very long. Therefore, geologic parameters are important in longwall mining production and planning.

Not all coalbeds are suitable for longwall mining. The technique works best in coalbeds that are extensive, mostly flat-lying, of generally uniform thickness, and free of discontinuities, such as major faults or other geologic features that could interfere with continuous coal extraction.

Zonguldak hard coal basin in Turkey is an example hard geologic condition. There are “Amasra”, “Karadon”, “Kozlu”, “Üzülmez”, “Armutçuk” regions in Zonguldak hard coal basin. During the North Anatolian formation are faulting and topographic irregularities affected the whole basin. In general, tectonics is very complicated in the basin. Both a lot of small faults and big (major) faults are complicating the planning and working. Inclination of the seams varies from east to west. Also, thicknesses of the seam have important changes within a few hundred meters. Fault zones are zones of weakness which create excessive pressure on the supporting systems. In addition, groundwater usually comes from fault zones. Also, methane content levels are high in Zonguldak basin.

In this study, geologic conditions are explained in underground coal mining. Zonguldak basin is given an example field study. As a result of this study, geologic parameters are determined as well before longwall panel planning.

Keywords: Geological parameters; Underground coal mine; Difficult working conditions; Production and planning

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IN MEMORY OF TOSUN KONUK

Context and characteristics of cold seeps in the Sea of Marmara from geophysical surveys, submersible observations, and monitoring

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Emissions through the seafloor of methane and hydrocarbon bearing fluids are common in sedimentary basins. The Sea of Marmara presents a remarkable case where active seafloor venting sites are found along a major plate boundary fault zone: the North Anatolian Fault. In this context, an influence of crustal strain on the characteristics of fluid emissions (fluxes and chemistry) is hypothesized, and selecting optimal sites for long term monitoring (in the EMSO framework) is an important objective of recent work. Gas in subsurface sediment and bubble plumes in the water column are widespread in the Sea of Marmara but preferentially found in specific settings: (1) along the trace of active faults, both major and minor (2) along the edges of deep basins (3) on structural highs and along anticlines (4) on some, but not all, zones affected by gravity processes. High-resolution AUV multibeam bathymetry and imagery were acquired at sites previously surveyed and sampled with the Nautile manned submersible. These detailed investigations show that the edges of the deep basins are preferential fluid emission sites even when this edge is not determined by an active fault. The geometry of coarse sediment bodies (sandy turbidites and scree) likely determines fluid emission along the basin edges. On the topographic highs between the basins, anticlines collect gas that may then leak to the seafloor along faults or vertical pipes. In all settings, small faults in the shallow sediments influence the distribution of fluid emissions at the10-100 m scale. Monitoring of fluxes and fluid composition performed at three sites showed that small-scale convection driven by salinity contrast or buoyant gas occurs at fluid emission sites. The flux variability associated with those processes may obscure deeper transient signals. However, one site located on a mud volcano recorded a burp of exotic fluids from a thermogenic hydrocarbon reservoir. This mud volcano is located within a few hundred meters wide deformation zone around the main strike-slip fault. We conclude that site selection is key to the success of future monitoring experiments. Indication of a deep fluid source component (distinct from the pervasive brackish water and biogenic gas originating from lake sediments deposited during glaciations) and location within a zone of active shearing are important criteria to consider.

Keywords: Sea of Marmara, Cold seeps, Tectonics

Submarine investigations of the submerged section of the North Anatolian Fault within the Sea of Marmara open new perspectives for the deep seafloor monitoring of earthquake hazards

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The İstanbul region, located near the submerged North Anatolian Fault (NAF) in the Sea of Marmara (SoM), is one of the most suitable (or appropriate) areas to test models aimed at improving the predictability of earthquakes. There are at least four reasons for this. The first two reasons are well known: i) there is a high probability that an earthquake of Mw > 7.0 will strike within the next decades along the NAF in the Sea of Marmara, directly affecting the heavily populated İstanbul area; and ii) the segment having the highest probability to rupture is relatively well determined. The other two reasons are less known as they both result from recent findings: 1) Recent work has reported tremors occurring at least 44 minutes before the Mw 7.4 İzmit earthquake, which devastated part of north western Turkey in 1999 [Bouchon et al, 2011]. 2) Gas emissions were found in the water column near the surface expression of known active faults [Géli et al, 2008]. Here, we present high-resolution, 3D seismic data, heat-flow data and geochemical data collected in 2009 during the Marmara-Demonstration Mission of the ESONET Programme (European Seafloor Observatory Network. The data, collected from where the NAF cuts gas-rich formations of the Thrace Basin province, show a diapiric feature that pierces the seafloor, within less than 1 km of the fault zone. It is proposed that at greater depth, the fault must interact with the source of the gas. This hypothesis could open new perspectives that were not even imaginable a few years ago, and supports the necessity to monitor gas emission activity along with seismicity. If seismic tremors or other anomalous seismic activity are found to be associated with anomalies in gas emission activity, then we will have more criteria for identifying that an anomalous and potentially dangerous situation is under way.

Keywords: Fluid-seismicity interactions; earthquake hazards

Steady late Quaternary slip on the North Anatolian fault in Cinarcik Basin, Marmara Sea

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The right-lateral North Anatolian Fault (NAF) accommodates about 23-25 mm/yr of motion between the Anatolian and Eurasian Plates. It is essential to understand the segmentation of the NAF beneath the Marmara Sea, where the major continental transform fault winds about 10 km from Istanbul and long-term behavior to assess seismic hazard for the whole area. The Marmara Sea contains three subbasins with water depths more than 1200 m, called from west to east the Tekirdag, Central and Cinarcik basins. These basins are separated by shallower topographic highs, the Western and Central highs. In Marmara Sea near Istanbul most of the current strain accumulation is across its northern Branch, here called the Main Marmara Fault (MMF). Large bends bound a releasing segment associated with extension and subsidence of the deep sedimentary Cinarcik Basin. Although the active tectonic elements of the Marmara basins have been considerably investigated, a stratigraphic age model has been lacking to characterize late Quaternary tectonics of the area. High-resolution multichannel seismic reflection data (MCS) from TAMAM 2008 and 2010 cruises imaged a stack of progressively tilted glacial period lowstand deltas within North Imrali basin. Seismic stratigraphy, tilting, fault vertical separations, and sediment volume was then used to develop an age model for five horizons between 109 and 540 ka.
We use our migrated high-resolution MCS-TAMAM data plus existing deep-penetration, low-resolution migrated MCS data for seismic stratigraphic interpretations in Cinarcik basin. These abundant MCS data of multiple resolutions in the Cinarcik basin together with the recently-developed stratigraphic age model are used to evaluate a model for the deep Marmara Sea basins. The deepest part of modern Cinarcik bathymetric basin is adjacent to a WNW-striking releasing segment of the MMF between the Tuzla and Istanbul bends. The deepest part of the 540 ka aged horizon is also adjacent to this segment. Isochore maps in Cinarcik basin indicate that older depocenters are successively farther west than younger ones. The deepest bathymetry and the eastern edge of the youngest horizon to sea floor 500 m isochore are close to the Tuzla bend in the MMF. Thus we conclude that the most rapid subsidence and sedimentation occur at the bending point of MMF near Tuzla, and then they shift along the fault with the time indicating the velocity of MMF through time. The eastern edges of depocenters have been transported steadily westward at ~19 mm/yr for the last 540 ka, and depocenters are subsiding at up to 7 to 10 mm/yr. These observations support oblique, steady-state slip on a non-vertical MMF.

Keywords: North Anatolian Fault, Marmara Sea, Cinarcik Basin, Seismic stratigraphy

Volcanic Debris Avalanche at the SE submarine slopes of Nisyros Volcano, Greece

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A spectacular hummocky topography offshore southeastern Nisyros was discovered using multibeam bathymetric mapping and seismic profiling. Remotely Operated Vehicles (ROVs) were used to document the external architecture and nature of the slide area. In addition, a detailed side scan survey was undertaken to evaluate the surface morphology of avalanche field and compare it with more recent examples of known debris avalanche deposits. The volcanic debris avalanche deposit comprises numerous hills rising up to 60m above the sea bottom and longitudinal ridges, revealing a horseshoe-shaped structure. The deposit covers an area of approximately 4,8 Km wide by 4,6 Km long (22 Km^2) with an estimated average thickness of 30m suggest a total volume of about 0.66 km^3. Hyperbolic reflectors observed in the seismic profiles, on top of sedimentary units, indicate outcrops of blocks that resulted from SE flank collapse of Nisyros volcano made of rhyolites (Nikia formation). The ROV observations from the eastern part of the debris avalanche confirm the alignment of ridges of hummocks in the NE-SW direction. A sudden deceleration of the debris flow can be proposed following our 3D analysis of the outcrop.
Due to the shape characteristics of the avalanche deposit we believe that the flank collapse was a singular failure, involving a rapid, virtually instantaneous, movement of the entire slide mass into the sea. Volcano flank collapse is an integral part in the lifetime of Nisyros volcano and is a large geohazard since it produces large debris avalanche and may triggers tsunami.

Keywords: Aegean Sea, Nisyros volcano, Debris avalanche, submarine, tsunamis

Quaternary basin formation along the North Anatolian Fault System in Marmara Sea, Turkey

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The North Anatolian Fault system (NAF) bifurcates westward into three major branches in northwest Turkey. The right-lateral motion of the NAF has driven formation of transtensional basins across releasing double bends or stepovers of fault strands, and more locally, formation of thrust-related folding across restraining geometries. Basin subsidence has resulted in the formation of the Marmara Sea, which hosts the Northern and Central branches of the NAF. Eurasian-Anatolian plate motion is now 23-25 mm/yr, most of it along the northern branch, the Main Marmara Fault.
We produced the first quantitative stratigraphic age model back to 540 ka for the basins of Marmara Sea. This model is based on new high-resolution multichannel seismic reflection imaging of stacked subsiding and tilting low-stand shelf-edge deltas. The reflection pattern both above and below the 540 ka horizon can be matched across tens of km, and even between basins. This distinctive reflection pattern can be explained if the acoustically transparent vs. reflective pattern is climate/sea level-controlled. We correlated the post-540 ka stratigraphy to several of the Marmara Sea basins, as well as the outer Southern Shelf. Furthermore, the global climate gradually shifted from 40-ka cycles prior to ~800 ka, to 100-ka cycles afterwards; this change is known as the Mid-Pleistocene climate transition. This transition is recognized in the stratigraphy and allows general inferences about pre-540 ka deformation.
Our seismic stratigraphic interpretation documents continual growth and tilting in the basins with no evidence of a change in pattern or rate for at least the last 540 ka. We could not correlate reflections to a basin along the Holocene-active Central Branch of the NAF in southernmost Marmara Sea. Instead, we counted erosional unconformities and matched them to the global sea level curve to construct a tentative chronostratigraphy for that basin. Progressive tilt in this basin is still active, and affects the inferred 540 ka horizon as well as the much thicker section below it. Progressive tilting of strata in the Cinarcik basin, located offshore Istanbul along the Main Marmara fault, has been active from before 540 ka to present. The North Imrali basin, located midway between the Cinarcik and Southern basins, exhibits progressive tilting that affects the entire section above basement, with the 540 ka horizon located approximately midway through the section. Based on these results, we propose that tilting and subsidence of most Marmara Sea basins has been continuous since 1 Ma or longer. The differential subsidence that produces tilting is driven by a dip-slip component on non-vertical faults, including the Main Marmara fault. More speculatively, bends in cross section on blind listric or anti-listric faults may drive differential subsidence. Thus, continuous and uniform basin formation implies steady fault slip.

Keywords: North Anatolian Fault; basin formation; Marmara Sea Turkey; continental transform faulting; Quaternary stratigraphy

3D sediment-basement tomography of the Northern Marmara Trough by a dense OBS network at the nodes of a grid of controlled source profiles along the North Anatolian fault

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A 3D tomographic inversion of first arrival times of shot profiles recorded by a dense OBS network provides an unprecedented constraint on the P waves velocities heterogeneity of the upper-crustal part of the North Marmara Trough (NMT), over a region of 180 km long by 50 km wide. One of the specific aims of this study is to provide a 3D initial model for the local earthquake tomography (LET). Hence, the shot inversion has been performed by using a code dedicated to LET with the possibility to jointly invert for additional controlled source first arrivals. After several tests to check the results trade-off with the inversion parameters, we build up a 3D *a priori* velocity model, in which the sea-bottom topography, the acoustic basement, the crystalline basement and the Moho interfaces have been considered. The reliability of the obtained features has been checked by checkerboard tests and also by their comparison with the deep-penetration multi-channel seismic (MCS) profiles, and with the wide-angle reflection and refraction (WARR) modeled profiles. This study provides the first 3D view of the basement topography along the active North Anatolian Fault (NAF). Clear basement depressions reaching down 6 km depth have been found beneath there sedimentary basins of the NMT. The North Imrali Basin located on the southern continental shelf is observed with a similar sedimentary thickness as its northern neighbours. The Central and Çinarcik basins are separated by a basement high (3 km depth) corresponding to the basement expression of Central High, with a crest position located 10 km north-westwards. On the contrary, Tekirdai and Central basins appear linked, forming a 60 km long basement depression. Beneath the bathymetric relief of Western High low velocities are observed down to 6 km depth and no basement high have been found.

Keywords: Marmara Sea; tomography; seismic; 3D structre

Underwater acoustic propagation model applications to Antalya Gulf, Turkey

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The main goal of this study is to summarize environmental acoustic characteristics of Eastern Mediterranean Sea (off shore Gulf of Antalya) by using some simulation model and selection the best available acoustic model for the area. In this study transmission loss and oceanographic data from the joint project conducted by NATO Undersea Research Center in collaboration with the Turkish Navy Department of Navigation, Hydrography and Oceanography were used. A parametric study using different "Underwater Acoustic Propagation Models" which were developed to use under the Matlab commercial technical computation package was performed. After selecting the proper acoustic model for area acoustic propagation model were performed and transmission loss simulations were made for various frequencies. At the end of the study convenient results were reached compared with in situ measurements by using the right parameters.

Keywords: underwater acoustic propagation; acoustic modeling; transmission loss; antalya gulf

Determining the acoustic turbidities in shore face area between Bandırma Bay and Gemlik Bay, South Marmara Sea, Turkey

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The main aim of this study is to determine the boundaries and causes of acoustic turbidities observed in high resolution shallow seismic reflection data acquired for PHD Study in shore face area between Bandırma and Gemlik Bay, Southern Marmara, which mask uppermost units. Although in the western part of the study area acoustic turbidities are not effect on the seismic sections, in the nearby part of the Kocasu River which is the most important discharge of the study area are starting to mask the uppermost sequence. It reaches the maximum wideness in front of the Kocasu River and immediately separates two units near east seismic section named 33. It's known that the delta structures are one of the most important gas sources. The gas-related features observed on the very high-resolution seismic reflection profiles as acoustic turbidity and blanking, strong multiple reflections, and to a lesser extent bright spots and phase reversal. Gas in shallow marine sediments has two main potential sources: (1)biogenic gas produced by bacterial degradation of organic matter at low temperatures, and (2) thermogenic gas produced by high-temperature degradation and cracking of organic compounds at considerable burial depths. In Çağatay vd. 2002, they determine significant amount of Corg and Total Carbon in ÇAG-1 core samples that were taken in study area before and specify that the mollusc shells are dense in the carbonate texture. With all of those information and acoustic turbidity map, the sources of those attributes are the sediments that are carried and deposited by Kocasu River, can be said. This work was supported by Scientific Research Projects Coordination Unit of Istanbul University Thesis Project number 6384.

Keywords: acoustic turbidities; South Marmara Sea; high resolution seismic

Wide spread gas emissions in the Sea of Marmara, results from systematic ship-borne multibeam echosounder water column imageries

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The number of seep areas identified on the sea bottom has been constantly increasing with the use of multi-scale imagery techniques. Until recently, acoustics in marine geosciences have been mostly used to explore the seabed and image sub-bottom units, with little attention to the water column. The Sea of Marmara located on the transform plate boundary between the Eurasian and Anatolian plates is characterized by an intense seismic activity causing catastrophic earthquakes. The understanding of the evolution of the fluid-fault coupling processes during the earthquake cycle is a challenge and the acoustic detection of gas emissions through the seabed may provide new insights on these processes. Fluid escapes are known to occur at the seabed in the Sea of Marmara. The primary goals of the conducted study were to 1) establish an accurate spatial distribution of the seeps at the scale of the entire sea and 2) investigate the relationship with the fault network and the sedimentary environment. Shipborne multibeam surveys of the water column were conducted there for the first time during the MARMESONET expedition in 2009. Data were acquired with a Simrad EM302 echosounder and analysed with the Sonarscope software (© Ifremer). Gas bubble echoes were very well detected within the entire water depth range. The distribution of water column acoustic echoes reveals that free gas emissions from the seabed are widespread. Numerous acoustic gas flares were detected in association with the North Anatolian fault system. However, gas emissions also spread around the edges of the sedimentary basins (e.g. Cinarcik and Tekirdag basins) and on structural highs (e.g. Western and Central highs).

Keywords: acoustic; water column; gas; seep

Grain size and total heavy mineral distribution in modern beach sediments of the Tuzla Delta (NE- Aegean Sea, Turkey) in relation to transport and depositional processes.

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The modern beaches of the Tuzla Delta are built on the northeastern Aegean coasts by the terrigenous input of the 55 km-long Tuzla River which drains a surface area of approximately 600 km^2 on the Biga Peninsula of the NW Turkey. The main purpose of this study is to investigate grain size distribution of sediments alongshore to provide data for heavy mineral exploration, coastal erosional and depositional processes in the light of river discharges and morpho-hydro-dynamic conditions. With this in mind, during July 2010, a total of 77 surficial (upper 5 cm) sediment samples were taken from the foreshore and backshore areas of coastal beaches of the Tuzla River delta. Proximities to river mouths, changing beach morphologies and prevailing current and wave regimes alongshore were taken into account. Detailed grain size analysis were performed using dry sieve sets and the results were statistically evaluated according to well-known petrographic procedures. Total heavy mineral fractions were separated from the bulk sediment sample using the heavy liquid bromoform (sg. 2,85).
Sediments are composed of varying grain size; 0,11 - 99,74 % pebble (> 4mm); 0,26-86,32 % granule (4-2 mm); 0,11 -86 % very coarse sand (2-1 mm); 0,02 - 71,39 % coarse sand (1-0,5 mm); 0,02 – 50,38 % medium sand (0,5-0,25 mm); 0,03-58,18 % fine sand (0,25-0,125 mm); and 0-5,12 % very fine sand (0,125-0,0625 mm). Especially in the areas with high terrestrial input of the Tuzla River into the Aegean Sea, beach sediments generally are rich in coarse sand. Mean grain size ranges from granule to medium sand (Mz=Φ -1,59 to 1,97). The sorting values indicates moderately well-sorted to poorly-sorted sediments (So= Φ -0,81 to 1,45). The total heavy mineral concentrations range from 0.13 to 47.10 % with an average value of 5.17%. With the grain size and total heavy mineral data, it can be suggested that Tuzla River mouth divides the shoreline system of the study area into two sections. The sediments from the northern section beaches constituted higher amounts of moderately-to moderately well-sorted coarse sand and higher total heavy mineral contents. The geomorphological field observations suggest that longshore grain size distribution in sediments can be explained by combined processes of terrestrial, marine and anthropogenic interactions at varying intensities. The study is still on progress and with new data contributions from the dominant wave and current regime will be considered. This study forms part of a project (09B4343019) supported by the Scientific Research Projects Office of the Ankara University.

Keywords: Eastern Aegean Sea; Tuzla Delta; sediment; grain size; total heavy mineral.

Holocene history of Mediterranean water inflow and channel-network complex in the İstanbul strait outlet area of the Black Sea

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Our high resolution seismic profiling and sediment coring along depth transects from -75 m to -307 m on the shelf and upper slope area off the Black Sea exit of the Istanbul (Boshorus) Strait show the evidence of two unconformities: a shelf-crossing pre-Younger Dryas unconformity (α) and a younger unconformity (α_1) that form the base of a shelf fan with its channel-leveé system. The morphological and chronostratigraphic evidence indicate that the shelf fan sequence started depositing after a strong Mediterranean inflow at ~7.3 ka (calib) BP, delayed 1.3-1.7 ka following the initial marine incursion at ~9 ka BP. The Mediterranean inflow was initially vigorous, causing widespread erosion in the Bosphorus channel and the middle and outer shelf areas, but it later slowed down in response to the rise of the Black Sea level to the global sealevel, allowing the deposition of the shelf fan. From ca 8 to 6 ka BP, the Black Sea level continued to rise in tendem with the global sea level. During the same time interval, Black Sea salinity increased and the density contrast between the Mediterranean and Black Sea waters decreased, reducing the amount of the Mediterranean inflow in general. Redox sensitive element profiles indicate that the flow in the main channel towards northwest and its ventilation effect on the nortwestern slope areas dimished around 5.3 ka BP. This modification in the course of the Mediterranean water plume at 5.3 ka BP was due to the onset of the activity of the rim current near the shelf edge. This was also the time when the first marine sediments started depositing in the Bosphorus channel after the reconnection.

Keywords: Hypoxia; Bosphorus channel; Black Sea; Holocene

Eastern Mediterranean tectonics and oil and gas potentials of this region

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More than 70 % of the world's oil and gas potential is in the Middle East (including the Eastern Mediterranean) and the Caspian and Black Sea regions. These provinces are the northern and southern sides of the Tethys Ocean. In this respect the Eastern Mediterranean and the grater part of the Middle East make up the southern segment of the Teyhys Ocean since the disintegration of the Pangea about 200 Ma. In this respect the Hellenic arc, Cyprus arc, East Anatolian Fault Zone, Bitlis Suture Zone and Zagros Mountains form the southern boundary of the African and Arab plates. The transition in young mountain belts, from ocean crust through the agglomeration of arc systems with long histories of oceanic closures, to a continental hinterland is well exemplified by the plate margin in the eastern Mediterranean. Two arcs (Hellenic and Cyprus) are perpendicular to the relative movements between the African and Eurasian plates. The Pliny-Srabo trenches and the Eastern Anatolian Fault zones are not completely parallel to the slip vector and generally show strike-slip movements. The boundary between the African plate and the Aegean/Anatolian microplate is in the process of transition from subduction to collision along the Cyprus Arc. In the west, north of the oceanic Herodotus Basin, subduction may be continuing; in the east, microcontinental blocks such as the Eratosthenes Seamount are already colliding with Cyprus to the north of the suture. The changes in crustal structure along and across this convergent zone are not well known except by inference from bathymetry, and from a couple of deep-penetrating wideangle seismic transects on the African plate margin. The Anaximander Mountains which are at the junctaposition of the Hellenic and Cyprus arcs where the Florence Rise and the Mediterranean Ridge intersect each other, are under compressional tectonics. The Latakya basins, Anaximander and Eratosthenes mountains with the Florence rise areas have different sedimenter accumulations and are made up of the plate edge normal and anormal oceanic crustal blocks. The Mediterranean Ridge which makes up of the greater parts of deep sea basins, is the sedimentary wedge formed as a result of subduction of the African lithosphere under the Aegean-Anatolian microplates. With the new discoveries of gas in the Levant basin as well as the Nile Delta, this province has gained a great importance as the hydrocarbon reservoirs. Indeed the Palymyra zone in Syria shall be becoming an another area of interest where this area has not been explored up to now.

Keywords: Eastern Mediterranean, closure of Tethys Ocean, Hellenic and Cyprus arcs, oil and gas potentials

Distribution of possible gas hydrate and shallow gas accumulations offshore of Amasra and Zonguldak

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The Black Sea has become a center of attention due to potential of energy resources in recent years. Both the eastern and the western Black Sea basins have significant sediment thickness which makes basins as a natural laboratory for the formation of the hydrocarbons. The study area is located in the Turkish continental margin of the western basin. Previous studies in the area indicate potential of gas and gas hydrate accumulations in the continental rise. 2200 km of high resolution multichannel seismic reflection and Chirp sub-bottom profiler data were collected offshore of Amasra and Zonguldak region from continental shelf to abyssal plain of Black Sea along the margin in 2010 and 2012. A 216 and 168 channel digital streamers have been used during these surveys and a 45+45 cubic inch Generator-Injector (GI) gun fired at every 25 m.
Widespread BSRs are observed on the high resolution multichannel seismic reflection data along the continental rise of the study area. They have negative polarity reflections and cross-cut the sedimentary strata and show similar morphology as the seabed. BSR reflections cover a total of 650 km^2 in the study area which indicates large amount of gas formation and migration in the area. We speculate that probably thermogenic gases from deeper sediments are the reason of the gas hydrate formations in the study area to produce this large amount of gas hydrate accumulations. There are also secondary BSR reflections reverberating primary BSR reflections periodically approx. every 100 ms indicating multi-BSR reflections. We suggest that secondary BSR levels may be paleo-BSRs related to paleo-gas hydrate stability zones and indicate a possible change in the thermobaric conditions of the gas hydrates. There are several responsible agents for BSR relocation. These include a change in the heat flow regime, a possible change of the sea level after last glacial maximum, change of the hydrate forming gases or gas composition. We suggest that the change in the thermobaric conditions was possibly due to the variations of temperature distribution due to the rapid sedimentation.
Interpretation of the seismic sections also shows possible gas accumulations as transparent and scattered zones. Instantaneous seismic attributes of the gas related zones are clearly point out gas accumulations in the study area. Possible gassy zones have bright reflections at top side and these levels have negative polarity and show low frequency zones below the bright reflections. Sub-bottom profiler data also show reflection-free zones reaching to the sea-bottom. Several reflection free columns are observed on the seismic data and are interpreted as gas chimneys. These formations are closely located at the possible gas accumulations and BSR reflections. In addition, Akçakoca-1 and Ayazlı-1 wells which are very close to the study area produces considerable amount of gas from Eocene turbidites and study area is suggested to have high potential in terms of potential energy resources.

Keywords: gas hydrate; BSR; gas; seismic; Black Sea

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Holocene ruptures along the North Anatolia Fault in the Marmara Sea, Turkey: Sedimentary processes, spatial extent and age

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The North Anatolian fault (NAF), which extends east west for over 1600 km across Turkey, is one of the world's major continental transforms. Since 1939, a sequence of M>7 earthquakes ruptured progressively westward the entire NAF east of Marmara. The most recent and westernmost events in this sequence, the Mw7.4 Izmit and Mw7.2 Duzce main shocks of 1999, ruptured about 160 km of the fault and were particularly destructive (~17,000 deaths). The only portion of the NAF that did not rupture in the last century is the segment beneath the Marmara Sea that is considered a seismic gap and presents high risk to Istanbul and surroundings. To decipher Holocene earthquake ruptures and the processes leading to their signature in the sedimentary record we applied submarine paleoseismology techniques to study a transect of three 10 m long cores recovered from the Central Basin. A multi-proxy approach similar to that used to study earthquake-generated turbidites in other setting was used (grain size variability, geochemical elements and physical properties). These measurements were calibrated to a chronology developed from short-lived radioisotopes and radiocarbon.

Discrete depositional events were sampled from the deepest part of Central Basin and previously from Tekirdag Basin and Izmit Gulf (McHugh et al., 2006). Most of these deposits are characterized by multiple sand and coarse silt beds, each normally graded, and that together grade upwards into non-stratified silt that also fines upwards and we refer to them as turbidites-homogenites (T-H). Elemental concentrations of Al and Si increase with the sand and coarser silt components indicative of terrigenous influx. These complex T-Hs are as thick as 1 m and dominate the sedimentation of the basins (≈80%). Interbedded with the T-H are ~10 cm thick fining upwards silt deposits and clay beds.

Large historic earthquakes are associated with such gravitational flow deposits. Frequent earthquakes along active plate boundaries such as the NAF in Marmara Sea are expected to prevent the build-up of unstable sediment, spontaneous mass wasting and flow deposition. We thus interpret all these depositional events to represent large earthquakes: the ones including transport of sand are proximal, and the ones without the sand are distal. Within the past 5000 years T-H were preserved with an average recurrence interval of ~350 years. This is consistent with previous estimates of the recurrence of large earthquakes in the Marmara Sea and with a constant slip rate for the NAF for the mid to late Holocene. We have tentatively linked T-H deposits to historical earthquakes in 557 AD, 740 AD, 1063, 1343, 1506, 1766, 1912 > Ms 7.4 and more distal 1963 in Tekirdag and Central Basins and Izmit Gulf.

The proximities of sedimentation events to inferred historical earthquake ruptures are consistent with previous findings for the Marmara Sea, Canal du Sud basin associated to the Enriquillo-Plantain Garden transform fault, Haiti, and the Calabria Ridge associated to the Calabria accretionary prism in the Ionian Abyssal Plain. These results point to the significance of submarine paleoseismology for understanding the long-term record of ruptures along tectonic boundaries.

Keywords: North Anatolia Fault; Marmara Sea; submarine paleoseismology; turbidites; homogenites

Preliminary Results of the Acoustic Survey along the Sakarya Canyon, Western Black Sea

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Sakarya Canyon is known as a quite deep marine canyon initiated from Karasu where Sakarya River flows into the sea. While shallower areas of the canyon are partially explored, there is no information about geological and geo-morphological structure of this canyon in deeper waters. In May 2012, an acoustic study was performed along the Sakarya Canyon using multi-channel seismic, Chirp sub-bottom profiler and multibeam echosounder systems simultaneously. Approximately 1000 km of high resolution seismic reflection data have been collected. 168 channel digital streamer, 45+45 inch^3 GI gun, 3.5 kHz Chirp sub-bottom profiler and 50 kHz multibeam echosounder systems were used during the survey.

Shallow and deeper bathymetric and geo-morphological structure of the Sakarya Canyon is revealed during the survey. There are primary and secondary canyon systems in the area both of which are in tributary form. Preliminary analysis of bathymetric data shows two separate meandering canyon heads which merge at approx. 500 m water depth extending northwards. These two channels further merge with another canyon extending in SW to NE direction, both of which then constitute the deeper parts of the Sakarya Canyon. In shallower parts, the cross-section of the canyon has V-shaped structure, while it becomes U-shaped form further north at approx. 1500 m water depths. Widespread gully formations exist at deeper parts of both primary and secondary canyons especially along the western flanks of the canyons.

Preliminary analysis of the seismic data reveals deeper sedimentary structure of the area. Shallow shelf zone shows a flat geo-morphology with sub-parallel sub-bottom layers which are deformed by near vertical faults in some places. Seismic profiles, cross-cutting the Sakarya Canyon head, indicate extensive sediment erosion, where sub-bottom layers is suddenly cut at the canyon wall, which indicates the existence of effective turbidity flows along the canyon. Seismic sections also show downslope mass movements in various sizes along the canyon walls.

Several column shaped scattered structures which are interpreted as gas chimneys can be seen in seismic sections at deep waters to the north of the Sakarya Canyon. Roots of these columns can be followed down to the deeper structures and sometimes acoustic turbidity zones, which indicate shallow gas accumulations, can be observed under the chimneys. In addition, Bottom Simulating Reflectors (BSRs) that indicate gas hydrate accumulations can also be observed around these structures.

Significant sediment erosion has been observed along the Sakarya Canyon and there is no evident sediment deposition inside the canyon. The terrigenous sediments in the area are transferred to continental rise area to the north by effective downslope turbidity flows and accumulate in the deeper areas. Widespread buried debris lobes and submarine slides are observed in this depositional area of the continental rise. To the further north, sediment waves along the abyssal plain are also observed. The amplitude of these waves is approximately 20 m and wave length is between 1000 and 1400 m.

Key Words: Sakarya Canyon, Western Blacksea, Acoustic Structures, Mass Movements, Turbidity Flows

Active tectonism of the Çınarcık Basin and the North Anatolian Fault in the Sea of Marmara using multichannel seismic reflection and multibeam bathymetry data

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Sedimentation, structural evolution, and fluid escape below the Sea of Marmara gives important clues to understanding the North Anatolian Fault (NAF). The Sea of Marmara is becoming a natural laboratory for structure, sedimentation, and fluid flow within the North Anatolian fault (NAF) system. Much marine geological and geophysical data has been collected in the Marmara Sea since the deadly 1999 M=7.4. İzmit earthquake and this area is becoming a natural laboratory to study continental transform faults in general. At the longitude of the Marmara Sea, the NAF comprises three branches; the northern one and the central one of them are located along north and south flanks of the Sea of Marmara. The north branch accounts for most of the current dextral motion and is associated with the three major basins. Two of these basins are the results of extension along the releasing side of bends along the transform. It is controversial whether the extensional component is partitioned to separate normal faults, or is instead absorbed by oblique right-normal slip on the non-vertical main northern branch of the NAF. To resolve this question, we studied high resolution multichannel seismic reflection (MCS) and multibeam bathymetry data collected by R/V K.Piri Reis and R/V Le-Suroit as part of two different projects respectively entitled “SeisMarmara”, “TAMAM” and “ESONET”. 3000 km of multichannel seismic reflection profiles were collected in 2008 and 2010 using 72, 111, and 240 channels of streamer with a 6.25 m group interval. The generator-injector airgun was fired every 12.5 or 18.75 m and the resulting MCS data has 10-230 Hz frequency band. The aim of study is investigate character of the North Anatolian Fault and secondary faults along the Çınarcık Basin. In addition, we test and increase the resolution of the younger part of a recently-published age model.
All profiles show that main northern branch of the NAF borders the Çınarcık Basin to the north. The syn-tectonic sediments about this fault and the unconformity at the base of these sediments become progressively older and deeper to the west, away from the Tuzla bend on the NAF. Thus this fault has a large vertical component slip. In contrast, we calculate about 2.5 mm/yr of extension on short normal faults in the southern flank of the basin, which is insufficient to account for the extension required by the releasing geometry of the NAF and current plate motion. Seismic lines do not image any large fault along the southern boundary of this basin. The extension in the Çınarcık Basin, therefore, is likely to be absorbed by the northern NAF. Given the component on responsible for subsidence on the basin side, this fault can accommodate the extension if it dips to the south.
We also produce and age model since last major bathyal onlap which is expected during the last interglacial at ~120,000 years. This model is based on dip-age scaling based on the assumption that tilt rate is constant. During high sea level, slow sedimentation results in fanning of dips and onlap that are correlated to 2nd order climate changes over the last 130 ka.

Keywords: Multichannel seismic reflection data, North Anatolian Fault, Çınarcık Basin, age model

Fault slip estimation and fluid activity along the North Anatolian Fault zone according to 3D marine seismic data in the Western High of the Sea of Marmara

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The submerged section of the North Anatolian Fault within the Sea of Marmara, is a case study of coupled fluid migration and deformation processes in a strike-slip shear zone. A zone on the Western High was selected for the acquisition of 3D high resolution during the MARMESONET cruise (2009), in great part because fluids originating from the upper depth range of the seismogenic zone are expelled through this zone. Thirty-three km2 of high resolution seismic data (with a frequency content of 50-180 Hz) have been collected in a 1.5 km wide swath along the main strike-slip fault strand, called the Main Marmara Fault (MMF). We examine this data to constrain the recent evolution of sedimentation, deformation and fluid emissions along the MMF on the Western High.
3D HR penetration ranged 100-500 m, in a context where recent sedimentation rate is constrained to 0.2-0.5 m/kyr from 10-30 m cores. Four main reflectors corresponding locally to onlap surfaces display relatively strong amplitude, and are affected by mass-wasting processes. This sequence of reflectors is regionally correlated within the Sea of Marmara and has been interpreted in terms of glacial-interglacial cycles over the last 330 000 to 450 000 years. As demonstrated for the Holocene, the onlap surfaces are likely to correspond to episodes of rapid sea-level rise at the end of glaciations and to lacustrine to marine transitions.
Several seismic reflectors display strong lateral variations of amplitude and polarity reversals that correlate with reflector topography. These characteristics indicate trapping of gas. Gas migration pipes are also observed and correlated with seafloor manifestations of fluid outflow. Several of these pipes appear to be associated with buried mud volcanoes, which built on surfaces interpreted as marine highstands.
Mass-transport deposits (MTDs) in the ponded basins, erosion on the highs and slope instabilities also appear associated with marine high-stands. At the OIS-9 transition, MTDs occur within basins on both sides of the fault, and display similar seismic character. Moreover, the eastward limit of the MTD complexes on both sides of the fault is a straight line striking N120 that does not correspond to a fault. This edge has an apparent offset of 7-8 km across the fault and we hypothesize that this is due to strike-slip motion. The fault slip rate thus obtained (20-24 mm/yr) is comparable with the present-day GPS motion across the Sea of Marmara, suggesting that this fault strand has taken up nearly all of the strike-slip motion over the last 330.000 years at least, but that the surface expression of the fault may have been different further back in the past.

Foraminifera and ostracoda studies in Iranian coastline of Persian Gulf (Lengeh to Booshehr port)

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The study area includes the northern part of Persian Gulf coast with warm and humid climate. Study area a distance of approximately 650 kilometers, which encompasses a very important part of the southern coastline of Iran. Studies consist three parts: microfaunistic, mineralogical and ecologic is based on identified groups of foraminifera and ostracoda. According to foraminifera investigation 42 samples including 6 genera and 36 species have been introduced.
Most common foraminifera have hyaline test. The main biological accumulation (Association) has identified the following:
Ammonia beccarii Linne Association
Species associated with this category include:
Ammonia tepida, Cushman, 1909
Asterorotalia dentata, Hofker, 1950
Elphidium craticulatum, Fichtel & Moll, 1798
Quinqueloculina seminulum Linne, 1758
Spiroloculina depressa, d'Orbigny, 1826
Triloculina tricarinata, d'Orbigny, 1826
Clavulina parisiensis, d'Orbigny, 1826
According to ostracoda investigation 8 samples including 3 genera and 5 species have been introduced with following main association:
Association. *Punctaparchites* sp
Species associated with this category include:
Echinocythere scabra Puri, 1954
Cytheretta sp.
Leptocythere pellucida Baird, 1850
Loxoconcha rhomboidea Fischer, 1977
Mineralogical experiments by X-ray difractometry method (XRD) shows that mineral deposits of research station have continental and clastic origin such as calcite, dolomite and quartz are more frequent.
In ecological studies physicochemical factors of sea water were measured. The presence and frequency of ostracoda and foraminifera were determined. Acidity of water in the region suggests that a fluctuation in water pH is negligible. Electrical conductivity of sea water depends on the frequency of the ions in the water. But the most important physicochemical factors affecting the development of foraminifera, dissolved oxygen is the frequency and variety of controls to.
Presence community living (biocenosis) rate to non-living population (taphocenosis) foraminifera and ostracoda in direct proportion are environmental pollutants. As to what the rate of infection increase the number and variety of live organism's community are added but the rate of taphocensis is reduced.
In general the main determining factor of microfauna frequency between Bushehr to Lenghe port were introduced kind of coastline bed.
Fine grain a bed includes silty and muddy have high rate of taphocensis and biocenosis, but frequency of biocensis in the absence or low contaminant more than the others. Therefore, the Persian Gulf microfauna community as suitable indicators for measuring environmental pollution considered.

Key words: microfauna; biocensis; taphocensis; environmental pollution

Identify characteristics Sedimentology and sedimentary environment deposits in the southern Caspian Sea

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The Caspian Sea is the largest lake in the world and it has special unique characteristics. Area of study is the southern margin the Caspian Sea (coasts of Iran) with the geographic location Longitude 36°, 34´N to 38°, 30´N and latitude 48°, 55´E to 54°, 03´E.
Geology terms of the Caspian Sea to be built the interior of the basin close to five million years ago. In the mid – Miocene the Caspian Sea separated from the Tethys Ocean and a basin brackish water occurs.
At first for study this area according to the depth (until 70m) of the sea and rivers entering to the sea provided a network for getting sediment samples and then take 80 samples from seabed with using Grab.
All of the samples analysis granulometry by wet method and also sedimentary environment characteristics were determined using the information Bathymetry.Grain size analysis shows that in the area can be Deposits is divided into 11 types. The continental platform in the study area so that can be divided into major three Area: continental platform eastern part of the South Caspian Sea has a very low slope and it is too long until 70 km, the slope of the continental platform in the western region has a very low but not as much the East and length this Area about 45 km and central part has greater slope than the other two areas and length is about 10 km.
According to the great diversity of sediment types and features of continental platform in this Area can be conclude that types of sediments resulting from factors such as:
Mostly sediment load carried by rivers.
Strength of carriers, erosion, distribution sedimentary particles by sea waves and submarine currents.
Most of the sedimentary particles in sizes 1(mm), 0.5(mm) and .025(mm) forming from broken pieces shell of organism Continental platform in the eastern area of according to great abundance biological components such as foraminifera, shells, etc. a good place to deposits of carbonate sediments are of biological source.
Continental platform in the West area of study although slope has a low and length has a high In addition to the biological particles have a detritic grains are much more than the east area.
Length continental platform in the central area of low and the slope is much more of both eastern and western regions Constituent particles of sedimentary deposits are detritic.

Q estimation from a marine seismic reflection data of Izmit Bay, NW Turkey: Comparison of correlation coefficient and L2 norm methods.

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The investigations based on petrology, grain size and chemistry of exposed fault zones indicate that the nature and extent of fault zone deformation vary with rock type and physical conditions. Since the attenuation is a petrophysical parameter being more sensitive to lithology and physical properties of the medium (pressure, temperature, saturation to fluid and gas, etc) than the velocity, it can be used as an indicator to determine the physical changes along the fault zones. One of the most common measures of attenuation is defined by the inverse of dimensionless quality factor (Q), which is a ratio of stored energy to dissipated energy during one cycle of the wave. Several Q estimation methods are available in the literature. In this study two of them, the correlation coefficient and L2 norm methods, are used in the Q estimation. In a former study it is observed that the correlation coefficient method has a limitation for the estimation of the Q value which is higher than 100. Here the aim is to use both methods in a marine seismic reflection data, and compare the results of Q variations along the seismic profile and the well observed North Anatolian Fault.

In the study, one of the marine seismic reflection data collected in the Western (Darica) Basin of Izmit Bay by MTA (Mineral Research and Exploration Institute of Turkey) research vessel Seismic-1 after 17th August 1999 earthquake is used for Q estimation. The Q value determined from a reflection seismogram is an average of the quality factors of the layers passed by the reflected wavelet. In this study the constant-Q approximation is considered, and the wavelet modelling technique is used. The wavelet modeling is based on the comparison of the attenuated synthetic wavelets by the observed wavelets. The measure of agreement of the wavelets are provided by the correlation coefficient and L2 norm methods. To obtain the synthetic wavelets, the arrival times of the prominent, isolated reflected waves are determined from the raw shot data of the seismic reflection profile. The sea bottom reflection is selected as the source wavelet. The attenuated synthetic wavelets are obtained by the convolution of the source wavelet, by the impulse response of constant-Q operator which is calculated at the observed travel times for a certain range of Q values, between 10 and 200 with an interval of 10 (Q-panel). The synthetic wavelets of the Q panel are compared with the observed wavelets, and the best agreement is assigned as the average Q value for the considered two way travel time.

It is observed that both correlation coefficient and L2 norm give low Q values around the fault and in shallow sediments. Some differences between the methods are observed at some deeper levels of the seismic section. For these levels it is seen that L2 norm gives more reliable results when compared to the correlation coefficient method. The reason of this difference is expected to be due to the limitation of the correlation coefficient method.

Keywords: seismic attenuation; Q estimation; wavelet modeling; North Anatolian Fault; Izmit Bay.

Active tectonics of Gulf of Sigacik (Western Anatolia) and surrounding area by multi channel seismic and chirp data: Evidence for submarine active faults occurred during 17 October 2005 Sigacik earthquake

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This study consists of the results of the multi-channel seismic reflection and chirp data acquisition by K. Piri Reis, research vessel of Dokuz Eylül University (Izmir-TURKEY), in Sığacık Gulf and Kuşadası Gulf (West Anatolia) in August-2005 and in March-2008. Data were acquired approximately along the 1300km seismic lines. On 17 October 2005, a series of earthquakes occurred in the same area about two months after the first cruise. The epicenters of the earthquake series are very close to our seismic profiles. Second cruise was realized in 2008, after this earthquake series. Two main seismic units, lower unit (Pre-Neogene) and upper unit (Neogene), can easily be determined on multi channel seismic sections. It is also observed on seismic sections that there are many active faults deform these units. Two main submarine basins can be determined from multi-channel seismic sections, Sığacık Basin and Kuşadası Basin. The upper unit in Sığacık Basin is deformed generally by strike slip faults. But there are some faults that have sharp vertical movements on lower unit. Some of these vertical movements are followed by strike-slip active faults along the upper unit indicating that these normal movements have changed to lateral recently. On the other hand, normal faults are dominant in Kuşadası Basin. The chirp data which have higher resolution and lower penetration than multi-channel seismic data allow being distinguished of the active faults. In the view of the processed data, the active faults, their continuation on land and the relationship with the earthquakes happened in the surrounding area were investigated.

Keywords: multi channel seismic reflection; chirp data; Sığacık earthquake; Sığacık and Kuşadası gulfs; active faults

Effects of transport and depositional conditions on the grain size distribution of beach sediments of the Finike Gulf (SW Turkey)

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The modern beaches of the Finike Gulf (SW-Turkey) are fed by the terrigenous input of 5 main rivers which drain mountainous regions of the hinterland. The major objective of this presentation is to investigate grain size characteristics of modern beach sediments, beach morphologies and to observe longshore current regime to understand depositional and transportation processes and related controls on sediment composition in this region. Further data should be provided to use in heavy mineral exploration and provenance studies. This study was supported by the Scientific Research Projects Office of the Ankara University (Project No:). During September 2009, apart from geomorphological field observations, 64 surficial sediment samples were collected from the foreshore and backshore subenvironments of the modern beaches of the Finike Gulf. Grain size analysis of the bulk sediment samples were performed using a set of dry sieves according to Folk (1974). Data was evaluated both statistically and graphically.
Sand with varying proportions is the dominant grain in beach sediments. Maximum grain size measurements are in pebble (>4 mm) is %66,66, granule (4-2 mm) is %93,85, very coarse sand (2-1 mm) is %89,20, coarse sand (1-0,5 mm) is %53,22, medium sand (0,5-0,250 mm) is %68,70, fine sand (0,250-0,125 mm) is %90,75, very fine sand (0,125-0,063 mm) % 31,48 and minimum grain size measurements are 0 for all the ranges. From west to east of the gulf fine sand ratios are decreasing. Very fine sand ratios on the west samples are higher than east part. Medium sand ratios are on average ratios on the wet and middle sections of the gulf. Coarse sand ratios are Very coarse sand and granule sized sand ratios are accelerating highly to the east of the gulf.

Keywords. The Finike Gulf; beach; sediment; grain size;

Interpretation of Gulf of Saros Magnetic Data with Semi-Automated Interpretation Methods

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The Gulf of Saros is located north of the Gelibolu Peninsula in northwestern Turkey in between the Sea of Marmara and the North Aegean Trough at the west end of the North Anatolian Fault. The Gulf of Saros has a graben system. The South-East region of Saros Graben is formed by strike slip Ganos Fault and Anafartalar reverse Fault. The purpose of this study is to determine boundary and depth of the Saros graben using the Semi-Automated Interpretation Methods. This study contains the application of the geophysical interpretation techniques, named Normalized Full Gradients, Euler Deconvolution Method and added to these methods searching Location of Maximal Points of the Horizontal Gradients (Boundary Analysis Method) in the Gulf of Saros. The first two methods require no prior knowledge of the magnetic source. Therefore they may be successfully applied in areas where the geology is poorly known. As a result, thickness of sediment was found to be about 3 km and boundary of the graben was determined.

Keywords: Gulf of Saros; Normalized Full Gradients; Euler Deconvolution Method; Boundary Analysis Method

Seismic reflection studies for gas hydrate and tectonic researches in the seas surrounding Turkey

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Gas hydrate refers to dirty white colour crystalline ice-like substance which formed under high pressure and low temperature by combining lattice-bearing water molecules and natural gas molecules. Because a volume of gas hydrate can store up to 164 times per volume gas, and the fact that gas hydrate occurs ubiquitously around the globe, it is considered as a strong competitor to conventional hydrocarbons and is viewed as a potential energy source.
Seismic laboratory have run several cruises in early 2005, 2007, 2008, 2010, 2011 and 2012 to collect, process and interpret the multichannel seismic reflection, multibeam bathymetry, sparker, deep tow side scan sonar and Chirp subbottom profiler data collected by R/V K. Piri Reis. The primary objectives of the SeisLab are to determine the distribution and to map the areal extent of the possible gas hydrate deposits, but also to understand the tectonism and fault mapping in the seas surrounding Turkey.

Keywords: Gas Hydrate, Seislab, Shelf, Continental Slope, seas of Turkey

Study of heavy metal concentrations in surficial sediments of the offshore Büyük Menderes River Delta (Western Turkey); anthropogenic and geological considerations.

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During the 1998 cruise of the Research Vessel "Piri Reis" of Dokuz Eylül University (İzmir, Turkey) off the Büyük Menderes River delta, surficial sediment samples (upper 2cm of seafloor) were obtained from 18 stations of between 19 and 81 m water depths using a Van Veen grab sampler. The main purpose of this study was to investigate the levels of heavy metal concentrations in relation to anthropogenic and geological conditions in the region. Radiocarbon datings from the two distal-prodelta cores along with available seismic profiling data suggest ages of the studied sediments of between 500 (prodelta) and 50 (delta-front) years BP. This presentation forms part of project supported by the Turkish Scientific and Technical Research Council (Project YDABÇAG-597G). Grain size analysis was carried out using dry-wet sieving techniques, total carbonate contents by volumetric method (release of CO_2 by acid treatment) and the contents of total organic carbon was determined by wet oxidation and titration method. ICP method was applied to determine total heavy metal contents in bulk sediments, after digestion of powdered sample with 4-acids. Accuracy and precision of the analytical methods were checked with geological reference materials. Pro-delta sediments are composed of coarser-grained materials with 27-52% sand and gravel and mud was dominant towards the delta-front (88-99%). Total carbonate contents in the prodelta (26-44%) were comparably higher than those towards the deltafront (16-23%). Under microscope, carbonate materials seem to be derived mostly from the benthic organism remains. Total organic carbon contents largely fall in the range of between 0,4-0,9%. Most of the element concentrations determined were comparable with those from average crustal rocks and shales and thus, representing average geological sources. Exceptions for Mg (1,44-3,34%), Cr (175-230 ppm) and Ni (77-331 ppm) can be related to the wide occurrences of metamorphic and magmatic rocks on the coastal hinterland. Whether or not, slightly increasing As concentrations (11-31 ppm) would imply some anthropogenic effects, sems to be likely due to intense agricultural activities on the lowland/delta. This study is going on with comparisons of heavy metal data from the Büyük Menderes River sediments.

Keywords. Eastern Aegean Sea; Büyük Menderes River; offshore delta; sediment; heavy metal

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Tectonic events responsible for shaping the Sea of Marmara and its surrounding region

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The Sea of Marmara formed in a region where successive convergent and strike-slip tectonic régimes had created a variety of structures with complex overprinting relationships. The convergent tectonic structures constituted its stratigraphic basement, whereas the strike-slip structures functioned coevally in part with its development. There is no doubt that all of these structures controlled to a certain extent the structural geology and geomorphology of the Sea of Marmara Basin. Therefore, without detailed knowledge of these structures, it may be difficult to understand fully the dynamic régimes responsible for the formation and shaping of the Sea of Marmara.
The main vestige of the older convergent tectonic régime in the Marmara Region and the surrounding area is the Thrace Basin. This basin developed as a fore arc basin between the Eocene and Oligocene above the Northward subducting Intra-Pontide Ocean. Its post-Oligocene history has been dominated by strike-slip tectonics that also led in their later stage to the opening of the Sea of Marmara over the Thrace Basin. Therefore, unravelling the structural evolution of the Thrace Basin may contribute to the understanding of the formation and the geological evolution of the Sea of Marmara Basin.
In this paper, the tectonic structures which were produced in the Thrace Basin by the convergent and the strike-slip tectonics are differentiated and their role in the formation and the configuration of the Sea of Marmara are discussed.

Keywords: Thrace Basin, North Anatolian Shear Zone, North Anatolian Fault, the Sea of Marmara

Petrographical and Geochemical Investigation of Bozcaada Eolinite: Significance on the Pleistocene Coastal Dynamics of the Depositional Records

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Pleistocene – Holocene eolinites observed along the southern coast of Bozcaada, mainly on-shore and partly off-shore, have some important records of depositional features reflecting the geologic/morphologic developments of the island during the Quaternary period. Moreover, eolinites are important for the paleogeographical and morphotectonic character of Bozcaada coast. Therefore, in this research; facies properties of eolinites in two localities namely Zunguma Cape and Yaylıca Bay have been studied in order to understand of Late Pleistocene geological evolution of Bozcaada. Eolinite deposits in Zunguma Cape is up to 5 meter-thick while the maximum thickness of Yaylıca eolinite less than 1.5 meter. Six samples from two different localities of the Zunguma Eolinite and 7 samples from 6 different localities of the Yaylıca Eolinite outcrops have been taken during field studies. Analytical and petrographical investigations such as; SEM, EDX, XRD, Stable Isotope Analyses and also thin-section studies on all eolinite samples have been performed.
Cross-bedded eolinites occurring on both two regions include poorly-sorted, mostly metamorphic polygenic grains. Based on petrographic investigation; there are some fossil shells and ooids between the grains based on petrographical investigations. SEM, EDX analysis have been performed to reveal inter-grains microtextural pattern and quantitative element content of eolinite deposits. These analyses show that grains are covered by micritic envelope indicating an inter-tidal environment. Element abundance of the micritic envelope ranges as O>Ca>C>Cl>Fe>Si>Mg>Al>Na in decreasing order in the Zunguma Cape and O>Ca>C>Fe>Si>Mg>Na>Cl>Al>K in the Yaylıca eolinite deposits.
According to element weight ratio (%wt) estimations, the mean values of %$MgCO_3$ are 4.98 and 4.82 for Zunguma and Yaylıca eolinite deposits respectively, which indicate the cement of high Mg calcite. Hovewer, meniscus cement developed over the micritic envelopes show that cementing processes developed under the meteoric conditions dominated by the terrestrial effects. According to XRD analyses, the mineral compositions of eolinite deposits are composed of calcite, quartz and dolomite. Stable isotope analyses on cements in Zunguma Cape deposits are decreasing from lower levels to higher level, on the first point as 1.76, 0.04-1.13 for ^{13}C, 1.44,- 0.51, -2.16 for ^{18}O; wheres increasing on the second point as -5.99, -4.34, -4.98 for ^{13}C, -4.53, -4.68, -4.92 for ^{18}O. On the other hand, in the Yaylıca deposits it has the rations of ^{13}C ranging from -0.21 to -4.42. When evoluated these results from Zunguma Cape eolinite together with OSL age data, eolinite forming resulted from the diagenesis of Late Pleistocene coast dune deposits on the southern coasts of Bozcaada, and also show that the cement originated from carbonates transported from the shallow shelf plain by the effect of drowning sea level in the last ice age.

Keywords: Eolinite; coast; stable isotopes; Bozcaada

This study is supported partly by 2010/162 project of COMU-BAP and includes preliminary results of the first author's PhD thesis.

The Paleogeography of Northwest Black Sea Coast: A Discussion of Competing Hypotheses

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All the existing ideas about paleogeography of the Black Sea basin over the last 20-18 kyr PB can be summarized in the form of three concepts about sea-level change. 1 - The concept about the abrupt change of the level with high amplitude (some tens meters) during very short time interval (100 days / 10 years), named "catastrophic flood hypothesis". 2 - The concept about spasmodic (step) rising of the sea level. According to this concept the sea level during this period rose as a whole smoothly from absolute marks of 80 -100 m, but with rather short-term delays (3-4 kyr). 3 - The hypothesis about oscillatory character of the level change against the background of general transgression in the postglacial time (LGT). The results of geological studying of limans of the Northern Black Sea Coast and ancient coastal lines on the shelf corroborate with the third hypothesis. Geological-mathematical model of sedimentation on the shelf and the spectral analysis of the Dnepr discharge during the last 4.0 kyr have allowed the allocation of the periodic component of various frequencies. It has been proved, that the periods of 1.6-2.0, 1.0-1.1 and 0.7-0.5 kyr lead to fluctuations of the sea level from 10-15 m to 3-5 m.

Keywords: transgression; regression; periodicity; sea level.

Enigmatic boulder accumulations on the southern coast of Crete: storm or tsunami deposits?

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The Eastern Mediterranean is one of the most seismically active regions in Europe with historical and recent records for strong earthquakes and resultant tsunamis, yet geological evidence for Holocene tsunami events is surprisingly rare. Crete, located in the centre of the Eastern Mediterranean and upon the Hellenic arc, should be expected to experience tsunamis resulting from large magnitude earthquakes (such as the AD365 earthquake that caused up to 9 m of uplift in western Crete) and volcanic eruptions (i.e., Santorini 1650 BC), yet to date only a few tsunami deposits have been described mainly from the far west of the island. Here, various enigmatic boulder deposits from the southern coastline of Crete are described. At three locations, broken and landward-imbricated slabs of beachrock were observed 1-2 m above sea level. Measurements of the axes of these slabs indicate that the largest weighs in excess of 5 tonnes, hydrodynamic equations imply that storm waves of 14-25 m high are needed to emplace these slabs whereas a tsunami of only 1-14 m high is needed. At another location, a lithologically varied grouping of large boulders, of up to 140 tonnes in weight, is cemented into beachrock exposed at present sea level. Some of the limestone boulders exhibit notches, typically formed at sea-level, that are no longer horizontally oriented. Calculations of wave heights needed to move these boulders indicate storm waves of > 7 m or tsunami waves of < 2 m. Given that the majority of observed boulders appear to have a littoral origin (beachrock composition, evidence of marine erosion), many are imbricated, and the calculated storm wave heights required to transport the boulders significantly exceed winter norms for this coast (~ 1 m high); these accumulations are interpreted as tsunami deposits. Furthermore, assuming that the timing of beachrock development along the southern Cretan coast is uniform, two tsunami events are inferred; one prior to beachrock development, allowing subsequent cementation of large boulders into the beachrock; one subsequent to beachrock formation allowing erosion and sub-aerial deposition of beachrock slabs.

Keywords: tsunami; crete; boulder deposit.

The evolution and activity of strands of the Central Branch of the North Anatolian Fault in Marmara Sea

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Under the The TAMAM (Turkish American MArmara Multichannel) Project, two cruises were performed using the R/V K. Piri Reis in order to map the major sedimentary basins and shallow fault patterns of the Marmara Sea. We acquired approximately 3000 km high resolution multichannel seismic and chirp data throughout the Sea of Marmara. There are multiple published interpretations for the three branches of the North Anatolian Fault (NAF). Analysis of these data allowed for a new interpretation of the geometry of the many strands of the Central branch of the NAF. Correlation of a new stratigraphic age model for the last 540 ka onto the outer Southern Shelf, and creation of a new age model for the inner Southern Shelf allowed evaluation of the evolution and activity of strands of the Central Branch of the NAF. Erosional unconformities are linked to specific glacial cycles, thus constructing a chronology. This new age model is then applied to the deformation history of the Central branch of the NAF.

The NAF, which splits in the Sea of Marmara region into three major fault branches, the Northern, the Central and the Southern branch, the Central branch of the NAF enters the Sea of Marmara in Gemlik Bay as a narrow zone. There, it diverges westward into many smaller strands in a fan pattern. The important southern strand strikes WSW and continues onland near the Kocasu River delta between Bandırma and Mudanya. The middle strand strikes to WNW and merges with the İmralı Fault, and the İmralı faults split again into the İmrali Ridge Fault across mid shelf.

The faults show inconsistent reflection patterns across fault strands and contractional folding in segments that would be restraining for right lateral slip.

Most of the faults increase their vertical component with depth at least to th 540 ka horizon. The thickness and amount of tilt below the 540ka horizon in the inner shelf basin indicates ongoing tilting through most or all of Quaternary time. On chirp seismic profiles, ongoing tilting is observed and most of the faults cut the Last Glacial Maximum unconformity and many cut even Holocene reflections.

Keywords: Marmara Sea, North Anatolian Fault; central branch; strike slip fault; erosional unconformity

Coastal Uplift and Sea-level Changes along the Eastern Black Sea Coast: New Marine Terrace Data from Eastern Pontides, Trabzon (Turkey) and Its Regional Significance

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Quaternary marine terrace sequence has been investigated in the vicinity of Trabzon (Turkey) along a ~20 km long strech of coast of the southeastern Black Sea. The sequence includes seven principal marine terraces. The upper shoreline angles of the main terraces were found at the following maximum elevations above mean sea level: 3 +/- 0.5 m (TH), 12 +/- 3 m (T1), 36 +/- 2 m (T2), 79 +/- 9m (T3), 120 +/- 3m (T4), 138 +/- 10m (T5), and 260 +/- 25m (T6). Fossil bivalves and gastropods from TH, T1, T2 and T3 deposits have been dated by Electron Spin Resonance method (ESR). The results show that ages of deposits from TH, T1, T2 and T3 terraces are of 5.141±0.294 ka, 124.8±26.0 ka, 292.5±49.8 ka and 407.998 ± 67.475 ka, respectively. Consequently, we correlate TH, T1, T2 and T3 to MIS 1, 5e, 9, 11, which correspond to the ~5, ~123, ~321 and ~400 ka highstands respectively. Estimated uplift rates deduced from the elevation of T1, T2 and T3 are of 0.07 +/- 0.05; 0.10 +/- 0.02; 0.17 +/- 0.03 mm/yr (or m/kyr). Extrapolation of the oldest uplift rate (i.e. determined on the highest dated terrace) shows that in the region of Trabzon, coastal positive vertical deformations are recorded since ~2 Ma which corresponds to the extrapolated age of the highest terrace of the sequence.
Ages of the raised terraces and shoreline deposits document that the southeastern Black Sea shore north of North Anatolian Fault has been experiencing maximal regional uplift of 0.017 +/- 0.03 mm/yr or m/ka. We propose that this local uplift owes its origin to the Pontides orogenesis: the latter being the consequence of the convergence of the African Arabian Plate with the Eurasian plate.
Comparison of Trabzon area uplift rates with other places around the Black Sea shows that the vertical reaction of the portion of coast is quite limited and that the Caucasus orogenesis seems to have had more effect on Quaternary coastal deformation than the Pontides orogenesis.
The Quaternary vertical shoreline displacements around the Black sea and vertical uplift rates in Eastern Turkey in particular are still poorly known New ESR data allow us to revise and reinterpret the Quaternary marine terrace deposits. They need further attention to refine our knowledge of the Pontides orogenesis in particular, and the Quaternary coastal deformation in general.

Keywords: Coastal uplift, Sea-level, Marine terrace, Electron Spin Resonance, Eastern Black Sea

Late Pleistocene-Holocene climate and vegetation records in Istanbul outlet area of Black Sea

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Sedimentological, stratigraphical, paleontological, palynological, physical and geochemical analyses of core HBS09 LG 01, recovered from -103 m water depth, in the Istanbul Strait outlet area of the Black Sea were carried out. Two lithostratigraphic units are identified within the sediments of the core of Upper-Pleistocene-Holocene age. The upper marine and lower lacustrine units are seperated by an unconformity with the base of the upper marine unit dated at 7,5 kyr BP. The upper unit can be distinguished with its higher clastic input (Ti, Fe, K) and lower Ca, TOC and TIC values in comparison to the lower lacustrine unit. The upper unit was deposited after the marine transgression of Mediterranean inflow that was followed by the anoxic conditions in the Black Sea. Pollen analyses from the core reveal that, the lower unit was deposited under cold and arid climatic conditions of Boreal Period, that is represented by herbs and steppes, whereas upper unit was deposited under humid and temperate climatic conditions of Atlantic Period, represented by warm - temperate tree taxa, among which *Quercus, Corylus* and *Betula* are abundant.

Keywords: Palynology; Black Sea; climate; vegetation; warm – temperate; TOC

Geochemical assessment of total heavy mineral distribution in modern beach sediments from the Gulf of Kuşadası, Western Turkey

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The sedimentary input of the Küçük Menderes River into the northern part of the Kuşadası Gulf was investigated on the modern Pamucak beaches to understand the source, transport and depositional conditions/processes of both terrigenous and marine origin. Special attention was paid to possible heavy mineral occurrences related to the rocks of the Menderes Massif from the coastal hinterland. A total of 117 surficial (uppermost 5 cm surface) sediment samples were collected in foreshore, backshore and dune sub-environments representing the entire beaches and fluvial discharge conditions. Grain size analysis was carried out using a dry sieve set whereas total heavy minerals were separetd from bulk sediment using heavy liquid bromoform (sg. 2,89). Multielement geochemical data was obtained from selected and representative bulk samples using ICP-ES method after digestion with 4-strong acids. Accuracy and precision of the analytical procedures was checked with international geological reference materials and replicates. Fine sand is the dominant grain size fraction in the sediments (36-98%) followed by medium sand (1-38%) whereas other fractions constitued minor amounts. Total heavy mineral concentrations (sg>2,85) varied between 0,54 and 14%, being mostly about 2%. Micas dominated by biotite make up larger portions of the total heavy minerals in sediments. Field observations suggest important role of wind effect to transport and deposit micas landward towards backshore and dune subenvironments. Of the elements analyzed, Cr (75-815 ppm), Ti (0,05-2,46%) and Fe (0,68-11,69%) showed relatively higher concentrations compared to the average earth's crust while other elements remain at similar lower levels. Examination under microscope suggests the presence of a wide variety of metamorphic rock fragments and minerals from the Menderes Massif which could be sources of the elements studied. A wide range of parameters, incl. grain size, beach morphology, heavy mineral content, source rocks, multielementchemistry, fluvial drainage, hydrodynamics, are interrelated to understand source to sink processes along the studied. This study was supported by the Scientific Research Projects Office of the Ankara University-BAPRO (Project: 99-05-01-02).

Keywords. Aegean Sea; beach; sediment; heavy mineral; geochemistry

Downslope mass movements and their possible relations of gas hydrate accumulations offshore Amasra and Zonguldak, central Black Sea

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The southern central Black Sea represents narrow shelf and a very steep continental slope. Recent studies show the active sedimentary processes sediment transportation from shelf to abyssal depths. Southern continental margin of the Black Sea also has extremely complex canyon systems from Bosphorus outlet to the eastern Black Sea. Study area is located in the central Black Sea Turkish continental slope and is under compressional tectonic regime of Western Pontides. Approx. 2200 km of high resolution multichannel seismic reflection, Chirp sub-bottom profiler and multibeam bathymetric data were collected offshore of Amasra and Zonguldak region from continental shelf to abyssal plain of Black Sea along the margin. We used 216 and 168 channel digital streamers in two surveys in 2010 and 2012, and a 45+45 cubic inch Generator-Injector (GI) gun fired at every 25 m. Chirp sub-bottom profiler system operates at 2,7-6,7 kHz frequency band with 3,5 kHz central frequency. A hull-mounted multibeam bathymetry system uses 50 kHz signal with 153 degrees max. swath width.
Acoustic data show that the shelf break in the study area is located at a water depth of about 100-120 m and continental slope deepens to 2200 m maximum water depths of the abyssal plain with a maximum slope of about 27 degrees. There are well developed canyon systems, channels and erosional structures along the margin especially on the continental slope and rise offshore of Amasra and Zonguldak. An unstable area in the NW consisting of several submarine slides and buried debris lobes is named Amasra mass failure zone. Different type of sliding with varying sizes including sliding in the steep slope zones, smaller–scale slides on the canyon walls, and relatively larger slides exist in the Amasra mass failure zone. Interpretations of the seismic data show that wide spread BSR reflections are terminating to primary glide surface of the large scale slide structures. We suggest that the slides in the Amasra mass failure zone is possibly triggered by excess pore pressures in shallow sediments due to the submarine fluid flow possibly produced from gas hydrate dissociation. Warmer Mediterranean water transportation during the rapid transgression period after the last glacial maximum in the Black Sea together with the rapid sedimentation possibly resulted in a destabilization of gas hydrates, which caused excess pore pressures in shallow sediments followed by sediment failures. Small-scale normal faults around these types of sedimentary structures are also observed and we suggest that these faults might be a secondary factor promoting the failures providing the suitable pathways for fluid flow as well as the suitable weak surfaces for the sliding.

Keywords: Seismic; slide; gas hydrate; BSR; Black Sea

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Canyon Systems, Submarine Channels and Possible Sediment Transportation Pathways from Sakarya Outlet to Amasra*

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The Black Sea is a back-arc basin separated by Mid-Black Sea Ridge to eastern and western basins. Both basins have extremely thick sediment depositions reaching to approx. 15 km. Recent studies have shown that there are several source-to-sink pathways especially along the continental slope.
In 2010 and 2012, an integral part of the Source-to-Sink Project has been initiated and study area located at the south central Black Sea funded by TÜBİTAK and EUROCORES, TOPO-EUROPE programme of the European Science Foundation. A total of 4400 km high resolution multichannel seismic reflection, Chirp sub-bottom profiler and multibeam bathymetric data were collected by *R/V K.Piri* Reis along the offshore areas covering from Amasra to Sakarya Outlet along the profiles from continental shelf to abyssal plain. Another multibeam bathymetric data also used collected by *R/V Poseidon* on Kozlu High in 2005. We used 216 and 168 channel digital streamers during the surveys and a 45+45 cubic inch Generator-Injector (GI) gun fired at every 25 m. A hull-mounted multibeam bathymetry system uses 50 kHz signal with 153 degrees max. swath width. During the surveys, a detailed 3 dimensional multibeam bathymetric map in an area between Sakarya and Amasra has been revealed.
Preliminary analysis of the multibeam bathymetry data shows that study area represents complex canyon systems and channels. It is observed that wide Sakarya Canyon is feeded by two different meander channels in N-S direction. Canyon walls have gentle slopes on the western side and have steeper slopes on the eastern flanks. The canyon systems located along the western area (e.g. offshore Sakarya and Ereğli) are also longer than those in the eastern area (offshore Zonguldak and Amasra). Northern boundaries of the canyon systems are also different and this border narrows from west to east. Eastern side of the study area has extremely steep continental slope approx. 30 degree within the narrow continental slope area. There is also a significant sedimentary ridge in the eastern side of the study area named as Amasra Bank. Both eastern and western sides of the study area have meandering channel systems. It is suggested that these kinds of channels are the primary sediment transportation pathways on southern side of the Black Sea. Seismic data also indicate strong sediment erosion along the canyon walls.
Seabed morphology also shows sediment waves in the deeper waters towards to north. These structures are entirely located at the continental rises of the study area and they narrows from eastern to western side of the study area. We also suggest that the sediment waves can be related to turbidity and contour current interactions.

Keywords: multibeam bathymetry; canyon; submarine channel; central Black Sea

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İçmecedere Beachrock (Bozcaada-Çanakkale-Türkiye): Results and Significance of Analytical Studies

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The Bozcaada, second biggest island in Turkey, is an interesting region in point of Late Pleistocene-Holocene geological formations. On the south coast of the island eolinites, beachrocks and rhizolithes are widely observed. These geological formations are important for understanding of the paleo-coastal environment. In this study, beachrocks occurring on both sides of the island namely İçmecedere beachrock that was not mentioned before in the literature have been investigated. Petrographic, analytic (XRD and SEM-EDX) and ^{14}C dating studies have been performed in order to clarifying the age and facies of beachrock .

The outcrops of the İçmecedere beachrock extends 20 meters parallel to the coastline and have heterometric structure with poorly sorted including block-sized and also fine clast. For geochemical analyzing and age dating samples have been taken from the three different points of beachrock which have a maximum 40 cm thickness. Calibrated radiocarbon datings from youngest beds yield to 950-750 years and 3860-3560 years from the oldest layers. Based on thin-section studies, beachrock is composed mainly of poorly sorted metamorphic rock fragments. Moreover, the cementing is weak and including cracked fossil shells among grains. SEM analyses were performed to determine the cement micromorphology among grains. The analysis, show that cementation started in intertidal zone and the grain surfaces were covered by micritic envelope. These micritic envelopes are covered by meniscus cement indicating the mixture of sea water and fresh water. Secondary cement which developed on the micritic cover states declining the sea level during the cementing. The older layers of beachrock with bridge cement were cemented during this sea-level declining stage. This period should be contemporaneous the declining of the sea-level at -2m in the Aegean Sea. According to the result of EDX analysis; element abundances in weight percent of micritic envelope and inter-grain cement range as O>C>Ca>Si>Al>Mg>Fe>Cl>Na in decreasing order. The mean value of $\%MgCO_3$ is 5.37 showing high Mg-calcite of cementing carbonate. Moreover, XRD analyses indicate the existence of dolomitic cement. According to stable isotope ($d^{18}O$ and $d^{13}C$) cementing material is ranging from 1.75 to 2.38 for ^{13}C and 1.28 to -1.81 for ^{18}O. These positive values indicate enrichment in heavy isotopes and also increasing in temperature during deposition of cementing material. This period correspond to arid stage at the end of climatic optimum on the Mediterranean (6-3 thousand years).

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Keywords: Beachrock; C-14 dating; coast; Bozcaada

Horizontal offsets on the North Anatolian fault (NAF) coupled with basin formation in the Marmara Sea

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Different accumulated offset reported for the North Anatolian transform boundary in the Marmara region (NAF) may relate to different tectonic phases. According to a recently developed chronostratigraphic model, the NAF has been operating in a steady-state mode for at least 0.5 my, including the Holocene. Several structures, each with substantial vertical component of differential deformation, exhibit steady growth through the stratigraphy of this period and possibly to much deeper and older horizons. Steady growth suggests that both pattern and rate of deformation are constant. These structures include the western (Tekirdag) and eastern (Cinarcik) basins of the Marmara Trough, which are developing on the releasing side of bends on the main (northern) branch of the transform (NAFN). The segment of the NAFN that borders the Tekirdag Basin is ~29km long and is lengthening at transform speed. This implies that the basin started forming ~1.4 my ago, if the NAFN has moved steadily at a current dextral rate of ~2 cm/y. Other tentative offset markers along the NAFN suggest similar accumulated displacements during the current basin-forming phase.

We propose that the Istanbul bend of the NAFN and the axis of the Central Marmara High (CMH) were juxtaposed at the onset of the current phase. Relief at that time may have been much lower. The CMH became gradually a ridge while translating westward and Cinarcik, Central and North Imrali basins subsided around it. In support of this hypothesis, the westernmost area of the Cinarcik Basin between the CMH and the Istanbul bend is structurally unusual in the Marmara Trough, exhibiting two phases of deformation within the "current" basin-forming regime. The trans-extensional growth structure characteristic of the asymmetric Cinarcik basin is clearly recognized on both sides of the Istanbul bend. West of the bend, however, this structure is overprinted by shortening. We interpret this "basin inversion" as the result of transition from the transtensive to the transpressive side of the Istanbul bend. No inversion is recognized west of the CMH. In our interpretation, therefore, the CMH marks the easternmost point that did not transition the bend and was not subjected to extension followed by compression. The offset between the Istanbul bend and the CMH is now ~22 km. It is significantly smaller than NAFN offsets elsewhere along the Marmara trough, which cluster at ~29 km. This shortfall may be accounted for by contributions from the Imrali fault, and its extension into the Central Basin, and from distributed deformation and clockwise rotation in the sliver between the Imrali fault and the NAFN. Besides the shortening near the Istanbul bend, the slower motion of this sliver requires NAFN-parallel extension at its western end, which may contribute to subsidence in the Central Basin.

The syn-basin offset on the NAFN in the Marmara Sea is about half of the offset recently obtained from Paleocene markers to the east. This suggests that the western NAF predates basin formation in the Marmara Sea and underwent a major reorganization, probably in the early Quaternary.

Keywords: North Anatolian Fault; Marmara Sea; Continental transform; Transform basin; Growth structures

Evidence for widespread gravitational creep and abundant gas in the Sea of Marmara transform basin from the TAMAM project

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High-resolution multi-channel seismic (MCS) data acquired during the Turkish American MArmara Multichannel project (TAMAM) in 2008 and 2010 and swath bathymetry data reveal extensive ‘wave’ fields in the sediments throughout the Marmara Sea as well as abundant shallow gas. The origin of similar ‘waves’ globally remains controversial; competing models ascribe them to sedimentary processes, tectonic shortening or downslope motion. Likewise, previous work based on older datasets in Marmara suggested that features here are folds formed by tectonic shortening or sediment waves formed by the interaction of bottom currents with seafloor topography. Determining their origin is essential to understand the tectonic and sedimentary evolution of the Marmara Sea. We use seismic and bathymetry data to demonstrate that these features are ‘creep folds’ on the tilting flanks of the Sea of Marmara.

Although ‘waves’ in the Marmara Sea exhibit some of the classical features of sedimentary waves, the following distinctive characteristics exclude a purely depositional origin: 1) parallelism between the crests of the ‘waves’ and bathymetric contours over a wide range of orientations, 2) steep flanks of the ‘waves’ (up to ~40º), and 3) increases in ‘wave’ amplitude with depth. These attributes support gravity-driven downslope creep that has been augmented by depositional processes. Creep folds have typical wavelengths of ~0.5-1 km, but MCS profiles indicate that wavelengths commonly change through time. Fold amplitudes also vary with depth, from ~20 m near the seafloor to a much as ~100-200 m at depth. Stratigraphic growth on the upslope flanks of folds indicates that they are syndepositional features that form slowly. Using our age model, which is based on a series of lowstand deltas, it appears that deformation is occurring over time periods of at least 0.5 m.y. Thus folds do not represent geologically instantaneous events, like submarine landslides previously identified in this region that are thought to be triggered by earthquakes. Structures indicative of gravitational collapse are observed in our data nearly everywhere in the basin with slopes of ~3-10°. The temporal and spatial evolution of the gravitational folds is clearly related to the evolution of slopes in the basin by vertical and lateral tectonic deformation. Fields of gravity folds, therefore, are powerful markers for reconstructing the tectonic history of basins.

We have also used the TAMAM data to map out the extent of shallow gas throughout the Marmara Sea and its relationship to faults and creep folds using two complementary approaches: 1) visual identification of attributes associated with gas (e.g., wipe-out zones, high amplitudes, polarity reversals), 2) instantaneous attribute analysis. This work demonstrates that shallow subsurface gas is particularly prevalent in sediments on the Central and Western Highs, including in regions of downslope creep, and in the North Imrali Basin. Furthermore, our initial results show abundant gas north of the Imrali Fault and along thrusts associated with the Central and Western highs. Gas is also observed near the NAF in places, but our results suggest that faults are not the dominant control on the shallow distribution of gas.

Seismo-acoustic Structure and Investigation of Shallow Gas Accumulations Along the Western Black Sea Continental Slope

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The Black Sea is a semi-isolated extensional basin surrounded by thrust belts and is considered to be a Mesozoic- Early Cenozoic marginal back-arc basin generated by the northwards subducting Tethys Ocean. The Black Sea basin comprises western and eastern Black Sea sub-basins, which are separated by a regional high, the Mid Black Sea Ridge. Recent studies in marine geology indicate potential geo-resources in the Black Sea. Methane seeps are common features around the Black Sea basin.
Investigation of gas and gas hydrate accumulations and determination of possible reservoirs in shallow marine environments have both economical and strategic importance. Today, the Black Sea is an important area in the world for hydrocarbon accumulations and seeps. In order to investigate gas and gas hydrate accumulations in the Western Black Sea continental slope, approximately 355 km of high resolution multichannel seismic data was collected in 2008. The data was processed using conventional processing steps. Anomalous zones of gas accumulations were determined on the final migrated sections using seismic attribute analysis. In a limited area, a Bottom Simulated Reflection (BSR) attributable to the gas hydrate accumulations was also observed.
Shallow gas accumulations were generally observed below the ridge structures forming anticline-type formations. The accumulations are located generally 100-200 m below the seabed, and the reflections from top of the gas reservoirs are distinguished by their distinctive negative polarity. Below these bright reflections are gassy sediments as semi-transparent dim zones. The instantaneous frequency sections show low frequency local anomalous zones, indicating a higher attenuation of seismic signal due to the gas accumulation.
Seismic stratigraphy has been correlated with İğneada-1 well information. Seismic data shows stratigraphy of the area down to Miocene times. Top Miocene reflection can be distinguished as a distinctive unconformity surface approx. 1 s below the seabed. It is an undulating surface with clear erosional surfaces at both flanks of each individual undulation indicating the existence of paleo-channels in the area. Paleo-surface maps and sediment thickness maps for top Miocene and top Pliocene times have been prepared.

Keywords: Seismic attributes, gas hydrates, shallow gas accumulations, bright-spot, post-Miocene stratigraphy.

Improving the accuracy of earthquake locations using Ocean Bottom Seismometers in the immediate vicinity of the North Anatolian Fault in the western and central parts of the Sea of Marmara

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The Marmara Sea is located between the Agean Sea and the Black Sea, along the North Anatolian strike-slip fault, which experienced a sixty year sequence of earthquakes since 1940, propagating to the west towards Istanbul. Prior to this sequence, which ended with the Izmit and Duzce earthquakes in 1999, at the eastern end of the SoM, the fault ruptured to the west in 1912 in Ganos, with an estimated moment magnitude of 7.4. Therefore, a major earthquake is expected within the Sea of Marmara seismic gap.
In order to better understand the seismicity and to reduce the threshold of detection, a network of ten OBS with four components was deployed by Ifremer with R/V Yunuz of Istanbul Technical University, in the western and central parts of the Marmara Sea to record the micro-seismicity from the immediate vicinity of the Main Marmara Fault, between april and august, 2011. The network was specifically designed to survey the segments crossing the Western High, where gas hydrates where recently found, the Central Basin and the Kumburgaz Basin. During this period more than one hundred earthquakes were detected by the CSEM (European-Mediterranean Seismological Centre) in the Sea of Marmara.
Because the basins of the Sea of Marmara are filled with more than 5 km of Plio- Quaternary soft (“slow”) sediments, it is of critical importance to take into account the velocity structure of the offshore domain, which is drastically different from the one onshore. To improve the localization of seismic events, a 3D velocity model was thus considered and implemented in the *Sytmis*® software developed by INERIS. This model is based on the tomographic data collected in 2001 using a controlled source experiment and on the numerous multichannel seismic profiles that provide information on, respectively, the deeper structures and the upper, sedimentary layers.
Preliminary results are presented. Special focus will be given on : i) the depth of the events below the Western High, where the NAF is known to intersect a gas reservoir ; ii) on the clustering of the micro-seismicity at both extremities of the Central Basin. As a perspective to future work, an attempt will be made to improve earthquake locations using the dataset from the permanent, cabled, Ocean Bottom Broad-Band Seismometers network operated by KOERI.

Keywords: seismology; Marmara Sea; ocean bottom seismometers

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PALEONTOLOGY & SEDIMENTOLOGY

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IN MEMORY OF EROL AKYOL

Geological setting and some properties of the Soma Miocene coal, Manisa-Turkey

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The Soma basin is one of the most productive lacustrine coal basins of western Anatolia-Turkey. The lower seam (kM1-2) and middle seam (kM3) are associated with a carbonate-dominated succession (Soma Formation) and the upper seam (kP1-2) occurs with siliciclastic and volcanogenic sedimentary rocks (Denis Formation) (Inci, 2002).The basin has a coal reserve of 660 Mt.
In this study, a total of 64 coal samples from 5 profiles were collected from lower, middle and upper seams, of which 3 profiles are from the lower seam. In addition, 23 rock samples were also taken from dirt bands, floor and roof rocks of the coal seams. Mineral phases in the coal samples and rock samples were determined using X-ray powder diffraction with CuKα radiation. Clay fraction minerals of the rock samples were also identified using X-ray diffraction (XRD). Micron-sized minerals of selected 20 samples were examined on the polished briquettes with SEM-EDX. Maceral analyses of all the coal samples with less than 1 mm grain size are performed on the polished briquettes.
This study indicates that clay minerals (smectite, kaolinite and illite) in claystones, calcite in clayey limestones and quartz in sandstones are more common minerals. The identifiable minerals in the coal samples with XRD are in general: quartz, clay minerals, calcite, siderite, pyrite, feldspar, dolomite, opal-CT, aragonite and gypsum. Quartz is more common in the lower and upper seams, and calcite in the middle seam.
The results of proximate analysis show that the ash yields of the Soma coals have a wide range, in which ash yields are higher in the coal samples from the upper seam in the Denis coal fıeld. Kaolinite is the abundant mineral of altered pyroclastic materials, which are identified in lower seam in the Eynez and Isıklar coal fields. In addition, alkali feldspar (sanidine?), chlorapatite and zircon have been also determined with SEM studies. These materials indicate contemporaneous volcanic inputs during peat formation. Maceral analysis shows that the lower seam includes higher huminite contents, whereas the middle and especially the upper seams are enriched in mineral matter. Mean values of random huminite reflectance measurements (%Rr) of the lower seam are found as 0.45% Rr in Eynez, 0.43 %Rr in Isiklar, and 0.38% Rr in Denis. Mean random reflectance values as well as volcanic inputs during peat formation in the lower seams are increasing from Denis to the Eynez coal fields. Mean values of %Rr of the middle seam in Isiklar and the upper seam in Denis are found as 0.46% Rr and 0.40% Rr, respectively. Mean values of random huminite reflectance of the coals indicate that coal rank can be classified as "subbituminous B" for the Eynez and Isiklar coals and "subbituminous C" for the Denis coals.

Keywords: Turkey; Soma; Miocene; coal; mineralogy; petrography; maceral

Geological setting and coal quality of the zeolite-bearing Çayırhan coal, Beypazarı-Turkey

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The Neogene Beypazarı Basin is located around 100 km northwest of Ankara in Central Anatolia. The basin is filled with mainly lacustrine and volcano-sedimentary rocks and the sequence contains economic coal resources (more than 400 million t), bituminous shale, clay and trona (Yağmurlu et al., 1988; İnci, 1991). The coal is extracted by the private Park Holding coal company applying underground mining, and used for power generation. The coal exploited from the Çayırhan coal field in the Beypazarı Basin is of Upper Miocene age and is associated with synchronous volcanic activity, which induced unusual coal characteristics such as high zeolite contents (Querol et al., 1995; Whateley et al., 1996; Querol et al., 1997). In the Çayırhan field, the pre-Neogene aged formations are unconformably overlain by the Neogene formations, from bottom to top, coal-bearing Çoraklar, trona-bearing Hırka, Karadoruk, Akpınar, Bozçayır, Acısu, Kırmızıtepe and gypsum-bearing Softa Formations. The Çoraklar Formation consists of clastic sedimentary rocks and two separate lignite seams. The lower lignite seam was deposited in the lower part of the Çoraklar Formation, whereas the thicker, economically important, upper lignite seam was deposited at the top of the formation. The upper coal seam averages 3.0 m thick, varying from 1.0 to 4.9 m (Whateley et al., 1996), and it is split by a 1 m-thick siltstone with chert nodules into the first (Tv) and the second (Tb) seams, which contain essentially different zeolites. The Tv seam contains Ca-rich zeolites (clinoptilolite / heulandite), while the Tb seam includes Na-rich zeolites (analcime). This is probably the result of variations in the chemistry of the original volcanoclastic or clastic material associated with the lignite or of variations in the chemistry of the circulating fluids (Whateley and Tuncalı, 1995 a,b). In this study, a total of 191 coal samples from the upper seam, of which 97 samples are from the Tv seam and 94 from the Tb seam, and 2 samples from the lower seam have been collected from 9 different points in the underground mines B, C and G sectors and 80 different boreholes, which are disributed in the coal basin. The mean values of the chemical analyses of the samples from the Tv seam on an air-dried basis are found as 7.45% moisture, 36.59% volatile matter, 34.21% ash yield, 3459 kcal/kg net calorific value, 4.59% total sulfur, 1.23% N, 40.28% C, 3.70% H, and 15.99% O. These analytical results for the Tb seam are as follows: 8.02% moisture, 35.50% volatile matter, 32.20% ash yield, 3639 kcal/kg net calorific value, 4.54% total sulfur, 1.33% N, 41.48% C, 3.98% H, and 16.46% O. The mean values indicate that the Tv and Tb seams have very similar chemical analysis results. In this study the chemical analysis results have been also evaluated in the lateral variations in the Çayırhan coal field.

Keywords: Turkey; Çayırhan; coal; chemical analysis; zeolite

Biostratigraphy and bio-events of the Abderaz Formation at Padeha village section, east of Kopeh-Dagh basin (NE Iran) based on planktonic foraminifera, inoceramids and echinoides

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In order to study the fossil contents of the Abderaz Formation for biostratigraphical purposes the 600 meters thick section was sampled at Padeha village section. The sequence is mainly made up of grey shales and marls with four units of chalky limestone in studied section. The lower contact of the formation with Aitamir Formation is conforming while the upper contact with Abtalkh Formation is continuous. Fifty one species belonging to 14 genera were identified and six biozones were differentiated. These are: 1- *Whiteinella archaeocretacea* (Bolli) partial range zone 2- *Helvetoglobotruncana helvetica* (Sigal) total range Zone, 3- *Marginotruncana schneegansi* (Dalbiez) *Interval Range Zone 4- Dicarinella concavata* (Sigal) interval Range Zone, 5- *Contusotruncana fornicata (Plummer)* and 6-*Globotruncana arca* Cushman Interval Range *Zone*. Based on, these an age of Uppermost Cenomanian-Upper Santonian is quoted to the formation (The planktonic foraminifera indicare a Latest Cenomanian-Late Santonian age for the formation). Some inoceramids such as *Cremnoceramus walterdorfensis walterdorfensis* and *Cremnoceramus deformis erectus* (Meek) have been detected respectively at Upper Turonian and the base of the Coniacian. The echinoides like *Echinocorys* gr.*scutata* and *Cordiceramus* sp. have been found at Coniacian-Santonian boundary. Finally according to last occurrence of the Marginotruncanids was showed the Santonian-Campanian boundary at early part of the Abtalkh Formation.

Keywords: Abderaz Formation; Biostratigraphy; Padeha village section; Planktonic foraminifera; Bio-events; Biozone

Palynofacies analysis of Seam I in the Marathousa Lignite Mine, Megalopolis Basin (Southern Greece)

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The lignite deposit at the Marathousa Mine, Megalopolis Basin (Peloponnese, Southern Greece) is divided into three seams (I-III). Lignite and inorganic samples were collected from Seam I (lower) at Marathousa Mine aiming to reconstruct the palaeoenvironmental conditions and to compare with results from previous studies.
The samples were analysed using palynofacies analysis (transmitted white light and fluorescence mode). The three main groups of kerogen are phytoclast, amorphous organic matter (AOM) and palynomorph. The phytoclast group is the major group and generally consists of the non-opaque, non-biostructured phytoclasts. Also pseudoamorphous phytoclast is common. The AOM group is predominantly of terrestrial origin (macrophyte tissue/amorphous humic particles). Pollen grains are dominant in the palynomorph group. Three palynofacies associations (A-C) were determined according to the composition, the distribution and the abundance of kerogen groups. The palynofacies association A corresponds to the predominance of the phytoclast group (76%, on average), that comprises mainly non-opaque phytoclast and pseudoamorphous components. The palynofacies association B is dominated by the phtyoclast group, which is associated with moderate content in amorphous components. In the palynofacies association C, the AOM group predominates (up to 61%) with secondary occurrence of phytoclast group (34%, on average). All these associations are related to the proximal anoxic (suboxic-anoxic or dysoxic-anoxic) shallow conditions. The palynofacies association B deposited under relatively shallower conditions than the other associations, because of the high proportion and variety of phytoclast group. The association C corresponds to relatively deeper proximal conditions than the others due to higher fluorescence intensity and abundance of AOM. This kind of AOM is related to anoxic and reducing environment and/or higher water depth.
The palynofacies analyses indicate that Seam I at Marathousa lignite mine deposited under shallow anoxic conditions. But mire and/or fresh lake/pond was never dried due to low proportion of opaque phytoclast, observation also supported from the very low intertinite percentage (≤1). However, the vertical distribution of kerogen groups along the studied profile indicates strong fluctuations and sharp changes, which reflect sudden water-level changes. The transition from oxic to suboxic-anoxic and dysoxic-anoxic conditions is considered to be responsible for the enrichment in sulphur at the bottom of each lignite layer. Previous palynological studies indicated that during peat accumulation in the basin the vegetation was dominated by herbaceous plants. This is suggested by the relatively high proportion of non-biostructured phytoclasts against biostructured phytoclasts and is probably related to the palaeovegetation and/or poor preservation conditions being also consistent with the very low tissue preservation index calculated from the maceral composition. On the other hand, pseudoamorphous phytoclasts indicate elevated bacterial activity being related to an alkaline environment. This environment is favourable for the degradation of plant tissues. The phytoclast-size variability in these associations is related to fluvial transport, also supported by the very high clastic mineral content in the same samples. The results of this study are satisfactorily matched with those from previous studies suggesting that palynofacies analysis is a useful tool for palaeoenvironmental reconstruction when combined with other methods (coal petrography, mineralogical analysis, geochemistry etc.).

Key words: palynofacies, kerogen, coal petrography, lignite, palaeoenvironment

Teaching geology in the field: natural field laboratories of Anatolia: Taşkesti field station, Bolu region, Turkey

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Exposure to geologic relationships in field settings is essential to educate a wellrounded geologist. Mastering the details of important field methods such as section measuring, structural data collection, and geologic mapping on topographic maps leads to informed geologic interpretations. This can only be achieved in a field camp setting where a wide range of well - exposed outcrops is contained within an easily accessible, logistically feasible area.
The Taşkesti field camp in Turkey offered by Black Hills Natural Sciences Field Station at South Dakota School of Mines satisfies these conditions. The area is an ideal natural laboratory due to the diversity of terranes and the neotectonic signature of northwest Anatolia. The region exposes young geologists to the field principles of the numerous disciplines within the science of geology. The students are exposed to varied sedimentary, metamorphic, and igneous terranes, geomorphic features, and structures as well as the progressive development of Turkey's complex tectonic setting. Potential field studies include mapping of Jurassic and Cretaceous stratigraphy of the Sakarya microcontinent, Paleocene granite in the Sivrihisar magmatic belt, and Tertiary stratigraphy and structure of the Haymana basin. The Taşkesti field camp area is further invaluable for students' exposure to actively deforming systems and the seismic hazards associated with the North Anatolian Fault Zone, a major plate boundary separating the Anatolian and Eurasian plates. Students also have the opportunity to gain a greater understanding of economic geology of northwest Anatolia by applying their field observations and interpretations to active and mining practices in the region. Combining the proximity of variable terranes with a complex geologic history makes the region surrounding Taşkesti, Bolu unique in allowing for a logistically simple and cost effective way to teach the next generation of geologists the vital principles of field geology.

Keywords: Bolu region; Turkey; Taskesti field station

Mississippian Conodonts from Taurides, Turkey

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Conodonts are important biostratigraphic tools for the delineation and calibration of the geochronological boundaries within the Carboniferous time interval. Some conodont species are excellent index microfossils and used generally as time-markers for the Lower Carboniferous (Mississippian). The Lower Carboniferous standard zonations could be generally applicable to open marine offshore environment. It is difficult to use these zonations in the shelf and shallow marine deposits since shallow marine conodonts are different from the open marine ones and they are less diverse and low in abundance. Therefore, different local zones have been suggested and these are correlated with the standard zonations. Eleven stratigraphic sections have been measured to determine the Mississippian conodont zonations in Taurides. Several beds within the measured sections are barren of conodonts, while others contain all important species including the markers of the stage boundaries in the Mississippian. Of all the studied sections, conodont elements have been recovered from AAO, BSe and HB sections in Central Taurides and the AS section cropping out in Eastern Taurides. Based on the bioevents (first occurrences / last occurrences) of biostratigraphically significant species within these sections, the following zones have been established across the Lower Carboniferous successions in Taurides (Turkey): *Polygnathus inornatus* Zone (Hastarian-Lower Tournaisian); *Gnathodus cuneiformis* Zone (Ivorian-Upper Tournaisian); *Polygnathus mehli mehli* Zone (Ivorian-Upper Tournaisian); *Gnathodus girtyi girtyi* Zone (Brigantian-Upper Visean); *Gnathodus girtyi simplex* Zone (Pendelian-Lower Serpukhovian); *Rhachistognathus muricatus* Zone (Zapaltyubinsky-Upper Serpukhovian) and *Declinognathodus inaequalis* - *Declinognathodus noduliferus* Zone (Bogdanovsky-Lower Bashkirian). Based on the recovered conodont assemblages, Visean - Serpukhovian boundary has been recognized by the first occurrence of *Gnathodus girtyi simplex* and the Mid-Carboniferous boundary is delineated by the first occurrence of *Declinognathodus inaequalis,* which is an index taxon for the basal part of the Bashkirian.

Keywords: Taurides, conodonts, mid-Carboniferous boundary, Visean-Serpukhovian boundary

Planktonic foraminifera and calcareous nannoplankton content of the Maastrichtian pelagic deposits of the Kapullu Formation of the Malatya Basin (Yeşilyurt area, Eastern Anatolia)

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The uppermost Cretaceous in southern part of the Malatya Basin (Yeşilyurt area, Eastern Anatolia) is represented by pelagic deposits, which are known as Kapullu Formation. The formation conformably rests over rudist-bearing İnekpınarı Formation and is unconformably overlain by conglomerates of Middle-Late Eocene Zorban Formation. Planktonic foraminifera and calcareous nannoplankton contents of the pelagic deposits of the Kapullu Formation were documented by 454 samples collected through three measured stratigraphic sections.

Thin shale layers-bearing dark grey, well-bedded bioclastic limestones of the İnekpınarı Formation gradually underlie the Kapullu Formation. Bioclastic limestones are dominated by rudstones with abundant reworked shallow-water lithobioclast, which are embedded in planktonic foraminifera-bearing micritic matrix. Besides, occurrence of planktonic foraminifers within the shale interlayers indicates that the uppermost part of the İnekpınarı Formation was accumulated in a 'deep' marine environment.

The more than 100-m-thick Kapullu Formation is mainly made up of abundant planktonic foraminifera and calcareous nannoplankton-bearing cream-beige claystone/shale and marl/clayey limestone alternation. Relatively hard marl and clayey limestone layers are dominated by planktonic foraminifera and calcisphere-bearing wackestones and carbonate mudstones. Claystones and shales are soft lithologies and yielded abundant isolated planktonic foraminifers and calcareous nannoplanktons. These pelagic layers indicate an autochthonous deposition. The succession includes calcarenite beds dominated by rudstones-floatstones in several stratigraphic levels. These layers are represented by abundance of shallow-water lithobioclasts embedded within the planktonic foraminifera and calcisphere-bearing micritic matrix (allochthonous deposits). The succession of alternation of claystone/shale and marl/clayey limestone includes sandstone interlayers, levels of slumped beds and conglomerates as well.

Studies on thin sections of hard lithologies and washed residues of soft lithologies have yielded divers planktonik foraminiferal assemblages. Presence of *Contusotruncana* cf. *contusa* (Cushman) and *Globotruncanita conica* (White) within the planktonic foraminifera assemblages suggests a late Maastrichtian age. Occurrence of *Abathomphalus mayaroensis* (Bolli) in stratigraphically higher levels indicates latest Maastrichtian. Records of *Cribrosphaerella daniae* Perch-Nielsen, *Lithraphidites quadratus* Bramlette and Martini and *Microrhabdulus undosus* Perch-Nielsen within the calcareous nannoplankton assemblages from the three measured sections suggest a late Maastrichtian age. Apart from the microfossils, rare inoceramids, ammonites and trace fossils were also observed through the successions.

The abundance of divers, large, thick-walled and complex planktonic foraminifera morphotypes (K-selection) and calcareous nannoplanktons indicate that the Kapullu Formation was deposited in a basinal conditions.

The study was financially supported by a TÜBİTAK Grant no. 109Y035.

Keywords: planktonic foraminifera; calcareous nannoplankton; Maastrichtian; Malatya Basin; Eastern Anatolia

Geological setting and sedimentological characteristics of the coal-bearing Danişmen Formation of Oligo-Miocene age at the north of Malkara, Tekirdağ-Turkey

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The geological setting and sedimentological characteristics of the coal-bearing Oligo-Miocene deposits at the north of Malkara (Tekirdağ) in the Thrace Basin and some coal properties have been evaluated. In this basin the Danişmen Formation of Oligo-Miocene age consists of numerous coal seams especially in the central and southern part of the basin. The coal seams at the north of Malkara, which were developed within deltaic deposits, have been extensively exploited both by underground and mainly open-cast mining methods.

During field studies, the geological setting and sedimentological properties of the Danişmen Formation have been evaluated for the depositional environments, especially for coal depositions. In addition, the coal and coal-bearing rock samples were also taken from five coal mines for characterization of coal seams within the Danişmen Formation.

Lithofacies and facies of the Danişmen Formation at the north of Malkara indicated that they were deposited in a series of elongate, fluvial-dominated deltas in a highstand succession. Facies that define the depositional framework in this deltaic succession include channel-mouth bar, distributary channel, crevasse splay, interdistributary bay, and delta plain.

The coal seams in the Danişmen Formation were deposited in ponds and swamps of a delta plain and in a lagoon. The X-ray powder diffraction studies of selected 11 coal samples indicated that the samples include more organic matter and less minerals such as clay minerals, quartz, pyrite, calcite. Coal petrographical analyses of these samples indicate that huminite (vitrinite) is the primary constituent of the coal and liptinite and inertinite are minor. The random reflectance values (%Rr, oil) of ulminite were measured in all the samples for the determinaton of coal rank, and the average value of 0.37% Rr oil of ulminite indicates that the coal rank is of lignite stage.

Key Words: Thrace Basin, Deltaic facies, coal-bearing sediments, coal petrography, coal rank.

Triassic to Jurassic foraminiferal content of the Homa-Akdağ (Sandıklı, Afyonkarahisar) sedimentary sequence

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Foraminiferal content of the Homa-Akdag (Sandıklı-Afyonkarahisar) sedimantary sequence consisting of shallow marine to ramp limestones with sandstone and limy mudstone intercalations, allow us to investigate and review the end-Rhaetian mass extinction resulting in the disappearance of numerous foraminiferal groups or genus.
In the Homa-Akdag sequence, although absence of the Triassic-Jurassic transition beds, a Lower to Middle Jurassic succestion is well observed. The Lower to Middle Jurassic sequence is represented by a Liassic to Dogger foraminiferal assamblages including some Triassic to Jurassic genera of *Glomospirella*, *Reophax*, *Trochammina*, “*Textularia*”, *Duotaxis*, *Gaudryinopsis* and *Gaudryina* belonging to Textulariina, *Endotriada* and *Endotriadella* from Fusulinina, *Ophthalmidium* belonging to Miliolina, and *Trocholina* from Involutinina. On the other hand the genus *Meandrovoluta* belonging to Meandrospirinae from Miliolina is found both the Lower and Middle Jurassic part of the section and has an evolutionary afinity with Triassic Meandrospirids.
Textularid forms are represented by *Glomospirella* sp., *Reophax* spp, *Trochammina* sp, “*Textularia*” sp., *Duotaxis metula*, *Gaudryinopsis* sp. and *Gaudryina* sp. that are found from Liassic to Dogger. Fusulinid foraminifer association includes *Endotriada* sp., *Endotriadella* spp. and *Endotriadella ifranensis* existing along the Liassic. Miliolinid foraminifer association contains *Meandrovoluta asiagoensis* observed from the Liassic to Bajotian and *Ophthalmidium* spp. Involutinids are represented only by *Trocholina* sp. found both in the Liassic and Dogger.

Keywords: Triassic–Jurassic boundary; Triassic-Jurassic foraminifera; evolution; mass extinction

Study of climate change in Ardebil province, northwest Iran, and its effects on regional drought and environmental pollution

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Regional climate change affects precipitation, evaporation, transpiration, soil moisture and wind speed in time and place. For this reason it is so important to formulate optimal policies and adaptation for climate change for future studies. Estimate or predict regional/smaller-scale climate variables (in point-scale such as station studies) would be possible if the output of numerical models of the atmospheric general circulation should be downscaling. Dynamical and statistical methods have been used at the station scale. Ardebil Province where is located in one of mountainous areas in northwest Iran. Generally it can be seen humid and cold climate in this region but, in recent years, climate change has caused the region to the Mediterranean and dry climate conditions change.

In this paper, downscaling statistical likelihood and LARS-WG model was used for climate change in Ardebil province. For this study, two climatic variables (temperature and precipitation) were used and climate change over a period of 10 years zoning was done in the area range. Statistical results show that temperature increase and precipitation decrease up to 38%, during the past 10 years. Regional climate change to Mediterranean and semi-arid climate and drought as a natural phenomenon is seem repetitive climate in this region. This phenomenon has created a problem for agriculture areas and has caused considerable environmental pollution.

Keywords: climate change; LARS-WG model; Ardebil province; temperature and precipitation zoning.

Integrated biostratigraphy of Upper Cretaceous Abderaz Formation at Padeha village section, East of Kopeh-Dagh basin (NE Iran)

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Based on planktic foraminifera, inoceramids and echinoids, we present a detailed biostratigrafic analysis of the Abderaz Formation at the 600 meters-thick Padeha village section, NE Iran. The sequence consists mainly of grey shales and marls with four units of chalky limestones intercalated. The lower contact of the Abderaz Fm. with the Aitamir Formation is conforming, while the upper contact with Abtalkh Fm. is continuous. Fifty-four species of planktic foraminifera belonging to 15 genera were identified, and six biozones were recognized: 1- *Whiteinella archaeocretacea* (Bolli) Partial Range Zone 2- *Helvetoglobotruncana helvetica* (Sigal) Total Range Zone, 3- *Marginotruncana schneegansi* (Dalbiez) Interval Range Zone *4-Dicarinella concavata* (Brotzen) Interval Range Zone, and 5- *Dicarinella asymetrica* (Sigal) Total Range Zone. Based on these data, the age of the Abderaz Fm is earliest Turonian to earliest Campanian. Inoceramids *Cremnoceramus walterdorfensis walterdorfensis* (Ander) and *Cremnoceramus deformis deformis* (Meek) have been identified in the upper Turonian and in the basal part of the lower-middle Coniacian respectively, while *Echinocorys* gr. *scutata* and *Cordiceramus* sp near the Coniacian/Santonian boundary.

Keywords: Abderaz Formation, Biostratigraphy, Padeha village section, Planktonic foraminifera, Bio-events

Planktonic foraminifera of pelagic deposits of the uppermost Cretaceous volcano-sedimentary successions in İnler Yaylası area (Şebinkarahisar, Eastern Pontides)

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The uppermost Cretaceous volcano-sedimentary successions cropping out in İnler Yaylası area and surroundings in 30 km northwest to Şebinkarahisar city (Eastern Black Sea Region) include thin pelagic limestone interlayers. Planktonic foraminifera content, age and depositional environment of the limestones are documented in this study.

The volcano-sedimentary rocks corresponding to the southern part of the Eastern Pontides, are of typical island arc-type successions and comprise a hydrothermally altered lower unit and an unconformably overlying upper unit. The lower unit is mainly made up of various volcanic rocks showing lateral and vertical transitions with each other. A 15-m-thick, red to grey coloured planktonic foraminifera-bearing pelagic limestones are observed within these volcanic rocks. The limestones including thin tuffite and shale interlayers, comprise dark red coloured, thick-bedded clayey limestone at the base, which pass into red, reddish grey to grey coloured well-bedded limestones to the top.

The limestones are represented by planktonic foraminifera-bearing wackestones and carbonate mudstones, which were examined in thin sections of 38 samples collected through the succession. A divers planktonic foraminiferal assocciations were observed within the limestones. The lower part of the sequence yields abundant planktonic foraminifers. Occurrences of *Abathomphalus mayaroensis* (Bolli) within the planktonic foraminiferal assemblages including *Contusotruncana fornicata* (Plummer), *Contusotruncana patelliformis* (Gandolfi), *Contusotruncana walfischensis* (Todd), *Gansserina gansseri* (Bolli), *Globotruncana arca* (Cushman), *Globotruncana bulloides* Vogler, *Globotruncana esnehensis* Nakkady, *Globotruncana falsostuarti* Sigal, *Globotruncana hilli* Pessagno, *Globotruncana linneiana* (d'Orbigny), *Globotruncana mariei* Banner & Blow, *Globotruncana orientalis* El-Naggar, *Globotruncana ventricosa* White, *Globotruncanella havanensis* (Voorwijk), *Globotruncanita angulata* (Tilev), *Globotruncanita conica* (White), *Globotruncanita stuarti* (de Lapparent), *Globotruncanita stuartiformis* (Dalbiez), *Radotruncana subspinosa* (Pessagno), *Rugoglobigerina hexacamerata* Broennimann, *Rugoglobigerina pennyi* Broennimann and *Rugoglobigerina rugosa* (Plummer) indicate that the whole limestone package was deposited during the latest Maastrichtian. The divers assemblages suggest a deposition in basinal conditions as well.

The first detailed planktonic foraminifera based study reveals the age and depositional environment of the pelagic deposits and accompanying volcanic rocks of the İnler Yaylası area in the Eastern Pontides.

This study was financially supported by a TÜBİTAK Grant no. 106Y144.

Keywords: planktonic foraminifera; Maastrichtian; volcano-sedimentary succession; İnler Yaylası; Eastern Pontides

Stratigraphy, Sedimentology and Paleogeographical evolution of the Lice Formation, (Siirt, SE Turkey)

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The study area includes the region between Baykan, Kurtalan and Şirvan (Siirt) which is located in the Bitlis-Zagros suture zone in Southeast Turkey. The aim of the study is to clarify the stratigraphy, sedimentology and palaeogeographical evolution of the Lice Formation.
The Lice Formation includes the Yapılar Member in its basal part which consist of claret-red colored, medium-thick layered sandstone, interlayered with gravel and cross-bedding sandstone. This sandstone unit is overlaid by a pink colored mudstone unit which in turn evolve to sandstones, conglomerates and carbonate-cemented gravel deposits.
The Yapılar Member is overlaid by the Sulha Member which consists of a green-claret colored mudstone unit containing gypsum and thin-layered sandstone beds with cross-bedding structures.
As a whole, the Lice Formation was deposited in a supra-tidal, sabkha environment during the Lower-Middle Miocene according to paleontological and palynogical data.

Keywords: Siirt, Lice Formation, supra-tidal, sabkha

Paleoclimate and mangrove forests in Turkey from the Middle Eocene to Late Miocene

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A lot of studies of the palaeoclimatic changes have been done in the Turkey recently. This changing and palaeogeography are effected on the vegetation. Especially, taxa of the mangrove and back-mangrove forests in Europe and America widespread in the coastal environment and under the humid and hot climatic conditions. In Turkey, taxa of these forests are defined in the Middle-?Late Eocene, Oligocene and Middle Miocene.

In the Middle-?Late Eocene, as it has been in Europe period the tropical climatic conditions are also is represented by the highest Coexistence Approach (CA) values (Mean annual temperature (MAT) 16.5-25°C, the mean annual coldest month (CMT) 9.6-13.1°C, the mean annual warmest month (WMT) 22.2-24.8°C and the mean annual precipitation (MAP) 1003-1520mm) in Turkey and this period is named as the Middle Eocene Climatic Optimum Period. This climatic condition have influence on development of mangrove marsh in some regions during the Middle-?Late Eocene time.

Temperature values decrease (The MAT values 17.2-20.8°C, CMT values 7.7-13.3°C, WMT values 26.5-27.9°C and MAP values 1217-1520mm) from the Middle-?Late Eocene to Early Oligocene (Rupelian) in Turkey as temperature values of Europe. Throughout the Oligocene, temperature values palynoflora of Turkey resemble with each other, although temperature have small changes in these regions related to the palaeotopography. According to the palynofloras with mangrove elements, warm climatic conditions during Oligocene had influence on the flora.

In the Early Miocene (Aquitanian), changing of palaeoclimate have not observed based on the temperature values of palynofloras and temperature values resemble to values of Oligocene. The Middle Miocene Climatic Optimum Period which causes the forming of warm subtropical climate defined in the late Early Miocene-early Middle Miocene is determined to be effecting lost of coal basins in Turkey. The temperature values indicate the differences between Turkey and Europe in this warm period. This temperature difference could be related to palaeogeography. Palaeovegetation of the late Early Miocene-early Middle Miocene time interval represented thermophilous species and also presence of the mangrove flora with *Avicennia* in the Milas-Ören region is determinated. Palaeoclimatic parameters are the MAT values 15.7-18.8°C, CMT values 9.6-13.1°C, WMT values 24.7-27.7°C and MAP 1122-1520mm of this time interval.

Throughout the Burdigalian-Serravallian time interval, palaeoclimate observes cooling and also this cooling starts in the Langhian time especially in the western Anatolia. The palaeoclimate changes from the subtropical to temperate during this time interval in Turkey (averages of the CMT are between 3 and 9°C). Climatic change that began in the Langhian time could be related to the expansion of terrestrial conditions in Turkey. Ongoing this cooling in the Serravallian time could be relates to continuing the extension of terrestrial conditions in Turkey and cooling period in the late Middle Miocene. Grassland species begin to play a role in palaeovegetation of Serravallian time and arctotertiary species are abundantly recorded in palynoflora of the time.

Palaeoclimate in the early and middle Tortonian (early Late Miocene) is colder than Serravallian and grassland species are abundantly observed in the palynoflora of early and middle Tortonian.

Keywords: palaeoclimate; paleovegetation, mangrove; Eocene; Oligocene; Miocene; Turkey

Sedimentological and petrographical characteristics of the coal bearing Oligocene and Miocene units in Gelibolu Peninsula, Çanakkale, NW Turkey.

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The aim of this study is to determine sedimentological and organic petrographical features of the coal bearing Oligocene and Miocene units exposed in the Gelibolu Peninsula in NW Turkey. Oligocene to Miocene marine and terrestrial sediments that bear coal levels are represented by two formations; Late Oligocene Osmancık Formation and Miocene Gazhanedere Formation. Depositional characteristic, lithological content and sedimentary structures of Osmancık Formation indicate delta front and delta plain environments and Gazhanedere Formation indicate fluvial to lacustrine environments. Coal quality investigations along with proximate analyses (moisture content, volatile matter, fixed carbon and ash) were performed on five samples. Calorific values of coals were between 2351-7387 kcal/kg and 2749-8808 kcal/kg from as-received and dry-ash-free basis, respectively. Coal petrographic analysis was performed on ten coal samples from Osmancık and Gazhanedere Formations. Petrographic analysis results of all coal samples tend to have similar coal petrographic properties. Huminite (50-78%) is the most abundant macerals group and most abundant maceral is gelinite in all coal samples. Besides, small amounts of liptinite (mostly less than %9) and inertinite (mostly less than %8) are observed within the coals. The mineral matter of coal samples is made of clay minerals, pyrite (mainly framboidal pyrite), calcite and quartz. The reflectance measurements (0,502-0,564%) indicate that the rank of coals is sub bituminous. Coal maceral was used to determining coal depositional environment. Syngenetic sulfide precipitation and high bacterial activity (only from framboidal and euhedral pyrite) inferred from low preservation of tissue structures indicate relatively high alkaline conditions of peat-forming environment.

Keywords: Sedimentology, coal-petrography, Turkey.

The Geological Study and the Formation Process of Neor Lake in Ardebil, Northwest of Iran

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The Neor Lake is located in 48 km of south east of Ardebil, North West Iran. The lake with 2480 m height is one of the most elevated lakes in The Iranian Plateau which has been emerged in a hole surrounded by the Baghroudagh Mountains. Its area is 2km^2, which is integrated in the cold seasons and in warm season has been seen in the form of 2 north and south large and small lakes. Activity of east and West fault lines of the Neor Lake influenced by Pasadenan compressional Orogenic phase in Pleistocene - Quaternary time, along with pressure from glacial fragments found in the zone caused to emerge Neor Lake Graben in the porphyry andesite rocks. Following this event, ice melting on the Groben and increased rainfall in the glacial age filled the hole and the Neor Lake has been emerged. Fans of eastern and southeastern margins of the lake, are including lake morphological phenomena which caused by destruction of andesite rocks and sedimentary deposits affected by the process of erosion in the lake feeding springs drainage systems and their accumulation along the lake margin have been created.

Keywords: Neor Lake; fault; glacier; Alluvial fan; Iran.

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NEW TRENDS AND APLICATIONS IN GEO-ENGINEERING

Conveners:
Reşat Ulusay and Paul Marinos

A new approach on the use of some soft computing techniques for landslide susceptibility mapping by geographical information systems

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In landslide literature, several applications of soft computing methods such as artificial neural networks (ANN), fuzzy inference systems, and decision trees for landslide susceptibility mapping can be found. In many of these studies, the effectiveness and validation of the models used are also discussed. To carry out analyses, more than one software, for example one statistical package and one geographical information systems software (GIS), are generally used together. In this study, two different artificial neural networks techniques were applied for obtaining landslide susceptibility mapping only by unique GIS software. For this purpose, Multi Layer Perceptron (MLP) back propagation neural network and Fuzzy Adaptive Resonance Theory (ARTMAP) neural network approaches were applied to the study area. The Fuzzy ARTMAP technique was firstly used in this study for the purpose of landslide susceptibility mapping. The study area was selected from Kürtün (Gümüşhane, North Turkey) district which is one of the most landslide prone areas in Turkey. Initially, eight landslide conditioning parameters such as lithology, altitude, slope gradient, slope aspect, distance to structural lineaments, distance to drainage lines, stream power index (SPI), and topographical wetness index (TWI) for the study area were produced in GIS media. Then, these parameters were analyzed by MLP and Fuzzy ARTMAP soft computing classifiers of the IDRISI Taiga GIS and remote sensing software. To accomplish the analyses, two main input groups are needed. These are conditioning parameters and training areas. For training areas, initially, landslide inventory map which was obtained by both field studies and topographical analyses was compared with lithological unit classes. With the help of these comparisons, frequency ratio (FR) values of landslide occurrence in the study area were determined. Using the FR values, five landslide susceptibility classes were differentiated from the lowest FR to highest FR values. After this differentiation, the training areas representing the landslide susceptibility classes were determined by using FR values of the lithology classes. By following this step, both landslide susceptibility conditioning parameters and training areas were used together in MLP and Fuzzy ARTMAP soft computing classifiers, and two landslide susceptibility index maps were finally obtained. In the final step, the maps obtained were validated by landslide occurrence areas. By validation of the landslide susceptibility maps produced, it was noticed that using by the methods proposed in this study to produce landslide susceptibility map with high accuracy is possible. Also, this approach proposed shows that only unique GIS software is sufficient when ANN methods are applied for landslide susceptibility mapping rather than using unique software.

Keywords: landslide susceptibility map; soft computing techniques; frequency ratio; geographical information systems

Empirical relationships between Cerchar Abrasiveness Index and physico-mechanical properties of granitic rocks

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In recent years, the rapid developments in mining operations and tunnel construction caused a rapidincrease in the number of excavation machines. In order to achieve the expected benefits of mechanical excavation machines, these machines should be selected in accordance with characteristics of rocks. Therefore, before the selection and the implementation of excavating machines, petrographic characteristics, abrasiveness and physico-mechanical properties of the rocks should be determined. It's known that, physico-mechanical properties of granitic rocks are generally better than those of many rock types although they cause some difficulties in excavation and increase the cutter costs.The aim of this study is to determine empirical relationships between Cerchar abrasiveness index and physical-mechanical properties of different granitic rocks using regression method. In the study, some laboratory experiments were conducted on samples collected from granite quarries from different parts of Turkey, particularly from the Marmara Region. In the first stage of the study, geological, petrographical, mineralogical, chemical, mechanical and surficial (roughness, waviness) characteristics of the collected granitic rocks were determined. Then empirical relationships between these properties and Cerchar Abrasiveness Index (CAI) were also determined using method of regression analysis. The results suggested that quartz content, grain size, surface roughness and waviness of the granitic rocks cause an increase in CAI. In addition, the uniaxial compressive strength, point load strength index and indirect tensile strength of the studied granitic rocks increase as CAI increases. On the contrary, Bohme abrasion resistance increases while CAI decreases.

Keywords: Granitic rocks, cerchar abrasiveness index, surficial characteristics, unaixial compressive strength, indirect tensile strength

Duplication of the Aokas tunnel: Geologic and geotechnical characterization of the crossed massive.The structure stability

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Underground work's constructions and design techniques depend closely of the geological environment. The properties of the massive rock influence directly on the various steps of their realization from where a geological and geotechnical studies become an absolute necessity to characterize the end of the massive rock and to control the imposed constraints. At the end we can conclude that the present work aims to define the geological and geotechnical conditions of the drilled massive, it consists mainly to determine the nature and the structure of the rock massive to cross; in addition, to determine the massive stability and the means of retaining. The route of the tunnel Aokas (Béjaïa) cross a massive and fractured limestone, where the karstification phenomenon is well developed and the best example being "fairy caves" contiguous on the old tunnel road in the NR 09. The two tunnel heads are located at the foot of two towering cliffs. All these characteristics make the tunnel in precarious potential stability. The detailed geological study allowed to determinate that the tunnel crosses through a karstified dolomitic limestone of the Babor's chain of the lower Jurassic age and a geotechnical study allowed a characterization of this massive regarding fracturing, mechanical and physical characteristics and lead finally to a geomechanical classification. The application of RMR and Q rock mass classification schemes shows that geological and geotechnical characteristics of the massive rock varies along the route and revealed also a succession of zones classified as IV (worst) and III (middle) category in witch the authors mean that these classes represent RMR system chosen for the tunnel. Based on the both classifications' schemes, support systems adopted were as follows: In category IV: A layer of welded mesh, lightweight metal hangers spaced by 1m, a layer of projected concrete thick of 100 mm, anchor bolts with a length of 4m and a mesh of 1m x 1,5m. Category III: a layer of projected concrete with a thickness of 5 cm, anchor bolts with a length of 4m and a mesh of 1m x1, 5m. The stability of the tunnel is ensured by a strong support system and when we compare this heavy support (metal hangers, anchor bolts and projected concrete) to with the existing tunnel, which is generally stable, and has not any retaining, the question is if its size is not excessive?. However, its lower depth, the importance of rock's fracturing, the significant seismicity of the region and the high traffic on the NR 09, offset the construction precautions which were taken. So the main idea is that there is a tunnel which exists without retaining just nearby the new one, and to ensure its stability a strengthened retaining system was realised.

Keywords: Tunnels; geomechanics classification; karstification; stability; support systems, limestone

Investigation of dynamic ground response in the southern coast of İzmir Bay, Turkey

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The southern coastline of İzmir Bay is a densely populated area and a commercial center in the city of İzmir, Turkey. The study area is located on soft / loose alluvial deposits at the coastline. The upcoming event of EXPO 2020 is planned to be organized in the west end of the area. For these reasons, this study is focused on this specific area. The geological and geotechnical conditions of the coastline were examined, firstly. Index and engineering properties of the soil layers were obtained from the reports of geological and geotechnical investigations. The soil classification based on SPT-N data according to NEHRP provisions as well as the variation of the average shear wave velocities in the upper 30 m were determined along the coastline. Dynamic behaviour of soils under an earthquake excitation is a major concern for the area. Dynamic site response analyses were carried out based on field and laboratory tests and earthquake time histories of some moderate scale earthquakes named as 1977 İzmir (M=5.3), 2003 Urla (M=5.6) and 2005 Uzunkuyu-Urla (M=5.9), which occurred nearby İzmir. The behaviour of the area during a probable moderate-to-strong earthquake was investigated through one-dimensional dynamic site response analyses using equivalent linear concept. Besides, liquefaction potential of the study area was evaluated using SPT-N data with the help of peak ground acceleration values obtained from dynamic site response analyses. Estimation of spectral amplification was performed based on shear wave velocity in the upper 30 m. The results were compiled together in the geotechnical earthquake engineering perspective and it is concluded that, the densely populated coastline may be vulnerable in the occurrence of a probable moderate-to-strong earthquake. It was determined in one-dimensional dynamic site response analyses that peak ground acceleration values for the 1977 İzmir Earthquake (M=5.3) were estimated between 0.30-0.35 g at Balçova-İnciraltı district. Peak ground acceleration values of the 2003 Urla (M=5.6) and the 2005 Uzunkuyu-Urla (M=5.9) Earthquakes were found as 0.10-0.15g due to the distance effect. On the contrary, the amplification effect was more pronounced for long distance earthquakes than close distance earthquakes. The spectral amplification factors were determined as high as 3.0-4.5 at the western part (İnciraltı) of the study area where alluvium depth is between 84-113 m. However, spectral amplification factors were found as 1.5-2.5 where bedrock depth is shallower (50-75 m). Low-to-medium susceptibility of liquefaction was calculated in saturated loose-to-medium fine sand and silty sand layers which were located in the upper 3.0-15.0 meters along the coastline.

Keywords: NEHRP classification; shear wave velocity; SPT-N; dynamic site response analyses; spectral amplification, liquefaction potential

Slope stability assesment of the open pit albite mine in the Çine- Karpuzlu (Aydın) Area

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The study area is a open pit albite mine which takes place in Aydın, Çine-Karpuzlu. Only leucocratic orthogneiss rock unit outcrops in the mine. The elevation of the base of the open pit is 395 m at present and 45 m thickness from the present base is planned to be mined out. The scope of this study is to determine the optimum overall slope angle of the slopes in the eastern part of the mine for different seismic conditions and water saturation degrees for the final cut of the slope. In this context, according to detailed field investigation and laboratory tests performed on rock material, numerical studies for deep slopes (H>100 m) were conducted.
In numerical modelling, applicability of the finite element method (FEM) involving shear strength reduction (SSR) technique by considering the Generalized Hoek-Brown Criterion and Equivalent Mohr-Coulomb parameters to jointed rock slopes in the eastern part of the Alipaşa open pit was investigated. A continuum based modelling was chosen for the reason that the orthogneiss rock mass is cut by several joint sets and foliation planes. Thus, the rock mass can be considered as homogeneous and isotropic. In this process, firstly five geotechnical cross-sections passing through the area affected from local block slides were taken; secondly stability analyses of overall slopes along these cross-sections considering the variations of Geological Strength Index (GSI), seismic acceleration (α_s), slope angle (α_{slope}) and water table location (WTL) were conducted using a two dimensional software Phase^2 V.7.013. The causes and mechanisms of slope instabilities, also the factor of safety values for each cross-section were determined. The results obtained from each criterion were compared by statistical software SPSS (Statistical Package for Social Sciences) to determine the optimum overall slope angle in terms of the best fitting criterion for the orthogneisses.
As a result, considering the SRF (Shear Reduction Factor) values obtained from both methods, the optimum overall slope angle was determined as 32˚ when the GSI, WTL and α_s values were taken as 42, 70% and 0.1g, respectively. Besides, when the slope becomes fully saturated after heavy rainstorms or an earthquake with a magnitude greater than 6.5 occurs, the slope will become instable even for 32˚ slope angle. The two methods matched well for slope angles under 40°. Inversely, for slope angle 40°, Equivalent Mohr-Coulomb parameters method underestimated the SRF values. For this reason, it was determined that the Generalized Hoek-Brown Method is less conservative and more reliable method for the investigated rock slopes.

Keywords: Finite element Method (FEM); slope stability; orthogneiss; albite open pit mine

Usability of granitic rocks as aggregate in hot-mix asphalt

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Properties of aggregates that are used more than 90% in asphalt pavements play an important role during service life of roads. To achieve good asphalt pavement performance, the strength and durability of aggregates should be at intended level, and should not be separated from asphalt (stripping) by the effect of water and traffic loads. Properties of granitic rocks like hardness, strength and durability are more favorable than many rock types. However, these types of rocks have limited usage as asphalt aggregates because of their stripping problem. The aim of this study is to correlate the usability of different types of granitic rocks as aggregate in hot mix asphalt. Studies were conducted on samples from granite quarries especially from Marmara region and from different regions of Turkey. Firstly, petrographical, mineralogical and chemical properties of the granitic rocks were determined. Then, standard aggregate tests were performed to evaluate the effects of aggregates to the hot mix asphalt properties. Stripping and pull-out tests were conducted on the granite aggregates to determine stripping properties caused by water and traffic loads. During the evaluation stage, basalt, limestone and sandstone aggregates, which have been widely used in hot mix asphalt production in Istanbul, were used as reference aggregates. According to test results, because of their composition, chemical and physical properties, granitic rock aggregates have different physico-mechanical and stripping properties.

Keywords: Aggregate, granitic rocks, hot-mix asphalt

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USAGE OF CONSTRUCTION MATERIALS, PRESENT AND ANCIENT TIME

Conveners:
Atiye Tuğrul, Tamer Topal and A. Bahadır Yavuz

Settlement walls of Çukuriçi Höyük - What stones could tell about prehistoric craftsman

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Çukuriçi Höyük is a tell site southeast of the ancient city of Ephesos. Excavations works at Çukuriçi Höyük at Western Anatolian coast have discovered a settlement that has been inhabited at least from the early 7th to the 3rd millennium BC. Since 2006 complex building structures of early 3rd millennium have been discovered and attributed to two phases of settlement (CuHö IV and CuHö III). These building structures, especially settlement walls, have raised several geoarchaeological questions: (1) What kind of rock types have been used for the buildings? (2) What is the source of these rocks? (3) Have these stones been quarried or randomly collected? (4) Does the composition of building stones and their origin change with different phases of the settlement?

Geological characterization and statistical identification of the distribution of rock types were the main techniques to generate a database to work with. More than 2400 building stones from settlement walls were counted and characterized through macroscopic visual analysis.

Craftsmen in Çukuriçi Höyük used 14 different rock types to construct the walls of the settlement. These rock types are three types of marble, grey-coloured mica schist, quartz-rich mica schist, vein quartz, serpentinite, schistose serpentinite, amphibolite, reddish meta-quartzite and two types of augen gneiss which varies in size of quartz minerals, beige dense gneiss were also included. Cavernous, whitish to beige, medium to coarse crystalline marble and grey-coloured mica schist were the primary building stones in both settlement phases accounting for 57,5 % during CuHö III and for 53,5 % during CuHö IV. Vein quartz (8 %), quartz-rich mica schist (13 %) and augen gneiss (5-7 %) were less commonly used for construction of the walls. Very rarely (<5 %) whitish, coarse-crystalline marble, dark-grey micaceous marble, gneiss, amphibolite, quartzite, serpentinite, and schistose serpentinite have been used. All stones show a sub-angular to moderately rounded shape, and limited size (maximum diameter 70-80 cm). The marble is partially cavernous and minor parts of the other rocks types are oxidized and weathered.

The rock types used as building stones crops out within the vicinity (3-4 km) of the settlement, and are in agreement with the local geology. The extensive use of mica schist and marble implies two possibilities: (1) These kinds of rocks were deliberately used due to their good physical properties in the construction of walls. (2) The pattern of use reflects the size or amount of natural outcrops for each rock unit. Presently, there is no evidence that any of the rocks were quarried. It seems that the building stones during the investigated phases of the settlement were collected from the surface, from eluvial debris, or from nearby creeks and rivers. Such an origin is suggested by the sub angular to well-rounded shapes, which are the result of eluvial and/or fluvial transport. The partially cavernous marble documents the influence of dissolution from surface weathering.

Result shows that the use of the rock building material has not been changed significantly in the investigated settlement phases. Further investigation is needed especially in older parts of the tell site to study if there was a significant change in building material.

Keywords: building stones, Çukuriçi Höyük, prehistoric settlement, Western Anatolia

Geological and geotechnical characterization of some deposits paving and ornamental stones in Algeria

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The mining industry and processing of natural stone have traditionally occupied a place in the Algerian architecture. The few remnants of old buildings in north Algeria is just one witness. Given its vast territory, Algeria has significant potential for pavement construction mainly is what we bring to this study. The pavement is the set of pads used in coating. Our study focuses, in fact a characterization of some deposits of paving and ornamental stone highlighting their specificity by a series of physical and mechanical testing. Integrated petro-physical study carried out nine varieties of pavement, has allowed us to set the relation between their petrographical and physico-mechanical properties. This study confirms that all this nine varieties can be used in several applications and uses.
As natural stone, paving is an example. This is a set of tiles from rocks to flow plates, the form of pieces of rock naturally or artificially limited by two parallel faces and much thinner (a few cm to 1 or 2 dm). Everyone agrees that this is the most durable material. Indeed each stone is unique because no place on earth suffers the same geological processes, has the same composition ground. Thus, even the natural stone tiles of the same rock type may have a different appearance and properties. The essential purpose is to characterize some varieties of slabs from some parts of Algeria, namely: Aflou Djelfa, Ath-Mansour (Bouira) and Azazga.
The geological richness of Algerian territory offers a choice in terms of quantity and quality. In the region of Laghouat, in addition to formations in which samples were taken (the upper Kimmeridgian), other formations, namely those of the Cretaceous, are of interest in the field of pavement, because the arrangement of the layers that are often sub-horizontal strata, facilitates extraction. Although it remains rudimentary. Similarly to the Djelfa region, we must focus on the different possibilities of extraction other than the Senonian formations.
Note also the famous black stone of Ath-Mansour, bituminous limestone of Cenomanian-Vraconian which is represented by a rhythmic alternation of black limestone intercalated by marl (M. Kieken, 1974). the latter promote and facilitate the extraction of this limestone.
In the region of Azazga, the geological formations exploited for paving are those of the Numidians flysch (Oligocene). They are part of the complex of flysch. According Gélard JP (1979 The Numidians sandstone covers a significant part in the eastern region of Azazga. However, the physical characteristics (color ...) of the sandstone vary from one place to another.
Some ornamental rock like marbles deposits were studied in the same way across Tlemcen and Filfila region in north Algeria.

Keywords: Algeria, coating, geological ,marbles, mechanical testing, ornamental, paving.

The application of cathodoluminescence in Early Helladic Pottery from Helike, Achaea, Greece.

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The abundant pottery discovered at the Early Helladic settlement of Helike in Achaea, Greece corresponds to a variety of complete and some unique vessels, cooking ware, transport and storage jars, large pithoi and pots, rich in shapes and decorations. These artifacts together with the architectural and other finds provide strong evidence on its historical and archaeological importance for the geographical region of Western Greece.

In the current study a total of 63 ceramic sherds were selected according to their shapes, the macroscopic characteristic of their paste and their stratigraphic-chronological and in-house context to be examined in order to determine their cathodoluminescence, petrographic-mineralogical and chemical properties. Sand samples collected from the main rivers and streams of the studied area were similarly analyzed. The analytical data obtained, enabled us to explore possible correlation between specific technological recipes and the source of their raw material.

Cathodoluminescence microscope (CL) was used in a first place, in order to distinguish the different mineral phases present as non-plastics as well as their compositional peculiarities. The integration of cathodoluminescence with thin section petrography and chemical analysis by means of optical microscopy and ICP-MS elemental analysis, respectively, led to the establishment of two main fabric groups and numerous single sample groups (loners) with a significant compositional and textural variability. We thus infer that locally available raw materials were used for their manufacture and unfold their technological properties.

The results obtained highlight the use of cathodoluminescence as a complimentary method that can comprise a useful tool for petrographical study of archaeological artifacts.

Keywords: ancient ceramics; cathodoluminescence; ceramic raw material; Helike

Ground stress measurements in Missouri Red Granite Quarry

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In Missouri, the horizontal stresses (pressures) in the near surface rock are uncommonly high. While the vertical stresses in rock are simply a function of the weight of the overlying rock, near surface stresses can be many times higher. The near surface horizontal stresses can be in excess of 5 times greater than the vertical stresses. In this research Flatjack method was used to measure of horizontal stress. The flatjack method is an approved method of method of measuring ground stresses. A saw cut is used to “relax” the stress in the ground by allowing the rock to deform in toward the cut. A hydraulic flat jack is used to inflate the slot; to push the rock back to its stressed position, as measured by a strain gauge on either side of the slot. The pressure in the jack, when the rock is exactly back to its original position, is equal to the ground stress before the saw cut was made. According to the results, present production direction for each pit is not good. Because the maximum stress direction is perpendicular with production direction. This case is caused Unintentional breakage results in the loss rock. The results show that production direction should be changed.

Keywords: stress measurements; flatjack; granite

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RADAR INTERFEROMETRY AND LAND SUBSIDENCE HAZARDS

Conveners:
Zhenhong Li, Noel Gourmelen
and Roberto Tomas Jover

Stability assessment of karst sinkhole in cherea area, N E Algeria

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The catastrophic collapse of residual soil covers overlaying solution cavities in karstic limestone areas constitutes a serious geological hazard around the world. It is a well known phenomenon related to the occurrence of underground solution cavities in limestone, dolomite and gypsous terrains. It is a real challenge for land use planners and engineers as it affects seriously the foundations stability and performance. In urban areas, generally the sudden collapse causes damages to properties, infrastructures, and even lives.

In recent years two large events of covers collapse over sinkholes were recorded. The first event resulted in a crater of more than 50 meters, in diameter, occurs in a non populated locality called Douamis. This first event has caused no damage and did not receive any attention from the local authorities. Recently on the 29th February 2009 at 03 am a spectacular sinkhole collapsed with a diameter of more than a hundred meters occurs in the center of the town of Cherea. This later event has caused severe damage to several houses, roads, water main supply, and sewages. It has caused a widespread panic among the population mainly those living too close to the crater. This time, as the phenomenon start to affect the security and the economy of the population, the local authorities have become very aware about the danger threatening several tens of thousands of peoples. The collapse is due to a sudden rupture of the roof of a large underground karst cavity. Karst cavities are in fact widespread in the Eocene limestone forming the upper formation under the quaternary cover in the Cherea syncline.

Both local authorities and residents are aware about the fact that every structure in the area could well be build totally or partially on a potentially collapsible void. The extension plans of the area could no more be established without a thorough knowledge of the underground conditions including the occurrence, depth, geometry and dimensions of the karst cavities.

Several exploration methods for the localization of underground cavities have been considered. Geological study, resistivity survey and borehole drilling were undertaken in order to locate the underground cavities and assess their depth, geometry, dimensions, etc.

Rock mass properties such as RMR, GSI along with other geo-mechanical parameters are assessed in order to estimate the stability of these underground. It has been found that under an imposed loading of varying intensity, the stability of the karst cavities depends on the geo-mechanical parameters (RMR, GSI, and E), of the host rock as well as the depth and dimensions of the gallery. It increases with RMR, GSI, E and roof thikness, it decreases as the cavity width increases. The calculation results shows that for an imposed surface load of 1 MN a ratio (roof thickness to gallery width) of of 0.2 and more indicate a stable conditions. Waltham (2005) cited several case studies from the USA and Britain where caves were stable with a roof thickness to width ratio varying from 0.1 to 0.5.

The study has allowed the establishement of a stability chart on the basis of the geomechanical parameters of the host rock, the roof thikness and the cavity width. It has also showed that underground galeries can be located along with the roof thikness and caviti width. It is thus possible to establish a sinkhole collapse hazard map for the town of Cherea as it is a valuable tool for its future extension. No town planning process can be undertaken for Cherea area without a map of this kind.

Keywords: Sinkhole, Karst, RMR, GSI, Hazard zoning, Tebessa.

InSAR as a complementary tool for forensic analysis in subsidence areas

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Synthetic Aperture Radar Interferometry (InSAR) is a powerful tool for measuring ground deformations resulting from natural processes such as landslides, earthquakes and volcanoes or from anthropogenic processes such as extraction of groundwater, oil and coal. These geological-geotechnical phenomena, may seriously affect man-constructed infrastructures (roads, buildings, dams, bridges, etc.). The precise geo-referenced and high resolution information provided by InSAR can be exploited by forensic engineers as a complementary tool for the interpretation of damages affecting infrastructures. In this paper we attempt to demonstrate the advantages and disadvantages of InSAR techniques for forensic analysis with several case studies.

Keywords: subsidence, InSAR, forensic analysis, civil and building engineering

Fault rupture model of the 2008 Dangxiong (Tibet, China) Mw 6.3 earthquake from Envisat and ALOS data

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On October 6, 2008, an Mw 6.3 earthquake occurred at Dangxiong county, southern Tibetan Plateau. In this study, Synthetic Aperture Radar (SAR) images from Envisat ASAR C-band descending Track 176 and ALOS PALSAR L-band ascending Track 500 are processed to generate the cosesimic deformation caused by the earthquake. To extract the source model, a downhill simplex non-linear inversion method is used to determine the fault rupture geometry, and an automatic fault discretization technique is employed to divide the fault plane to construct the optimal slip model, in which the uncertainties of the fault parameters are assessed by Monte Carlo method. The inverted results show that the earthquake strikes almost south-north direction and has a normal faulting focal mechanism with average rake angle and slip of -117.8° and 0.75 m, respectively. Peak slip of 2.15 m is located at a depth of 7.5 km. The inverted geodetic moment is 4.43×10^{18} N m (Mw 6.40), 69.5% of which is released at depth ranging from 4.5 to 11 km. The slip model suggests that shallow slip takes place at some fault patches near the earth's surface and postseismic afterslip occurs below the coseismic rupture area after earthquake.

Keywords: rupture model; Dangxiong Mw 6.3 earthquake; Envisat; ALOS; inversion

Inversion for Coseismic Slip Distribution of the 2010 Mw 6.9 Yushu Earthquake from InSAR Data Using Angular Dislocations

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The Mw 6.9 Yushu earthquake occurred on the left-lateral Ganzi-Yushu fault in Qinghai, China on 14 April 2010. In this paper, the focal mechanism of the earthquake is explored using angular dislocations. We present a new method to model the fault geometry with Triangular Dislocation Elements (TDEs) and deduce the analytical expressions of the strains associated with angular dislocations in an arbitrary depth of elastic half-space. This new method can prevent the emergence of dislocation gaps and overlap zones in the fault geometry modelled with Rectangular Dislocation Elements (RDEs) and control the extension of the fault surface in depth well. We extract a refined rupture trace of the causative fault according to two InSAR coseismic interferograms and the field investigation results using the tools in the software ArcMap™. A non-planar fault geometry, the dip of which decreases linearly with depth, is constructed with RDEs. The inversion results show that the slip model of the TDE is better than the RDE model on the criterion, c, which weighs up the weighted misfit of unit smoothness. Both models can fit the InSAR observations better than others, especially near the Yushu fault and at the northwest and southeast ends. The maximum slip is approximately 1.6 m, and the magnitude of Yushu earthquake is Mw 6.8. Furthermore, we calculate the static Coulomb stress change on two-dimensional optimally oriented planes and find that the Coulomb stress change triggered by the slip on TDEs can better fit the spatial distribution of aftershocks.

Keywords: Yushu Earthquake; InSAR; fault geometry; coseismic slip distributions; rectangular dislocations; angular dislocations; Coulomb stress

Coseismic and postseismic slips of the 23 October 2011, Mw 7.1 Van (Eastern Turkey) Earthquake from InSAR and GPS observations

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A Mw 7.1 earthquake struck Van, Eastern Turkey on 23 October 2011 (UTC 10:41:21, Local time 13:41:21), causing 604 fatalities and over 60k homeless. The hypocenter of this event is located to the north of the Bitlis structure zone, a convergence zone between the Arabian and Eurasian plates in the Eastern Anatolia. Previous studies suggest a northerly convergence rate of about 24 mm/yr for the Arabian plate. In this study, we used five datasets, namely Envisat, Radarsat-2, COSMO-SkyMED, TerraSAR-X and GPS to investigate the focal mechanism, coseismic slip distribution and postseismic motion of the 23 October 2011, Mw 7.1 Van earthquake. Our preliminary dislocation model with Envisat, COSMO-SkyMED and GPS suggests this earthquake is associated with a buried ENW-WSW oriented and north-dipping thrust fault, which is consistent with aftershock locations. InSAR time series techniques were employed to analyse the Radarsat-2, COSMO-SkyMED and TerraSAR-X datasets collected after the event, all indicating that the coseismic fault continues to slip.

Keywords: InSAR; coseismic displacement; postseismic motion; Van Earthquake

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*COMET+: Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics

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ENGINEERING SEISMOLOGY

Conveners:
Oğuz Özel and Eşref Yalçınkaya

Analysis of Amplification Factor and Seismic Velocity Model by Using Earthquake Acceleration Records: An Example of Bursa (Turkey)

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In this study, it is aimed to determine the vulnerability of the region by calculating amplification factor using predominant period which affects the structure during the earthquake within the boundaries of the city of Bursa (Turkey). Amplification values in predominant period were calculated using acceleration records taken from a seismic station in the region. The values were determined by using MATLAB-based SUA and EERA softwares and the results were compared. Five earthquake acceleration records were obtained from Bursa and N-S components of these records were evaluated. After acceleration records were transformed to a specific data format, amplification value was calculated as 2,2 by using MATLAB-based SUA software where predominant period was 0,45 in the study area. Also seismic velocity model was obtained. Five acceleration records of the same station were utilized in EERA software. In this algorithm amplification value was determined as 2,05 for the predominant period 0,26. As a conclusion, results of EERA and MATLAB-based SUA softwares were compared and they support each other.

Keywords: Amplification factor; Seismic velocity model; Bursa; Matlab

Analyzing acceleration waveforms and determining source parameters of 23 October 2011 Van Earthquake (Mw = 7.2)

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In this study, the acceleration records, which were downloaded from AFAD web page (http://kyh.deprem.gov.tr), of 23 October 2011 Van Earthquake main shock (Mw=7.2) and its aftershocks ($M_L \geq 4$) occurred between 23.10.2011 and 29.02.2012 were analyzed. The back azimuths of the NS and EW components of acceleration seismograms were calculated to convert them to S wave radial (SV) and tangential (SH) components. P- and S-wave first arrival times were read from acceleration waveforms, and these converted waveforms were integrated to generate velocity and displacement seismograms by using trapezoidal integration method. The waveforms were analyzed and the spectral parameters such as corner frequency (f_0), F_{max}, the spectral level (Ω) and stress drop ($\Delta\sigma$) were determined from the spectrum of acceleration and displacement seismograms. Source parameters (source radius, seismic moment) were also tried to determine using acceleration and displacement spectrums based on Aki's ω^2 source model. In this presentation, we will discuss the relationship of the source parameters of the Van Earthquake obtained from both spectrums were examined.
Furthermore, we analyzed acceleration data of each station using Nakamura (1989) spectral ratio method to derive site classifications and calculated site amplifications. The results from the first part were tried to interpret based on the site classification and amplifications.

Keywords: Source parameters, H/V method, Site characterization, Van Earthquakes.

Comparison of site amplifications using by different methods

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This study mostly concerns with assessment of strong-motion data that has been recorded by the local strong-motion IzmirNET array, located in Western Anatolia, Turkey. 16 strong-motion stations represent four main geological units. Site response and soil characteristics have been revealed by using distinct techniques. Standard Spectral Ratio (SSR), Horizontal to Vertical spectral ratio (H/V) and Generalized Inversion Scheme (GIS) are applied to selected earthquakes that appropriate for these methods. Added to these techniques, the microtremor H/V study is also analyzed at the stations. The graphics of the resulting spectra were compared to correlate with the site characteristics.
Volcanic units exhibited flat spectrum as expected at BYR, MNV and KYN station locations. The mean amplification factor is acquired for quaternary alluvium generally varies from 4-8 times for BYN, KON, KSK and CMD stations. The highest amplification of among the stations is 9 at 1 Hz dominant frequency for MVS station where deep sediments and quaternary alluvial deposits present over there.
Analyzed site characteristic shows good correlation with the geological formations as well as expected ground deformation in the city.

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Keywords: site; amplification; Izmir; spectral ratio.

Determination of Resonance Periods of Engineering Structure from the Microtremor Measurements in the Faculty of Engineering Building, Tınaztepe Campus of Dokuz Eylül University

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Aegean Region has a quite active structure with seismicity aspects. Izmir and its surroundings are included in the first degree earthquake zone of Turkey. There are over ten active faults in around Izmir. The active faults have possibility producing major earthquakes. Considering the seismicity of Izmir, therefore it is very important to understand the behavior of buildings against earthquake. Microtremor measurements were carried out the Faculty of Engineering Building, Tınaztepe Campus of Dokuz Eylül University at the specified floors with the reference station at outside of the building. Total of 4 units microtremor records were simultaneously taken. Seismometers in the building are positioned to coincide with center of mass of the building. On average 30-minute recordings were made. The reference station was away at least 10 times the length of the building. Amplitude spectra of the microtremor records were calculated using the technique of Nakamura. As a result, the resonance periods of soil and the building were obtained. H/V ration was determined as 1.2 for the predominant period 0.07 on ground floor. H/V ration was determined as 1.85 for the predominant period 0.11 on the second floor. H/V ration was determined as 2.0 for the predominant period 0.17 on the fourth floor. The last H/V ration was determined as 1.5 for the predominant period 0.07 on the reference station.

Keywords: Soil-Structure Interaction; Nakamura’s Technique; Microtremor ; Tınaztepe Campus

Establishment of borehole observation system and high resolution seismic studies in the western part of the main Marmara Fault in the frame of a EU-FP7 project titled as MARSITE.

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The main objective of this study is to install a multi-parameter borehole system and surface array as close to the main Marmara Fault (MMF) in the western Marmara Sea as possible, and measure continuously the evolution of the state of the fault zone surrounding the MMF and to detect any anomaly or change which may occur before earthquakes by making use of the data from the arrays already running in the eastern part of the Marmara Sea. The multi-parameter borehole system will be composed of very wide dynamic range and stable borehole (VBB) broad band seismic sensor, and incorporate 3-D strain meter, tilt meter, and temperature and local hydrostatic pressure measuring devices. The borehole seismic station will use the latest update technologies and design ideas to record "Earth tides" signals to the smallest magnitude -3 events. Bringing face to face the seismograms of microearthquakes recorded by borehole and surface instruments portrays quite different contents. The shorter recording duration and nearly flat frequency spectrum up to the Nyquist frequencies of borehole records are faced with longer recording duration and rapid decay of spectral amplitudes at higher frequencies of a surface seismogram. The main causative of the observed differences are near surface geology effects that mask most of the source related information the seismograms include, and that give rise to scattering, generating longer duration seismograms. In view of these circumstances, studies on microearthquakes employing surface seismograms may bring on misleading results. Particularly, the works on earthquake physics and nucleation process of earthquakes requires elaborate analysis of tiny events. It is obvious from the studies on the nucleation process of the 1999 earthquake that tens of minutes before the major rupture initiate noteworthy microearthquake activity happened. The starting point of the 1999 rupture was a site of swarm activity noticed a few decades prior the main shock. Nowadays, analogous case is probable in western Marmara Sea region, prone to a major event in near future where the seismic activity is prevailing along the impending rupture zone. Deploying a borehole system eastern end of the Ganos fault zone may yield invaluable data to closely inspect and monitor the last stages of the preparation stage of major rupture.

Keywords: Borehole seismometer; Ganos fault; microearthquakes; western Marmara

Determination of liquefaction resistance and allowable bearing capacity of soils based on V_S (Shear wave) velocity: A case study from Isparta Süleyman Demirel Industrial Purification Plant

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It was a very common procedure to investigate liquefaction risk with standard penetration test (SPT). However, this method has been used rarely after the development of conic penetration method in 1971, Becker penetration method for gravels and V_S measurements. These developments were yielded a new way of looking at the liquefaction potential analysis and these were started to be applied for field studies. S-wave (V_S) measurements may be a reasonable alternative in order to carry out penetration tests for the gravelly and unconsolidated overburden. The method is hereby presented in order to calculate the ultimate bearing capacity for shallow foundations. In this study, V_S values were used in order to determine liquefaction resistance and allowable bearing capacity of soil with a method which uses Cyclic Stress Ratio (CSR) and Cyclic Resistance Ratio (CRR) applied to V_S values. All the application steps of the method were defined briefly. Data were collected along 4 profiles using seismic refraction method for the site investigations which were carried out at the Isparta Süleyman Demirel Industrial Purification Plant. Based on the assessment of field data, high liquefaction potential was determined in the first layers of the all profiles. Especially in case of existing silt and clay layers, even if the calculated values were in the probable liquefaction area on the chart for CRR vs. Overburden Stress-Corrected Vs, the risk is ignorable when the cyclic stress ratio is greater than 0,2. Also allowable bearing capacity values were calculated and all of the layers were defined in the safe zone.

Keywords: Allowable bearing capacity; CRR; CSR; Liquefaction resistance; S-wave; Seismic refraction;

Analysis of ambient noise from accelerometric array

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An efficient and robust cross-correlation technique for estimation of surface wave Green's function between two locations is applied to a set of ambient noise data recorded during 1 month by a small aperture local accelerometric network (Polat et al. 2009) in Izmir, capital of the Aegean Sea region of Turkey with its more than 3 millions inhabitants. We have estimated more than 40 group velocities of Rayleigh waves in the period band of 0.5-2.0 seconds from correlation pairs of 10 accelerograph stations. Relatively dense and uniform coverage of the pairs provided group velocity dispersion curves. The resulting group-velocities correlate well with the characteristic features of geological map of Izmir and surrounding areas. We generally observed low velocities for the sedimentary basins around Gulf of Izmir, and high velocities for the regions where the Miosen-aged volcanic and andesitic units outcrop. The high-dynamic information range from the accelerograph network can improve the resolution of the subsurface structures which is responsible for the results of strong ground motion.

Keywords: Cross-correlation; ambient noise; accelerometer

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