
**May, 6-7 2017**

# BOOK OF ABSTRACTS

# Oral Presentations


# Tracking subducted seamounts and fragments of oceanic lithosphere:

# unique examples from SW and E-Iran

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Suture zones may preserve relicts of subducted ocean floor and thus key information in deep processes and/or later exhumation. We herein report on several localities from SW and E Iran, where critical observations can be made owing to the quality of exposures and rock preservation :

1— the unique record of a large-scale, subducted former seamount (the ~20-25 km large Siah Kuh massif), now sandwiched in the Zagros suture zone. This seamount is recognized by its magmatic (ie, massive basaltic flows, commonly pillow basalts, with subordinate and more differenciated subvolcanic rocks and ophiolite-type gabbros ; serpentinites and metaperidotites found along major internal thrust contacts) and sedimentary organization (basalts overlain by reef limestone and/or cherts, with local debris-flows, new eruptions and a sedimentation evolving towards pelagic limestones and flyschs, accompanying slope instabilities and isostatic deepening of the seamount below the CCD). HP-LT minerals (lawsonite, aragonite, blue amphiboles) found in the (E-MORB to OIB) basalts across many parts of the structure, particularly in zones of localized compressive deformation, indicate shallow subduction of the seamount to seismogenic depths, between 15-20 and 25 km. Syn-subduction deformation patterns coeval with the slicing of the seamount are assisted by décollements rooting in serpentinite and/or oceanic metasediments. No sign of major seismogenic deformation is visible (i.e., such as pseudotachylites), which in the present debate supports the view that seamounts are rather obstacles (ie, ‘barriers’) than asperities promoting seismic rupture.
2— an almost intact piece of partly subducted ophiolite (with ~50-50 % basalts/peridotites), with local lawsonite and blueschist recrystallizations suggesting similar

depths, is also found in the ophiolite ridge lto the SW of Birijand (E-Iran).

Information on deeper portions of the subduction zone are provided by two other examples:

3— The Seghin unit (SW Iran), which is a piece of oceanic lithoshere returned during the Late Cretaceous, made of ~50-50 % of serpentinites and omphacite-lawsonite-glaucophane ± garnet metabasalts (Agard et al, 2006; Angiboust et al, 2016). This unit can readily be interpreted as lithogically equivalent to the Birjand ophiolite ridge but disrupted at ~60 km depth, with 100-200 m thick strips of metabasalts now embedded in matrix serpentinites.

4— In the Sistan suture zone (E. Iran, between the Lut and Afghan blocks), two kinds of subduction-related tectonic mélanges can be distinghuished: a flysch-matrix mélange and a serpentinite-matrix mélange. While the first one includes barely metamorphosed radiolarites and basalts of maximum greenschist-facies grade (<~340°C), the serpentinite-matrix mélange includes strongly disrupted blocks of various grades and lithologies: mafic eclogites, epidote-amphibolite rocks, blue-amphibole-bearing metacherts, and greenschist-facies metabasalts. While eclogites reached peak PT conditions of 520°C and 2.2 GPa, other rocks (though less-well constrained) did not exceed 1.2 GPa and originate from three different depth zones. Observed structures, rock types and the very similar phengite and amphibole Ar-Ar ages (ie, 87.5 ± 3

Ma for fourteen samples across > 100 km and all kinds of rocks) allow to refine subduction dynamics and extreme disruption during early subduction.

All these examples provide important clues on detachment and exhumation mechanisms in subduction zones.

# Land subsidence monitoring in Qazvin plain using Synthetic Aperture Radar interferometry

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A large area in Qazvin plain, in north-center of Iran, is subject to the land subsidence induced by overexploitation of groundwater. In this study, in order to study the subsidence, Interferometric Synthetic Aperture Radar (InSAR) is used. The time series analysis of small baseline subset (SBAS) algorithms is used for deformation time series analysis. The data set consists of 20 and 18 images of descending tracks D192 and D421 during 2003 to 2010. The time series results revealed that the area is subsiding continuously. Mean line of sight deformation velocity maps obtained from time series analysis demonstrated ~30-35 mm/yr for the 2003-2010

time period land subsidence in the study area. Comparison between the extent of subsidence from InSAR results and plain wells density map in Qazvin plain determines the subsidence occurred in the area with the density of deep wells.

## Introduction

Land subsidence due to the overexploitation of aquifers for industrial and agricultural purposes has been a common geo-hazard in many arid countries and districts of the world. The over extraction of the groundwater usually caused to declining of the water table, increases of the compressional stress on the skeleton of the aquifer and finally land subsidence. This subsidence may associate with building and infrastructure destabilization, surface rupture and accelerated erosion along earth fissures and drainage systems. In Iran, high rate of extracting water from underground source due to agricultural activity, industrial development and population growth caused decreasing the ground water level and consequently subsidence occurs and its trace is seen as cracks and fractures in the ground surface in some place in Iran. Therefore, mapping the spatial coverage and monitoring the temporal evolution of land subsidence can help us to mitigate significant economic and widespread damage associated with this phenomenon (Herrera et al., 2009). In this study, we provide the first direct measurement of occurring subsidence in Qazvin plain as one of the important plain in Iran in terms of industrial, agriculture and population point. This region is located in the north-central Iran (Figure1).

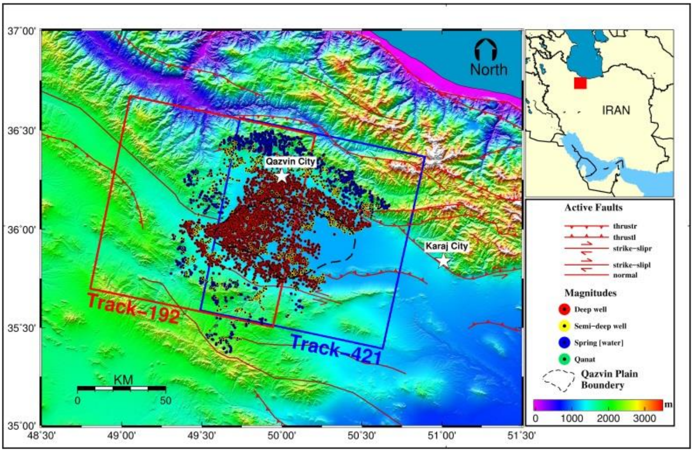
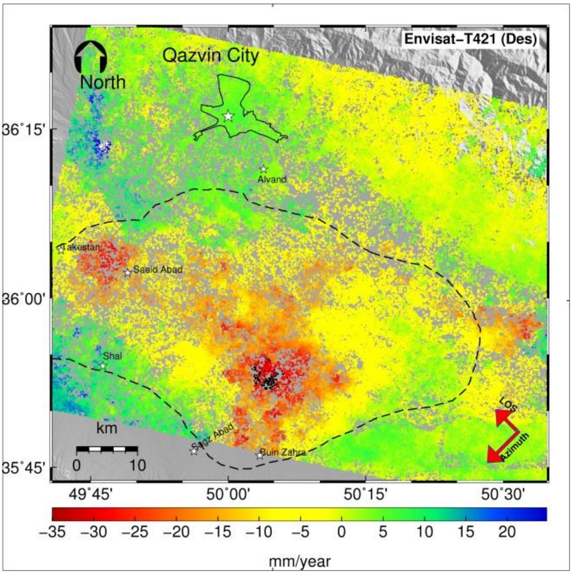



Figure 1. Inset: Outline map of Iran with red rectangle showing the Qazvin area. Main figure: The blue and red rectangles show the location of two adjacent tracks study in this study and red lines show active faults on area that are super imposed on shaded SRTM topography. The circles show the location of wells and other source water in Qazvin plain.

**InSAR processing and results**

To investigate the areal extent and temporal evolution of ground subsidence in the Qazvin plain, we processed two sets of the Synthetic Aperture Radar images, consisting 20 and 18 ENVISAT ASAR images from descending tracks D192 and D421, respectively, during 2003 to 2010. The SAR data were processed using the repeat-pass method implemented in the DORIS software (Kampes et al., 2003). Precise Orbital Data Record (ODR) with radial precision of 5-6 cm for ENVISAT satellite has been used to estimate the phase signature due to orbital separation (flatting). Then the 90m SRTM DEM (Shuttle Radar Topography Mission Digital Elevation Model) has been used to estimate the topographic phase contribution. We generated 40 and 31 interferograms for tracks D192 and 421, respectively, with perpendicular baseline smaller than 500m and temporal baseline larger than 2 months and less than 5 years.  In the following, we apply Small BAseline Subsets approach (Berardino et al., 2002) to estimate mean velocity of surface deformation in Line of Sight of satellite.

The SBAS results for track number 192 and 421 indicate surface deformation in average 30 mm/yr going far away from satellite from 2003 to 2010 (Figure2). According to the active fault trace in Figure 1, we can project this deformation in vertical direction which can be interpreted as land subsidence. At present 3879 of 8165 registered wells in Qazvin plain are using for agricultural purposes. Unfortunately, this excessive extraction of water resources for the agricultural fields caused subsidence occurs widely in the area. Subsidence results in cracking and hence property damage and it creates surface rupture in Qazvin plain.



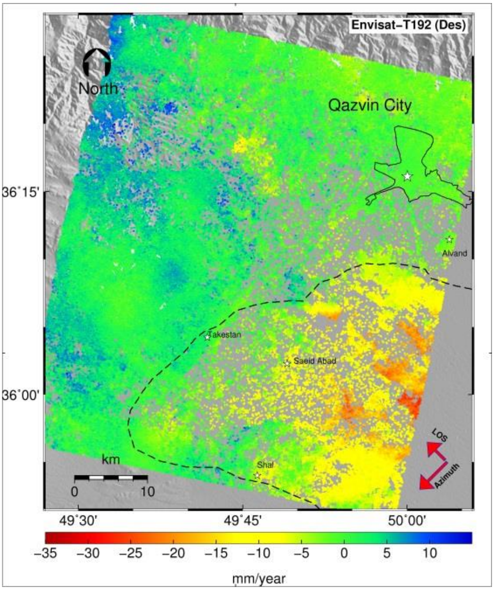



Figure 2: Mean velocity map of ground surface in LOS direction from InSAR time series analysis for track D421 (left) and D192 (right).

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# Active tectonics of the Dasht-E Bayaz fault (NE Iran)

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Previous studies clearly display evidence that only a part of the convergence between Arabia and Eurasia is accommodated within the major Zagros mountain belt and more than 50% of the deformation associated with this convergence is transferred towards the North inducing a distribution of deformation throughout all the Iranian territory until its northern boundary in the Kopeh Dagh. (e.g. Shabanian et al. 2009, 2010, 2012).

In this context the Lut block was considered as a rigid block undergoing a rotation without internal deformation, this block being northerly bounded by the Doruneh fault system (e.g. Farbod et al., 2012, 2015). On 31 August 1968 a major earthquake with magnitude of 7.3 (Gheitanchi et al., 1993) affected northeastern part of Lut block in Dasht-e Bayaz Area. This earthquake was very destructive: more than 10,000 people deaths (85% of the population) and many villages were destroyed (more than 12,000 destroyed houses). Surface rupture associated with this earthquake propagated with an East-West direction, all along 70 km long rupture. It produced an average co-seismic horizontal displacement of 3m (max. displacement of 4.5 m, cf. photography) (Tchalenko and Ambraseys, 1970; Tchalenko and Berberian, 1975). This earthquake reactivated a fault, which is probably a major structural and geodynamic accident of NE Iran and also the subject of this research. A combined approaches including structural geology, morphotectonics, quantitative geomorphology and cosmogenic nuclide dating ($^{10}$Be) will permit us to describe the kinematics, as well as the geodynamic role of Dasht-e Bayaz fault in the context of Arabia-Eurasia collision.

A systematic fault kinematics permit to determine the tectonic regime all along the Dasht-e Bayaz fault, presently a pure strike-slip fault regime characterized by a relatively homogeneous regional direction of compression ($\sigma1$ NE-SW), compatible with the tectonic regime, obtained along the Doruneh Fault. In both cases we provided evidence for a change in the tectonic stress regime during Plio-quaternary: first characterized by a direction of $\sigma1$ NW-SE and second, from recent to present-day, with $\sigma1$ NE-SW, the change probably occurred in the early Quaternary.

The analysis of satellite images combined with field study has permitted us to define the fault system segmentation and to propose a seismogenic/faulting behavior in Holocene. The fault is characterized by a low level of segmentation and seems to proceed a characteristic seismic behavior, with evidenced geomorphological marker lateral displacements multiple of 3 to 4 meters. A more detailed analysis of these geomorphologic markers along the fault associated with dating ($^{10}$Be dating is in progress) will permit to determine the fault slip rate of this major fault and consequently to characterize and quantify the active deformation field.

**Key words :** Iran, Dasht-e Bayaz fault, Strike-Slip fault, Kinematics, active tectonics.


Photograph (@ Dr. Haghipour) of the Dasht-e Bayaz earthquake co-seismic displacement

TRIGGER international conference
Trans-disciplinary Research on Iranian Geology, Geodynamics, Earthquakes and Resources
May, 6-7 2017 - Tehran, Iran
Geological Survey of Iran

# The role of syn-sedimentary structural control on the sediment-hosted Zn-Pb deposits in the Irankuh and Tiran Mining Districts, SE of Malayer-Esfahan Metallogenic Belt, Iran

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The Malayer-Esfahan Metallogenic Belt (MEMB), located in the former back-arc basin, as a part of Sanandaj-Sirjan, which exposes numerous Lower Cretaceous sediment-hosted Zn-Pb-(Ag-Ba-Cu) deposits. Among them, the Irankuh Mining District (IMD) and the

Tiran Mining District (TMD) are located in the southern and northeastern part of the Esfahan region, respectively. Based on the previous research, these deposits are of SEDEX-type and their formation was controlled by NW-SE-trending syn-sedimentary normal fault (SSNF). In IMD, Lower Cretaceous detrital-carbonate rocks unconformably overlie Jurassic detrital rocks ($J_s$). Black siltstone ($K_1$, 15m), pyroclastic and volcanic rocks ($K_v$, 50m) and dolostone ($K_{3d}$, 300m) forming the basis of Lower Cretaceous sediments (all named as $K_c$ ore-bearing horizon), are the main host rocks of Zn-Pb (Ba-Cu) ores. Sedimentation continued by the deposition of carbonates ($K_{4L}$, 100 m and $K_L$, 120m) and shales intercalated with limestone ($K_s$, 120m) units in IMD. In TMD, Lower Cretaceous sedimentation started with the deposition of detrital-carbonate sediments ($K_c$, 40m), which unconformably overlie detrital Triassic unit, stratigraphycally equivalent to the $K_c$ ore horizon in IMD. During the deposition of $K_{3d}$ and $K_{4L}$ (about 570 m) in IMD, sedimentation in TMD was low though. $K_L$, the main carbonate rocks in TMD (400m thick) was further covered by black limy siltstone and limestone ($K_s$, 500m). $K_s$ and volcanic and volcanoclastic rocks, located in/or near SSNF, are the main host rocks of ore in TMD. Considering the structural events, the NW-SE trending

SSNF mainly control mineralization in both IMD and TMD, resulting in the formation of a graben basin. Activation of SSNF in IMD started by the ingress of the Lower Cretaceous Sea during the Barremian, resulting in the deposition of a thick volcano-sedimentary series ($K_v$, $K_1$, $K_{2L}$, $K_{3L}$, $K_{4L}$, $K_L$ and $K_s$). At this time, SSNF of TMD did not evolved causing a minor thickness of sediments in comparison with IMD. The higher thickness of Lower Cretaceous strata in IMD could also confirm the subsidence of Irankuh basin during the Barremian. Hydrothermal ore fluids ascending along SSNF, introduced within suitable host rocks and formed Zn-Pb ore bodies in IMD. Thus, we suggest that the formation of graben basin, the activation of normal faults and volcanism in relation to tension structure in IMD are related to asthenosphere upwelling and thinning of lithosphere. In the time of deposition of $K_L$ unit, both IMD and TMD are under the Lower Cretaceous Sea during the Aptian. The activity of SSNF and generation of graben basin in TMD started after the deposition of $K_L$. It resulted in the basin subsidence and sedimentation of a higher thickness for $K_s$ unit. Ore fluids ascending along this fault, caused deposition of ore minerals in $K_s$ and in volcanic to volcaniclastic rocks. At this time, the activity of SSNF stopped in IMD, marked by an absence

Zn-Pb-(Cu) ore mineralization in the $K_S$ unit. Finally, based on these observation, ore mineralization in IMD and TMD occurred in various stratigraphic horizons (Kc and Ks) due to syn-sedimentary faulting and reactivation of faults during the Barremian and the Aptian, and therefore the repetition of sulfide mineralization process in two different horizon.

# A case of Triggered seismicity around Masjed Soleyman Dam, South West of Iran

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Continued seismicity in the Masjed Soleyman region accompanied by increasing rate of earthquakes 9 years after completing the impoundment. In order to better understanding of the impact of this reservoir on seismic activity of the area, a local seismic network of 12 seismological stations was installed in the area. 1216 well-located events recorded during a period of 3 years from 2009 to 2011 were used in this study. The largest recorded event during the monitoring of Masjed Soleyman reservoir had local magnitude of $M_L$=5.2. Discriminatory characteristics used to identify the reservoir triggered seismicity in the area. The continued seismicity in the vicinity of the dam area indicates the presence of high stresses and a very close relation between the water level changes and occurrence of

earthquakes shows that seismicity is affected by reservoir filling. Discriminatory characteristics for the events greater than 3 in the monitoring period of network illustrated that earthquakes with which are located in the south part of reservoir and in the vicinity of Baghe-Malek fault have the properties of reservoir triggered seismicity , likewise aftershocks of the earthquake with $M_W$=5.6 occurred just 90 days after completion of impoundment. Results show that the key reasons for low D-values and high b-values are seepage of water in the crust and pore pressure diffusion which actually is the main reasons for the incidence of reservoir triggered earthquakes. It can be said that impounding the dam caused heterogeneity in the crust and changed the stress distribution of area, especially in the vicinity of Baghe-Malek fault. The correlation between the fractal dimension and the b-value showed the impact of reservoir loading in the nearby area.

# Peak temperatures and structural constraints across the southern Sanandaj-Sirjan zone (Kor-e-Sefid, Neyriz province)

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Iran is made of an aggregation of continental blocks that formed and separated during opening and closure of Tethyan oceanic basins. Since the onset of convergence between the Arabian and Central Iranian plates during the lowermost Jurassic, the Sanandaj-Sirjan zone (SSZ) has been representing the active upper plate margin above the subduction zone. Like the Zagros orogenic fold and thrust belt, the SSZ was later affected by collision since the Oligocene.

The SSZ hosts strongly deformed, predominantly Precambrian to Cretaceous metamorphic rocks but many ambiguities remain on their age, nature and metamorphic

conditions. Based on petrographic and geodynamic studies, somewhat contrasting evolutions were suggested along strike the SSZ, but most studies have so far focused on the north (Hamadan, Golpaygan,…) and quantitative P-T estimates are completely lacking in the south.
This study focuses on deformation patterns and peak temperature conditions in the southern SSZ in an attempt to relate them tightly, and to shed light on the regional-scale geodynamic context. Samples with abundant carboniferous matter were collected along two main cross sections. Peak temperatures were estimated using the Raman spectroscopy calibration of the degree of (irreversible) graphitization of carboniferous material inside the samples. Thermodynamic modelling and estimation of P-T paths is still in progress.

Maximum temperatures range from 341±14°C to 585±22°C. Permian samples show the lowest grade, with temperatures < ~400°C, while temperatures for Paleozoic and Precambrian samples are generally > 500°C (the latter ones showing slightly higher temperatures).

This high-resolution spatial distribution of temperatures places constraints on the structural evolution on our representative transects and provides a refined tectono-metamorphic frame, with implications for the geodynamic evolution of the Sanandaj-Sirjan zone.

# Determination of parameters of the Earth's crust types in the Eastern Black Sea Basin based on complex interpretation of reflection plus refraction seismic data and potential fields

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The purpose of this study is to create a model of the deep structure of the Eastern Black Sea basin basement, based on the analysis of the latest geophysical studies in complex with the retrospective geologic data of the region.

In our study we relied upon the materials of regional CDP reflected waves studies in the Black Sea received in 2011–2012 under an international research project implemented by Geology Without Limits. The advantages of this survey are distinguished by their regional nature of the research, which allows referring to the tectonic structures of the area in question. Within the framework of the scientific cooperation agreement with the University of Southampton, our team of authors got access to the materials of the the Ocean Bottom Seismometer survey (OBS) survey. Additionally, the data of Sandwell v 23.1 satellite altimetric survey, and of the global Earth Magnetic Anomaly Grid св EMAG3 were used to data interpretation.

To study the deep part of the section, we need to involve additional a priori information along with seismic survey materials. CDP data allowing forming a concept about the shape of borders and the character of extension of the studied horizon, virtually do not give any information about the substance composition. The OBS materials, in turn, make the analysis of the structure’s substance composition possible, by evaluating the elastic waves’ transmission velocity. Unfortunately, within the area studied, the OBS method is only represented by a thin net of 2D lines, which reduces substantially the accuracy of the area’s interpretation constructions.

As additional information about the basement structure, the results were used of the solution of the gravity force’s anomalous field depth inversion (using GeosoftVOXI software).

As boundary conditions for the inversion, the start model's geometry was limited by the basement surface. As basic inversion field, the previously obtained gravity force's anomalous field with reduced water layer and sedimentary cover's effect was used.

The integrated analysis of CDP, OBS and potential fields data allowed creating regional patterns and updating the material composition of the Eastern Black Sea basement. Using the gravity field inversion (with establishment of boundary conditions based on the existing seismic data), building two-dimension petro-density models, and performing integrated interpretation of the seismic data, we managed to determine the horizontal position and depth horizons of the submerged blocks of sub-continental crust – the Shatsky Rise, the Andrusov Rise, the Arkhangelsky Ridge, the Ordu Ridge and local elements of the Eastern Black Sea basin tectonic structure. Determine a system of the Eastern Black Sea basin faults (mainly east-west trending and north-south trending).

The result of this study is the creation of a regional crystalline basement grid of the Black Sea basin. The principal difference of this grid from similar but more regional schemes is the presence of the thinned sub oceanic crust within the Eastern Black Sea basin, and more accurate delineation of boundaries of the crystalline basement structural elements. elements within the Eastern Black Sea basin: the Arkhangelsky Rise, the Eastern Black Sea hollow, the Ordu Ridge.

# The metamorphic core of the Zagros orogen and the contrasts with the Himalayas

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Metamorphic core zones are the key elements of orogenic belts, preserving records of pre- and post-collisional deformation in the overriding plate, and may be indicators of the stage of tectonic development of any given collision zone. The Sanandaj-Sirjan arc (SSA) of Iran-Iraq is a region of intense plutonism and polyphase deformation localized along the northern side of the Neotethyan suture of the Zagros Mountains, and represents the "core zone" of the Arabia-Eurasia segment of the broader Asian collision zone. Metamorphism of Paleozoic-Mesozoic cover rocks is generally subgreenschist to low greenschist facies, but locally increases to Buchan-type amphibolite facies near Jurassic to Paleocene batholiths. Barrovian-type metamorphism is restricted to fault-bounded basement blocks exhumed either by extensional detachment within the SSA or localized as thrust slices near the suture zone. However, first-order questions still surround the metamorphic history. For instance, 1) what was the metamorphic grade of Gondwanan basement rocks before the voluminous Prototethyan, and Neotethyan arc magmatism? 2) How much of the metamorphism is due to the early Cimmerian orogeny and closure of the Paleotethys Ocean? And, 3) Is there any relationship between magmatism or metamorphism within the SSA and the Africa-Arabia collision, as is the case for the Himalaya and India-Asia collision? Initial metamorphic grade of the Precambrian basement rocks is still an enigmatic aspect of the SSA due to the general lack of isotopic dating, but at least in Takab region, the age of Buchan-Barrovian metamorphism of the Precambrian protoliths is already pinned down as Paleocene, using U-Pb dating of monazite; coeval with the age of granitoid emplacement in the region. In regard to attributing the pre-Shemshak tectonic deformation and the folding of kyanite-grade metamorphism in the southeastern SSA to the Late Triassic-Early Jurassic collision of the northern margin of the Cimmerian continent with Turan block, the closing of Paleotethys does not explain why the most intense tectonic deformation and metamorphism are on the southern margin of the Cimmerian continent rather than to the north. Also, peak metamorphism in the southeastern SSA occurred in Middle Jurassic time, well after closing of the Paleotethys Ocean. The Middle Jurassic metamorphism there overlaps with the peak of Neotethyan arc magmatism in the region, based on U-Pb dating of zircons from the granitoids. As regards the third question, a review of $^{40}Ar/^{39}Ar$ thermochronology data on white micas from the metamorphic core across the SSA reveals two peaks in cooling and exhumation through the 370˚C isotherm, one in the Middle Jurassic and the other in the Paleocene time. These ages predate the mid-Tertiary Arabia-Asia collision. In contrast to the Himalayan collision zone, there is no record of post-collisional anatexis of the downgoing slab, at least at currently exposed structural levels. Rather, these ages, and the preservation of mostly Buchan-type pre-collisional metamorphism, suggest that the metamorphic core of SSA has largely evolved from the plutonic heat of the Mesozoic-Tertiary arc magmas, and is generally devoid of post-collisional metamorphism and intracontinental anatectic granites.

Regional metamorphism in the Zagros and the Himalayas thus exhibit unambiguous contrasts that may reflect two different stages in orogenic evolution and, in particular, denudation of the upper levels of the metamorphic core. The Himalayan mountain belt of Pakistan-India-Tibet and Nepal represents a region of more complex deformation that includes the development of extensively exposed, thick crustal nappes exhumed from mid-crustal depths. In addition to pre-collisional, Andean-type plutonic belts (and the related Buchan-type metamorphic rocks), it contains two parallel, collision-related granitoid belts of Miocene age, and four distinct metamorphic zones. None of these post-collisional features have been identified in the SSA. In particular, the Central Himalayan metamorphic belt includes an inverted metamorphic system of late Miocene-Pliocene age quite unlike anything observed within the SSA. Although the SSA probably contains some manifestation of collision-related metamorphism at deep crustal levels, but their absence at currently exposed levels is clear. We conclude that despite their similar position along the Asian collision zone, the SSA lacks any record of the collision-related metamorphic rocks that characterize the metamorphic core zone of the India-Asia collision zone. The contrast may reflect the fact that India-Asia collision process began 20 to 30 million years earlier than the Arabia-Asia collision, and thus represents a more “mature” stage of mountain building.


# Applying of Depth- Number fractal modeling to determinate the seismic zones of Makran accretionary wedge, SE IRAN

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## Abstract:

The Makran accretionary prism in the south east of Iran, tectonically is consequence of Indian oceanic crust beneath the Iranian continental crust convergence and subduction. Numerous studies mentioned that Makran trench shows abnormal seismic pattern which undiscovered and non-understood completely yet. This investigation attempt to consider Makran seismicity since 1900 till 2014, based on the ISC seismic data catalogue, satellite images and geological maps by applying fractal

Depth-Number (D-N) method. The usage seismic data processed and reclassified in term of the magnitude and depth. According to the log- log plot, the Makran seismicity divided to four population zones with thresholds 1, 1.52 and 1.82 that are equal to 0.018, 0.217 and 2.33 which represent “shallow zone”, “middle zone” and “deep zone”, respectively. The fractal models by MATLAB defined an asymmetric convex pattern occurs in the middle zone. On the other hand, the deep zone shows semi-symmetrical seismic pattern with shallow zone. The data spatial distribution reveals tow gaps in 33.11 and 125.8 km depth which were related to the Makran basement and the subduction in high temperature conditions. Additionally, an oblique subduction toward the Zagros-Makran transition zone is expected.

**Keywords:** Depth-Number fractal model, Seismicity, Makran, MATLAB.

# Subway Vibrations Impact Assessment on H/V curves in a selected region in Tehran

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Nowadays, with the ever growing population of cities and the increasing demand for housing, many approaches have been made to improve the safety of buildings in case of natural hazards, specially earthquakes. Since Tehran, the capital of Iran, is a populated metropolitan surrounded by active faults and is founded on alluvium; the study of site effects in Tehran is a necessity.

Utilizing ambient vibrations known as microtremors (short period vibrations that result from natural or artificial sources), to estimate site effects, is now widely regarded as a cheaper and a more environmentally friendly method than borehole logging specially in urban areas.

The H/V method (Nakamura's technique, 1989) is evaluated by the ratio between the Fourier amplitude spectra of the horizontal and the vertical component of microtremors which contains some of site properties.

Nakamura (1989) assumed, only the horizontal component of microtremors is influenced by soil properties and minute vertical movements will not be amplified by surface layers, but the spectral properties of the source in both horizontal and vertical components will be preserved.

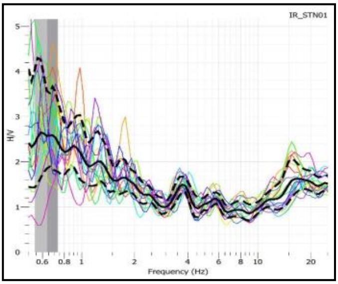
In this study, a microtremor survey of 4 points (single station basis) near Tarasht subway station in Tehran was carried out. The data were recorded in two periods, first at midnight when there was no subway activity (vibration) and second at noon when subway activity was at its peak in order to compare the effects of subway vibrations on site effects. Utilizing the H/V method the resonance frequency ($f_0$) and amplification factor ($A_0$) of the soil for each station was measured (Table 1).

According to the results, the fundamental frequency for each station at midnight, when there is no subway activity, is below 1 Hz for all the stations but the fundamental frequency at noon, when activity reaches its peak and vibrations associated with subway activity are recorded, is more than 2 Hz and about three times the measured frequencies at midnight. The amplification factor corresponding to the maximum of H/V curve for each station at midnight has different values between 1.5 and 3.5, but at noon when the vibrations associated with subway activity are at their highest, this factor had smaller values than that of midnight (Figure 1).

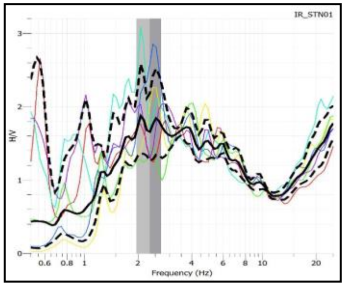
The results show that subway activity and its associated vibrations and other ambient noise in the area have significant effects on fundamental frequency and amplification factor of soil. For this reason It was proposed that for reducing the adverse effects of subway vibrations, it is better to carry out microtremor surveys at a time when subway activity is at its lowest, for example at midnight and also at a place where is far from moving subways if possible.

**Table 1.** Results of fundamental frequency and amplification factor.

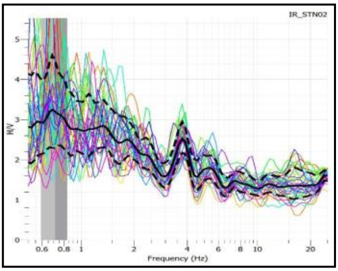
| | **Peak subway activity** | | **Non-subway activity** | |
|---|---|---|---|---|
| **station** | **$f_0$ (Hz)** | **$A_0$ (max H/V)** | **$f_0$ (Hz)** | **$A_0$ (max H/V)** |
| 1 | 2.33 | 1.66 | 0.64 | 2.58 |
| 2 | 2.32 | 2.41 | 0.71 | 3.2 |
| 3 | 2.41 | 1.23 | 0.8 | 1.74 |
| 4 | 3.83 | 1.16 | 0.69 | 2.18 |



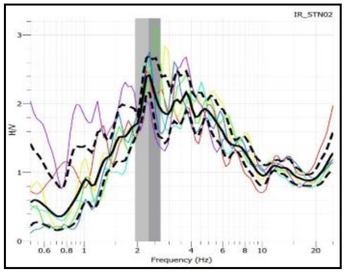

*a.*




*b.*




*c.*




*d.*

**Figure 1.** Resulting H/V curves for stations 1 and 2 using Geopsy software. The solid black lines show the mean H/V curve and the dotted black lines show the standard deviation range: Survey results carried out at midnight (left) and survey results carried out at noon (right).

# The Urmia Lake Carbonate Beachrocks in Golmankhaneh Area, NW Iran

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## Abstract

Lake Urmia, in the northwestern corner of Iran, is one of the largest permanent hypersaline lakes in the world and the largest lake in the Middle East. This closed continental basin with high ecological significance is

recognized as a national park and a UNESCO Biosphere Reserve, and has been protected under the Ramsar wetlands convention. Such a unique lacustrine basin has been faced with a sharp decline in water surface (which is directly affected by the entering runoff) in recent years. This dramatic decline, as a function of extensive anthropogenic activities and general climate aridification, is putting the survival of the Urmia Lake at risk.

The critical situation of the lake caused many governmental and non-governmental organizations to pay attention to the matter. Meantime, the achievements in the Paris climate change conference created a positive atmosphere for international activities to restore Lake Urmia. The newly started French-Persian project is one of the recent lake rescue projects aiming to obtain high resolution records of the Holocene paleoenvironmental and paleoclimatic changes in the lake area, and to indicate human impacts on this ecosystem.

Sedimentological study of the Holocene deposits of the basin is a part of the mentioned comprehensive project to show evidences of the paleoclimatic and paleoecologic changes and lake level variations. For the first step, two sediment cores (each of them ~12 m long) have been obtained from recently dried out parts of the western corner of the Urmia Lake (Golman-Khaneh area). The core sediments are not yet dated; nevertheless, they most probably present the latest Pleistocene and Holocene. The studied sedimentary succession consists of great amounts of sand with intercalations of organic matter rich clayish/silty deposits, and some horizons of palesol. The upper (thin) part of the succession, which is exposed at the surface as beachrock, comprises 10 to 15 cm of well cemented hard crust of carbonates. Detailed facies analysis of the Golman-Khaneh beachrocks (based on field observations and laboratory studies) has led to recognition of sandy ooid grainstone and peloid (fecal pellet) grainstone facies. Occurrence of the carbonate beachrocks in the overwhelmingly silicilcastic environment indicates reduction in sediment influx from the land and considerable lake level rise during Holocene, related to climatic oscillations. Thinness of the carbonate beachrocks in the studied area can be attributed to short period of the lake level highstand or subsequent erosional phase.

**Key words**: Core Sediments, Beachrocks, Carbonate Facies, Lake Level Fluctuations, Holocene, Lake Urmia, Iran

# Links between long-term and short-term rheology of the lithosphere: insights from strike-slip fault modeling

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The classical inter-seismic mechanical models of the lithosphere assume that the Earth lithosphere is a horizontally layered medium with homogeneous rheological properties at a given depth. Recently, more sophisticated models have been proposed in order to include lateral variations of physical parameters. These models have been shown to be as effective, and sometimes more, at reproducing the geodetic data during the seismic cycle than the laterally homogeneous stratified models.

These new models have in common to require a finite width low viscosity zone underneath the fault zone. Proposed explanations for the formation of these localised low viscosity zones include grain size reduction, shear heating and localised presence of fluids. All these mechanisms are valid in order to locally weaken an initially strong lower crust. However, they are not efficient to localise strain across strike slip faults in post-orogenic setting when the lower crust is already weak.

A previous numerical modelling study showed that metamorphic core complexes are exhumed underneath transtensional step-over in post orogenic setting. Here, we designed a parametric study of the impact of the initial thickness of the weak crust and the width of the step-over on the intensity of strain localisation. We find that the smaller the width of the step-over and the thicker the lower crustal low viscosity channel are, the most intense is the localisation.

In a second round of experiments, we do not impose the step-over kinematic and find that transtensional boundary conditions are sufficient to trigger long lasting weakening of the crust through the exhumation of lower crustal material. This long-term tectonic structural modification of the crust obtained over long time scale results in localised low viscosity weak zones that develop selfconsistently beneath strike slip fault zone within the aseismic part of the crust.

Having shown that in post orogenic settings, the long-term strain localisation occurs through geometrical reorganisation of the original layering, we introduce this modified geometry into viscoelastic models intended to mimic the interseismic behaviour of a strike slip fault. We find that this modification of the geometry of the brittle-ductile transition is sufficient to explain the inter-seismic strain localisation across a strike-slip fault zone. We conclude that long time after an earthquake has occurred, the interseismic geodetic signal is more prone to reflect the rheology of the crust than post-seismic relaxation.

# Geology and Origin of Mineralization in the Mehdiabad Zn-Pb-Ba (Cu) Deposit, Yazd Block, Central Iran

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The Zn-Pb-Ba (Cu) Mehdiabad deposit is located in the Yazd Anarak metallogenic belt, 550 km to the southeast of Tehran. The host-rock of the deposit consists of silty limestone and dolomite in Lower Cretaceous sedimentary series. The main occurrences are the Calamine mine (CM), the Black-Hill Ore (BHO), the East Ridge (ER) and the Central Valley Orebody (CVOB). The orebody consists of primary sulfide ore and supergene non-sulfide ore, this latter one having been mined at CM. The total geological resource of the Mehdiabad deposit is about 218 Mt at 7.20% Zn, 2.30% Pb, and 51 g/t Ag. Despite its huge size, the deposit has been scarcely studied. Modern investigations only include the geology and the mineralogy of the deposit, as well as geochemical constraints on the oxide ores and pas to current weathering conditions. The classification of the Mehdiabad is currently debated and it has been considered as MVT, Irish-type [1] or SEDEX deposit.

Mineralization occurs as stratabound blanket-like, tabular orebodies and breccias. Zn-Pb-Ba (Cu) mineralization of the Mehdiabad deposit occurs along two horizons. The sulfide and non-sulfide ores of horizon I (BHO, CVOB, ER) is hosted within organic matter-rich shale, silty limestone, dolomite and silty shale of the Taft Formation, whereas the non-sulfide ore of the ore horizon II (CM) are hosted in limy shale and thin-bedded limestone of the Abkuh Formation. The most abundant sulfide minerals within the ore horizons are sphalerite, galena, pyrite and chalcopyrite that coexist with baryte. Diagenetic replacement textures, pyrite framboids and laminated colloform sulfide aggregates were recognized. Together with the presence of normal syn-sedimentary faults and the lateral metal zonation, these features support that sulfide mineralization was coeval with the formation of the Lower Cretaceous host rocks.

The non-sulfide ore include hemimorphite, hydrozincite, and smithsonite, as the principal zinc-bearing minerals. Cerussite and anglesite also occur, generally associated with lenses of residual or supergene galena. The non-sulfide zinc ore of the Mehdiabad deposit can be subdivided into a red zinc ore (RZO), including Fe-oxi-hydroxides such as goethite, hematite, and a white zinc ore (WZO). Two important factors have contributed to the genesis of the non-sulfide mineralization: 1) the proximity to the surface of the sulfide ore and 2) the presence of highly permeable karst-originated breccia that allowed percolation of metal-rich groundwaters.

# Prediction of Magnitude and Epicentral Distance from a Single Seismic Record

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## ABSTRACT

The Magnitude and an amplitude parameter $P_{max}$ determined from the very beginning of P wave are important for earthquake early warning (EEW), yet their dependence on source mechanism, focal depth and epicentral distance has not been fully studied. We examined a method to estimate an earthquake's magnitude and epicentral distance using only initial part of P-wave data (3 s) for application in earthquake early warning systems (EEWS). The B-Δ method is used to estimate the epicentral distance from a single station data in a short amount of time. Fitting a simple function with the form of *y(t)=Bt*exp(-At)* to the first few seconds of the waveform envelope, coefficients *A* and *B* are determined by the least-squares method. *Log B* is inversely proportional to *log Δ*, where *Δ* is the epicentral distance. This relation holds true regardless of earthquake magnitude. *B* values are calculated on the basis of vertical-component accelerograms of Iranian earthquakes with magnitude range $M_w=4.5\text{-}6.5$ and epicentral distances less than 120 km. Using this method, we could estimate the epicentral distance by $\log\Delta=-0.7\log B+2.52$ and earthquake magnitude by $M_{est}=1.9\log P_{max} - 1.76\log B + 5.6$. The greatest advantage of this method is its accuracy and rapidness.

**Keywords:** Earthquake Early Warning Systems, B-Δ method, Single Station.

# The Makran Subduction Zone an area of Complex Seismicity

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The Makran subduction zone is the result of northward subduction of the Arabian Plate beneath the Eurasian plate in the northwestern Indian Ocean. The region has a complicated tectonic setting located at a triple junction with the Indian Plate The evolution and deformational history of an accretionary complex is the result of a continuous process, not series of separate events. Therefore, some of the provinces defined today do not represent different tectonic/structural settings or events, but as different stages in the evolution of an accretionary complex. Also, what has been observed and defined offshore is an integrated part and continuation in time of the onshore areas, only younger in age and to some extent less deformed. Thus, understanding the onshore is important, both for the offshore tectonic evolution and the depositional history.

The Makran Subduction Zone is unique due to its geological and seismological characteristics. It shows relatively low seismicity in comparison with the surrounding region and other subduction zones. This differences also could be seen at the east and west Makran region, where the western Makran shows much lower seismicity compared with the east. However, three tsunamis in the Makran region have been reported; including two events of seismic origin. The most recent tsunamigenic event occurred on 27 November 1945 associated with an earthquake of magnitude 8.1. It caused about 4000 casualties along the Makran coast affecting Iran, Pakistan, Oman and the United Arab Emirates. At the time, only a few villages were located along the Makran coast, some of these coastal villages have since developed into fast-expanding cities with hundreds of thousands inhabitants. Since then, the relative long period without large events is posing a potential threat of major tsunamigenic disasters in this coastal region.

The recent advances in tsunami study has led the scientist for better understanding of the cause of tsunami, its propagation and most importantly the system of warning ahead of tsunami arrival to the vulnerable coastal area. In addition now the secondary sources' for strengthening the devastating effect of the tsunami for example the splay faulting, landslide caused by the parent earthquake sources has been advancing. The onshore earthquake close to coast or located at the onshore part of the subduction zone has triggered creation of mud-volcano Island offshore and onshore for example large earthquake of onshore Iran 2013 event need to be considered.

So a more comprehensive study both on the onshore and offshore is essential in better understanding of the region. This has led to the plan for seismic data acquisition and other required non-seismic data such as GPS and some initial geological field work. In this presentation the recent development will be elaborated and discussed.

# Iron-oxide mineralogy of banded iron formations in the Takab region, North Western Iran

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**Abstract.** Siliceous banded and nodular iron ores intercalated in mica schists and marbles of Precambrian age, were studied from the NW part of Iran (Takab region). The iron ore is composed of magnetite, which was partly transformed into maghemite and hematite along fractures and cleavages during a major oxidizing deformation event. Quartz shows undulose extinction. Both quartz and iron oxides partly form 120° triple

junctions, but essentially grain boundary migrations. In the nodular ore, grain boundary migration is more pronounced leading also to grain isolation quartz is partially annealed. Iron oxides are agglomerated, elongated and disrupted. These finding indicate a longer recrystallization episode in the nodular ore. The iron oxide grains contain inclusions of euhedral, zoned and corroded zircons and euhedral monazite. Magnetite contains traces of Al. Hematite and goethite show higher Al, Si and Ca contents. Later hydrothermal solutions precipitated goethite surrounding the magnetite-hematite-maghemite grains and replacing hematite. Barite and uraninite occur in fractures of iron oxides, Mn-Ba-Pb oxi-hydroxides and scheelite occur interstitial to iron oxides.

# Spatial extent of intermediate-time scale vertical tectonic motions across the eastern Zagros, Iran

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The Zagros fold belt of Iran marks the present southern front of the broad Arabia-Eurasia collision zone. GPS and seismicity show the Zagros absorbs an important part of the overall convergence. Our study area covers south-eastern Zagros, where the continental collision (the Zagros) switches to the oceanic subduction (the Makran wedge). We have mapped deformed fluvial terraces along the Kol River using kinematic GPS and high-resolution imagery in order to unravel the spatial extent of vertical displacements and to analyze active deformation and its implications for seismicity. The Kol River intersects a few active folds and faults, as well as Mountain Front Fault (MFF) and High Zagros Fault (HZF). The long profile of the river shows two different spatial extent of

vertical incision, 1) short-wavelength incision ($d_s$), controlled by structural reactivation of pre-existing structures and lateral folds propagation (plunge panel growth), and 2) master relief breakpoints along the river ($b_n$) toward the entire course of the river (toward the HZF). We attribute both distribution patterns of vertical incision (raised river terraces) and topography of the river channel to reflect differential rock uplift (mechanism and time) along the river. The $d_s$ and $b_n$ are respectively consistent and inconsistent with the seismicity pattern. We suggest a young scenario of geologic strain accommodation over the active ramp of the MFF. On the other side, we estimate limited slip for the HZF, consistence with the current hypothesis about uplift propagation across the Zagros belt and through time toward the foreland. Cosmogenic nuclide exposure ages of the Kol River strath terraces (in process) improve understanding of recent crustal deformation rates and its variations through time and space across and eastern Zagros. Such information helps to provides more reliable estimates of seismic hazard for the Zagros, amongst the world's most seismically active mountain ranges.

# Metal Fractionation between Water-Liquid Hydrocarbon and Solid Organic Matter produced by Interaction between Carbonaceous Rocks and Hydrothermal Solution: Simulation in batch reactor

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Affinity of metals for organic matter is explained by redox properties or complexation even if the nature of complexes is not well known. MVT, roll front type, salt diapir are the most common deposits where organic matter and metals are associated. Oil shales are source rocks for oil but also sources of metals. The simulation of thermal maturation conducted on samples of immature source rocks should help to understand the behaviour of metals during diagenesis and metamorphism in carbonaceous environments.

The scientific objective of this study is to model the maturation of organic rich shales (kukersite) from Slantsy (Russia) in presence of hydrothermal solution in lab. Experiments were conducted to approximate the partition coefficients of metals between oil and water. Hydrous pyrolysis (Lewan 1983; 1993) was performed on shale samples in the presence of pure water (experiment A) and of an aqueous solution enriched in metals (Cu, Mo) (experiment B). In the second case, natural quartz rich in decrepitated inclusions has been added in order to trap the fluid phases generated during the experiment (Pironon et al. 2007). At the end of experiments, quartz with fluid inclusions, expelled oil, residual kukersite impregnated by bitumen, and water were collected and analysed. Expelled oil occurred in the reactor as a floating layer on the water surface and as adsorbed pyrolysate on the rock fragments. The final purpose is to evaluate the metal partitioning between rocks, generated hydrocarbons and aqueous solutions. Indeed, interactions between rocks enriched in organic carbon and high temperature (>300°C) hydrothermal fluids are poorly known.

The analysis of Slantsy combustible shale before experiment shows a major elemental composition dominated by volatiles (71% of LOI). This mostly corresponds to organic and inorganic carbon (50 mass%,), water and sulfur (1.5 mass%). The inorganic phases are dominated by calcite and aluminosilicates. The $Fe^{2+}$ / $Fe^{3+}$ ratio is close to 0.5. The trace elements with a strong affinity with carbonate, clay and/or organic materials are the most concentrated (Sr, Zn, Ba, Pb, Ni, Rb, V).

Metal concentration in expelled oils is low and do not exceed 5 ppm. Cr and Ni coming from the corrosion of the autoclave display similar concentrations in the two experiments. Cu moved from the doped aqueous solution to the expelled oil B. At the opposite, Mo is less concentrated in experiment B than in experiment A. The experimental conditions have allowed the synthesis of fluid inclusions and the genesis of liquid oil and gas. $CO_2$ concentration is probably of mixed origin, coming from organic matter maturation and carbonate dissolution. LA-ICPMS technique has shown its ability to detect trace elements inside aqueous solutions, oils and solid residues. The experiments show that metals are mainly concentrated into the solid residue. Oil is suspected to concentrate Cu, Ni and Cr and not Mo. These results are very promising in understanding mechanisms of hydrocarbon maturation and element partitioning during fluid-rock interaction.

# Meteorites from the Lut Desert: Commencing a New Field of Study in Iran

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After their fall on the surface of the Earth, meteorites are under the destructive effects of the terrestrial environment. Water is amongst the most important agents that control the meteorite weathering process [1]. Dry climate makes the hot and cold deserts suitable regions for better preservation of meteorites. Collecting deserts meteorites, gives us the opportunity to have access to different types of extraterrestrial samples to study the formation and the evolution of solar system. In addition, they give information about the flux of extraterrestrial matter in time and space, their weathering process, and palaoclimatic conditions of the hosting surface at the 10-100 ka timescale [2].

Lut Desert (Iran) was suggested as a potentially suitable place for meteorites preservation [3]. Field works in this desert during the last two years resulted in recovery of hundreds of meteorite fragments.

Our systematic study on these meteorites deals with their classification, distribution, and weathering. Classification of these samples, which appear in the Meteoritical Bulletin of the Meteoritical Society, shows that all of them are ordinary chondrites. The majority of them are H5 with a high probability of being paired. Following the H5s, recently L5 chondrites have been recovered in high numbers and look to be paired as well. L5 samples represent a very well preserved fusion crust, in contrast to most of the H5 meteorites which have lost the fusion crust during weathering.

Optical microscopy and the measurement of magnetic susceptibility reveals that the H5 samples are heavily weathered and the original FeNi metal and troilite are transformed to Fe oxides/hydroxides. Magnetic susceptibility tends to decrease with increasing the weathering grade, however in some highly weathered samples it increases. This effect is related to the formation of secondary magnetic minerals. In contrast to H5s, in most of the L5s, less than 20 % of the primary

FeNi metal and troilite is weathered which shows a younger terrestrial age for these samples than H5s.

Whole rock chemical compositions of representative samples from the Lut Desert, show that terrestrial weathering has resulted in observable changes in the composition of these samples compared to the average composition of fall chondrites. Among them the most significant changes include increasing Li, Sr, LREEs, Tl, Th and U and decreasing Cr and Rb contents. Modification of the REE composition suggests a fast weathering rate and a wetter climate than today over the last tens of thousands of years.

Our studies on the weathering of meteorites from Lut and comparing them with the samples from other hot deserts, show significant differences in the weathering processes occurring in different regions with different climatic regimes.

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# Active fault studies in the Tehran region, North Central Iran

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The capital city of Iran, Tehran with a population about one-fifth of the whole country population, is located in the southern part of the Central Alborz mountains. These mountain ranges accommodate a part of tectonic deformation that is originated from the convergence between the Arabian and Eurasian plates. Active fault studies in this region indicate that not only the northern and southern parts of the city are controlled by the main active faults (such as; Mosha, North Tehran faults from the northern part and North Ray, South Ray, Kahrizak and Pishva faults from the southern part but also there are several shorter active faults inside the city (such as; Mahmoudieh and Davoudieh faults). Our recent studies show that the morphology of all E-W alluvial hills within the city (such as; Lavizan, Abbass Abad-Guisha, and Chitgar hills) is controlled by active fault segments. The fault strands could be related to an en echelon left-stepping basement fault zone. This en echelon pattern is propagated not only inside the city but it is continued both to the east and west. Based on the studies on fault geometry and kinematics, slip per-event and preliminary slip rate, this seismic zone is capable to produce moderate to large seismic events within the capital city.

# Kinematics of active faulting in Alborz and implications for recent changes of regional geodynamics within the South-Caspian region.

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We herein review and discuss the question of the kinematics of active faulting in Alborz and the question of the recent geodynamical evolution of the South-Caspian region. Many works have proposed that the present strain-partitioning observed in Alborz (i.e. left-lateral wrenching associated with range-parallel thrust faults) is associated with the westward motion of the South-Caspian basin (eg Jackson et al., 2002). But the question of the onset of this motion is still in debate. Hollingsworth et al. (2008) proposed that the South-Caspian basin motion started 10 Ma ago. This is twice earlier than the ~5 Ma proposed by Axen et al. (2001) and Allen et al. (2002), and even more than the ~ 1.5 Ma proposed by Ritz et al. (2006).

Axen et al. (2001) and Allen et al. (2002) interpretation is based on the observations in western Central Alborz, where the combination of range-parallel right-lateral faults and thrusts indicate that this part of Alborz was a right-lateral transpressional zone 5±2 Ma ago, which gives a maximum bound for the onset of the South Caspian basin westwards motion.

Using a morphotectonics approach, Ritz et al. (2006) showed that a recent change in kinematics occurred along the Mosha, Taleghan and Firuzkuh faults in southern Central Alborz. At large time and space scales, these faults correspond to thrust faults characterized by the overthrusting of Paleozoic and Mesozoic formations over Neogene formations. However, when studied over the Quaternary time scale, these faults appear as strike-slip faults along which the left-lateral wrenching of the Alborz mountain range is occurring. Along the Mosha and Taleghan faults, this left-lateral motion is associated with a normal component due to the obliquity of the faults with respect to the general trend of the range (Ritz, 2009). The cumulated topography associated with the normal component is small and does not reverse the reliefs showing that the kinematical change (from mainly reverse to left-lateral-normal) is recent. The total horizontal displacement and the associated horizontal slip rate along the Mosha fault being estimated at 3-5 km and of ~2 mm/yr, respectively, the change of kinematics would have occurred between 1.0-2.8 Ma ago, contemporaneously with the onset of the Damavand volcanic activity.

In eastern Central Alborz, Hollingsworth (2007) described about the same amount of total displacement along the Jajarm fault (4–5 km). Assuming that the 2–4 mm/yr of left-lateral shearing measured by GPS across eastern Central Alborz (Djamour et al., 2010) is taken mainly along this strike-slip fault, and that this slip rate remained constant over the Pleistocene, then the beginning of the left-lateral wrenching inside the Alborz - and therefore the beginning of the westwards motion of the South-Caspian basin - is also estimated around 2 Ma.

But, if we consider the interpretation of a total right-lateral displacement of 35 km across the Mosha fault in Central Alborz (Allen et al., 2003) and along the Ashkabad fault in Kopet Dagh (Holligsworth et al., 2008), the onset of the south-Caspian westward motion would be rather around ~10 Ma.

Moreover, it is true that features as the 80 km deep earthquakes beneath the Apsheron-Balkan Sill (ABS) (Jackson et al., 2002) or the Pliocene subsidence observed within the northwest of the South Caspian basin (Allen et al., 2002) suggest that the South Caspian basin had started subducting below the ABS before the Pleistocene.

It seems therefore, that the motion of the South Caspian basin is more complex than proposed so far A possible interpretation is to consider that a northwards subduction first started between the mid-Miocene and the Pliocene, and then a westward component of motion - associated with a clockwise rotation of the basin (Djamour et al., 2010) has been added during the Pleistocene (Ritz, 2009).

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# The Khuzestan Dust, Geological and Environmental Evidences, SW Iran

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Recently the Khuzestan province in southwest of Iran is affected by duststorm phenomena and makes some problems in agriculture, Transportation, Communication and human health side effect in this province. Mineralogy, Geochemistry of particles and Geo-Environmental characteristics of trace elements is very important for detecting of major pollutant. The collected dust samples were analyzed for grain size, mineralogy, and chemical composition. The dust is predominantly Aluminosilicates (clay minerals and feldspars), quartz and carbonates with minor amounts of gypsum. The particles are mostly sub-rounded to sub-angular and generally between 5 to 20 µm in size. XRD studies show that calcite and quartz are the major constituents in most samples, and clay minerals such as Illite and Kaolinite are also present. The most important oxides are SiO2, Al2O3, Fe2O3, CaO and MgO. An eroded sedimentary environment presented for the source of these particles. Factor analysis has been done, and four factors extracted in this work, Enrichment Factor for all measured elements show that most of elements analyzed have a natural abundance. However, several elements such as Ba, Ni, Nb, Cr, Ca, Pb, Co and Mn have higher than natural abundances due to anthropogenic enrichment by various enrichment factors. Some ratios like Ti/Nb, Ga/Al, Rb/K show all of the dust samples have chemical homogeneity and indicating a similar provenance or source area. The dust aerosol samples have very similar rare earth element (REE) patterns, with relative enrichment of light REE, a slight depletion of heavy REE, and a strongly negative europium anomaly.

**Keywords:** Dust, Khuzestan, Environmental, Mineralogy, Geochemistry

# Assessment of seismic damage level at urban scale: a new approach based on ambient vibration measurements with an example case study on Beirut (Lebanon)

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Post-seismic investigations repeatedly indicate that structures having frequencies close to foundation soil frequencies exhibit significantly heavier damages (Caracas 1967; Mexico 1985; Pujili, Ecuador 1996; L'Aquila 2009). However this observation is generally not taken directly into account neither in present-day seismic regulations (small scale), nor in large-scale seismic risk analysis.

The present paper thus focuses on a comprehensive numerical analysis to investigate the effect of coincidence between site and building frequencies, with an example application to the city of Beirut (Lebanon). A total of 887 realistic soil profiles are coupled with a set of 141 single degree-of-freedom (SDOF) elastoplastic oscillators, and their combined response are computed both for linear and non-linear soil behavior, for a large number (60) of synthetic input signals with various PGA levels and frequency contents. The associated damage is quantified on the basis of the maximum displacement as compared to both yield and ultimate post-elastic displacements, according to the RISK-UE project recommendations (Lagomarsino and Giovinazzi, 2006). It is also compared with the damage obtained in the case of a similar building located on rock. The correlation between this soil/rock damage increment and a number of simplified mechanical and loading parameters is then analyzed using a neural network approach. The results emphasize the key role played by the building/soil frequency ratio even when both soil and building behave non-linearly; other important parameters are the PGA level, the soil/rock velocity contrast and the building ductility. A numerical investigation based on simulation of ambient noise for the whole set of 887 profiles also indicates that the amplitude of H/V ratio may be considered as a satisfactory proxy for site amplification when applied to measurements at urban scale. A very easy implementation of this method, using ambient vibration measurements both at ground level and within buildings, is illustrated with an example application for the city of Beirut (Lebanon).

Keywords: spectral coincidence, seismic damage, Neural Network, microtremor, Beirut.

# Lithospheric and Mantle deformation in the Western Iranian Plateau as Revealed by Seismic Anisotropy Measurements

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We present results from shear-wave splitting seismic anisotropy measurements on core –refracted seismic phases in the western part of the Iranian plateau. SKS and SKKS phases were used to infer the fast-axis directions and time delays of anisotropy under a vast region that comprises the NW Zagros, Western Alborz, The Talesh Mountains and NW Iran. The data come from four temporary passive seismic networks that we employed over a multi-year time interval. A total of 130 seismic stations cover the study region, with each station in operation for a period of 3 months to 3 years. With these measurements we are able to considerably extend our understanding of our knowledge of the state of lithospheric and upper-mantle anisotropy in the western part of the Iranian plateau. The measurements show a rather strong strike-parallel anisotropy under the Zagros orogen where various geophysical data show a very thick lithosphere (~ 250 km). Due to the large thickness of the lithosphere of the Zagros, the anisotropy signal is most probably controlled by the deformation fabric of the lithosphere, as opposed to being controlled by the underlying asthenospheric flow field. In the Alborz region and in NW Iran, the fast-axis directions are mostly SW-NE directed, which are at sharp angles to the strikes of the Western Alborz (NW-SE) and Talesh Mountains (N-S). Geophysical and other geodynamic data in Eastern Turkey, NW Iran and the Alborz show a considerably thinner lithosphere compared to the Zagros. Therefore the anisotropy signal will be controlled more by mantle flow processes than by the lithospheric fabrics. Sandvol et al. (2003) obtained very similar results in Eastern Turkey. Comparison of our results with that work suggests that there is a smooth continuation of the upper mantle structures from Eastern Turkey into NW Iran. The plate velocity vectors in the no-net rotation frame of reference in NW and Northern Iran are overall northeastward directed, and show strong correlation with the fast-axis directions we have obtained. We interpret the shear-wave splitting results in the Alborz and NW Iran as mostly asthenopheric in origin. In the interval between the Zagros Mountains in the South, and the Alborz in the North, are situated the Sanandaj-Sirjan Zone (SSZ), the Urmieh-Dokhtar Magmatic Arc (UDMA) and a sliver of central Iran. These regions mark the older subduction arc structures that existed prior to the Zagros and Alborz mountain building processes. The mantle wedge flow field under these regions, its deformational fabric and its mineralogical assemblage might have significant influence on the seismic anisotropic structure. In addition the processes of slab break-off that have been proposed during the evolution of the subduction and collision process in the Iranian plateau can greatly affect the mantle flow field and consequentially the anisotropic structure. There are sharp and discontinuous variations in the fast-axis directions as we transition from the Zagros to SSZ and UDMA. These directions go though several rotations over relatively short distances before finally transitioning to the SW-NE directions in the Alborz .

The significant variation in fast axis orientations from the Zagros to SSZ and central Iran, suggests a rapid change in upper mantle rheology. The rotation of chain parallel fast orientations in Zagros to the NE-SW trending further north which is perpendicular to collisional suture and parallel to no-net rotation plate motion vectors may be related to the asthenospheric flow. It could be as a result of the Neo-Tethyan slab break-off proposed by Agard et al. (2011) and the thinned lithosphere of the central Iran. Although the vertically coherent deformation of the crust and upper mantle is still a candidate mechanism, the asthenospheric flow seems to be the most probable scenario for generating the observed average delay times. To the north, the fast orientations continue to rotate toward the NW-SE trend which is perpendicular to the collision direction. In case of slab break-off, a local mantle flow around the remnant sinking Neo-Tethyan slab is the best candidate to justify the NW-SE trending fast orientations in northern central Iran and southern Alborz.

# The role of active couple indentation in geodynamics of N-NW Iran and its influence on synchronous left and right lateral earthquake faulting in Alborz and Iranian Azerbaijan

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**Abstract:**

In the central portion of the Arabia-Eurasia collision zone, the N-NW of Iran reveals an interesting active tectonism characterized by synchronous sinistral and dextral earthquake faulting along the co-linear WNW-striking West-Central Alborz and Iranian Azerbaijan neighboring zones. These structural zones are deforming as a single deformable territory between Central Iran and South Caspian more rigid domains. In this recent study, we investigate tectonic interactions of these active structural zones and their influence on the geodynamics of the N-NW of Iran based on morphotectonic and seismotectonic investigations. Indentation tectonics plays an important role in the geodynamics of this territory. In general view, the rigid Arabian plate acts as a main indenter which bulldozes the less rigid crustal domains ahead into folded belts and push some blocks aside. In this deformation system, South Caspian Basin plays role as a backstop. In the study area, the structural domains of Alborz (to the east) and Iranian Azerbaijan-Caucasus (to the west) are torn by NNW-striking Astara-Talesh dextral transpressional zone. Morphotectonic and seismotectonic features in this central portion of NW Iran confirm right lateral faulting concentrated along the NNW-striking deformation zone. We discuss also the contraction

trajectories derived from kinematics and geometry of active folding and faulting features observed in the study region. Our study highlights two prominent sets of fan-shaped trajectories dominated in the west and east sides of the N-S zone in Astara-Zandjan direction. The fan-shaped pattern of these two laterally convergent sets of trajectories within Talesh-Azerbaijan and Alborz domains can be explained by a couple-indentation geodynamic model.

# Geodynamics, ore deposits and fluid inclusions: Structural position and geochemistry of fluids associated with the Lavrion Pb-Zn-Fe-Ag district (Greece)

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Fluids are responsible of advective heat and element transfer within the Earth’s crust. The thermal-mechanical evolution of rocks involved in an orogenic wedge is associated with the circulation of fluids from different reservoirs, namely magmatic, metamorphic, meteoric, marine or diagenetic, promoting fluid-rock interactions leading to mobilisation, transfer and deposition of metals. Fluid inclusions evidence these paleofluid circulations. Their study is thus of key importance to understand ore deposition. An example relating fluid circulation, geodynamics and ore deposits is shown by the Lavrion Pb-Zn-Fe-Ag deposit in the Attico-Cycladic orogenic wedge formed during the Alpine orogeny.

From a multi-method and multi-scale approach using structural geology, petrography, mineral thermobarometry, element and isotope geochemistry, and

*PVTX* data of associated fluid inclusions, this study deciphers the relationships between fluid circulation, fluid-rock interactions and mobilisation-transport-deposits of metals. Marbles and schists from the Evia Island and the Lavrion peninsula testify a complex orogenic history marked by an Eocene burial phase followed by syn- and post-orogenic exhumation. Gravitational collapse of the Aegean belt, triggered by slab retreat, is accommodated by the activation of low-angle detachments and results in post-orogenic exhumation and an increase in the geothermal gradient. The structural position of Pb-Zn-Fe-Ag deposits from the Lavrion area attests of an emplacement during ductile to brittle deformation conditions. Mineralization (skarn, carbonate replacement) is associated with marble decarbonation and fluid circulation attributed to the emplacement of granodiorite magmas. The progressive exhumation of the orogenic wedge allows the transition toward brittle conditions and opens the system to surficial meteoritic fluids. This opening leads to a dolomitisation phase allowing localisation of the brittle deformation and the circulation of external fluid. This meteoritic fluid circulation is responsible to remobilisation of metals from primary deposits allowing thus a second phase of deposition in a pure brittle deformation (epithermal veins). Finally, the collapse of the orogenic wedge at its current level (sea level) resulted in a late supergene remobilisation phase in an oxidizing environment.

# Tectonic and climatic controls on mountain belt evolution: examples from the Himalaya and from Iran

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The relative controls of tectonic and climatic processes on mountain belt evolution have been a subject of study and discussion in the geodynamics community for over two decades, since the realisation that strong feedbacks may exists between tectonics and climatic, coupled through surface processes and the evolution of topography. However, while such feedbacks have been inferred from theory and modelling studies, it has proven challenging to demonstrate them in natural examples. In this presentation, I will demonstrate this on-going discussion through the example of the Himalayan mountain belt, and will subsequently highlight what we can learn from the evolution of the Zagros and Alborz mountain ranges in Iran.

In the Himalaya, lateral variations in topography, geological structure, exhumation and precipitation correlate strongly, sparking numerous studies on the processes controlling these links. In particular, it has been argued that strong exhumation at the topographic front of the high range is focused by climatic forcing, through orographic precipitation, and that this focused exhumation may have driven recent out-of-sequence thrusting in the mountain belt. However, thermo-kinematic model predict that tectonic factors, in particular the geometry of the Main Himalayan detachment along which India under-thrusts the Himalaya and Tibet, controls these spatial patterns in topography and exhumation. A quantitative comparison of patterns of topography, fluvial incision power and exhumation along transects where the detachment geometry is independently predicted to vary, corroborates this model. These results imply that along-strike climatic variations in the Himalaya respond to tectonics rather than driving it. The presence or absence of a mid-crustal ramp may be due to inherited structures on the under-thrusting Indian Plate or, alternatively, may reflect transient behaviour of the accreting Lesser Himalayan thrust stack, which may oscillate between frontal accretion (without a ramp) and basal accretion in the presence of a ramp.

However, climate may play a role in the overall structure and geometry of mountain belts through its control on erosion, sediment transport and deposition. New thermo-mechanical models show that the structural style of both thin- and thick-skinned fold-and-thrust belts is strongly dependent on the thickness of syn-orogenic sediments trapped in the fold-and-thrust belt, which is itself controlled by the climatically modulated efficiency of erosion and sediment transport. Application of this model to the Zagros mountain belt suggests that the large width and basement involvement in this belt may be controlled by inefficient sediment export from this arid region. The Alborz Mountains, in contrast, are a more classical doubly-vergent narrow mountain belt, although the relationship between orographic precipitation and the evolution of this mountain belt are not yet fully understood. This relationship may be complicated by kilometre-scale base-level oscillations through periodic drawdown of the Caspian Sea in the Late Miocene - Pliocene.

# Characterization of active fault behavior in Eastern Iran for a realistic seismic hazard assessment using space geodesy (GNSS and InSAR)

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The Arabia-Eurasia collision induces 25 mm/yr of NS shortening throughout eastern Iran, with 15 mm/yr of NS shear between central Iran and Afghanistan, accommodated by the faults limiting the Lut block, and 5 mm/yr remaining to be absorbed north of the Doruneh fault (i.e. south of Binalud and Kopeh Dagh). Our GNSS measurements highlight that 5 NS trending faults slip right laterally at significant rates (1-5 mm/yr) to absorb the shear across the Lut block. The 600 km long EW trending Doruneh fault is found to slip left laterally by 0-2 mm/yr as constraint by a sparse GNSS network, and with 1-3 mm/yr according to an extended InSAR study. GNSS measurements on the South Caspian block yield 7 mm/yr of right lateral slip on the Ashkabad fault at its NE boundary, and 4-6 mm/yr on the Shahroud fault system (SFS) at its SE limit. A dedicated InSAR study localized 5 mm/yr of slip on the Abr and Jajarm strand of the SFS, highlighting the large seismogenic potential of these faults.

# Towards a Novel Geodetic-based Probabilistic Seismic Hazard Model for Iran

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Seismic hazard evaluation in intercontinental regions such as Iran is a difficult and challenging task, taking into account the long return periods of large earthquakes and their clustering behavior in time. Probabilistic seismic hazard studies have previously been conducted based on the extrapolation of the large earthquakes frequencies from rates of small events recorded in instrumental era. Unfortunately, factors such as incomplete catalogs, long term return period of large earthquakes and short term catalog leads to unreliable results. Here, a preliminary probabilistic seismic hazard analysis (PSHA) for Iran has been conducted using seismic moment rates obtained through combined analysis and modeling of the Iranian seismic, geodetic, and geologic data. For some place in the world,

data is used in hazard analysis by researchers. Recent investigations in regions such as California, New Zealand and Italy show that estimated earthquake rates based on the geodetic and geological data are usually larger than those derived from earthquake catalogs. In this regard, using novel and alternative approaches in hazard assessment will greatly improve our knowledge and many questions about spatial-temporal distribution of earthquakes could be answered. Moreover, the ground motion parameters uncertainty as hazard analysis output will be reduced. In a recent study (Khodaverdian et al. 2015) the long-term deformation of the Iranian Plateau is estimated by the Neokinema software using updated Iranian database including latest fault traces, geologic fault offset rates, GPS velocities, principal stress directions, and velocity boundary conditions. Using this deformation model, for the first time an independent hazard estimate for the Iranian Plateau will be obtained through the seismic moment rate required to accommodate current rates of deformation from geodetic and geological data.

**Key Words:** Hazard analysis, GPS, Slip rate, Deformation model, Recurrence rate of earthquake, Geodetic strain rate.

# Reevaluation of seismic hazard zoning maps in SW Asia, and providing a basis for the future trend for activities

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The reevaluation of seismic hazard analysis in the south Asian region is a need for earthquake risk reduction in this region. The problem will be the evaluation of availablility of proper source data and means of seismic hazard assement, and the definition of new source model for seismic hazard analysis in this region. The up-to-date assessment of seismic hazard and the new scope will be represented as well as the challenges in the futre (near-field assessment of seismic hazard, spectral accelerograms, etc…).

This article summarizes a recent study in the framework of the GEM (Global Earth model) and EMME (Earthquake Model of the Middle East) project to establish the new catalog of seismicity for the middle east, using all historical (pre-1900), early and modern instrumental events up to 2006. After omitting the duplicate events, aftershocks and foreshocks, and converting all magnitude to Mw scale, 27174 main events remain for new catalog of Middle East from 1250 B.C. through 2006. The magnitude of completeness (Mc) was determined by cumulative frequency-magnitude distribution. Value of Mc is around 5.5, 5.0, 4.5 and 4.0, for the time periods before1960, 1963, 1975 and 1995, respectively. The average of teleseismic depths in all regions is less than 20 km. Minimum depth corresponds to Northern region (Alborz-Azarbayjan, Armania) with ~ 6 km. In the other subregions depths are between 10 and 16 km. In this study, a uniform catalog of earthquakes in Middle East has provided a reliable and most complete collection of available information for seismic study, long with the EMME (Working Pakage-1) project (a sub project of GEM project www.globalearthquakemodel.com). After unifying the catalog by using regional conversion equations between mb, Ms, ML and Mw and convert to Mw scale, there is a catalog with 28244 events from all of historical and instrumental events, in Mw magnitude scale. In this primary catalog summary of earthquake origin times, longitude, latitude, magnitudes and depth for each event presented. (a sub-project of Global Earthquake Model; GEM project) which was focused in the middle east. There is only one event with more than 8 magnitudes in this region (1945 in Makran, magnitude of 8.1). Moreover, there are 134 events between 7 and 8, 560 records between 6 and 7, 4041 events between 5 and 6. The maximum and minimum magnitudes in this catalog are 3.8 and 8.1 respectively. The magnitude of completeness was determined by cumulative frequency-magnitude distribution [24]. The threshold of magnitude based on all Middle East earthquake data was calculated 5.5, 5.0, 4.5 and 4 (or less than 4) for the time periods before 1960, 1963, 1975 and 1995, respectively.

According to this investigation in Middle East region by averages of depth for each subregion are estimated by using software ZMAP and by plotting all of events in their depth. Average of depth for Alborz-Azarbayjan and

Armania; Makran, Arabian Peninsula and Turkey; Kopeh-Dogh; Central-Iran; Zagros and Afghanistan-Pakistan are approximately 6; 10; 11; 16; 14 and 12 respectively. Most of the events occurred in depths of less than 20 in Middle East region.

This study provide a context for the future studies in the context of global earthquake hazard and risk studies and therefore the basis for future phase is now provided. The works on coping with the uncertainties, integration of the local catalogs, threshold of the earthquake magnitudes for different parts of the region and the consistency of the seismicity parameters (i.e. depth, focal mechanism, ..etc) will be the major issues to be covered in the next phase of the EMME-GEM project.

# POSTERS

# Ore deposits and Mineral Resources of Iran: Temporal-Spatial Distribution and Key Targets

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Iran embraces several geological zones or belts, most with Late Precambrian Pan-African basement, evolved variably during Phanerozoic and shaped into the current configuration during Eurasia-Africa/Arabia convergence. The main belts/zones include Zagros fold-thrust belt (ZB), Sanandaj-Sirjan metamorphic-plutonic belt (SSB) and Urumieh-Dokhtar belt (UDB) in west-southwest, Makran prism (MP) in southeast, Alborz-Azarbaijan (AA) and its extension eastward to Binaloud zone (BZ) in north, Kopet-Dagh (KD) in northeast, Central Iran (CI) consisting of Lut, Tabas, Kashmar-Kerman and Yazd blocks (LB, TB, KKB, YB, respectively), and Dasht-Kavir (DK) or Sabzevar zone (SZ) and Qom basin (QB) to the north and west-northwest of CI.

Late Precambrian-Early Cambrian is marked by abundant iron-apatite±REE deposits of IOCG affinity in an arc setting in KKB, represented by world-class Chadormalu and Choghart, uranium deposits/occurrences in highly metasomatized rocks, and SEDEX-type Pb-Zn-Ag and distal iron ore represented by Kushk and Muteh. Neoproterozoic calc-alkaline granitoids in the basement assemblages offer a potential to be investigated, although most are deeply eroded. No major ores are reported associated with Ordovician-Carboniferous basins, partly due to long hiatuses in sedimentary record and/or poor preservation of rocks. Potential exists for sedimentary phosphate in Carboniferous strata. Silurian alkali basalts and syenite in East Alborz and in KKB suggest extension. The episode and possible associated ores merit thorough investigation.

Upper Carboniferous-Permian is marked by continental rifting, A-type magmas, marine transgression and opening of Neotethys. Distal sedimentary-diagenetic base metals ores occur in Permian strata; other ore potentials in Permian-Mesozoic basins and ores associated with A-type magmas (e.g., HFSE, Sn, W, F, REEs) are to be investigated. Triassic-Jurassic granites associated with Cimmerian convergence and continental collision occur in CI and BZ, and provide potential for granite-related ores. The countrywide Upper Triassic-Jurassic continental basins developed following Cimmerian orogeny, host Iranian coal deposits. Sedimentary iron ores are locally developed.

Mesozoic, dominantly Jurassic, subduction-related calc-alkaline I-type plutons in SSB and elsewhere are host to granite-related ores, including Au, Sn, W; volcanic and subvolcanic equivalents are mostly eroded. Metamorphic assemblages of variable origins in SSB and BZ host orogenic gold and a variety of industrial minerals/rocks. Numerous Pb-Zn-barite-fluorite deposits and occurrences of MVT affinity occur in carbonates, and less commonly clastic sediments, of different ages; Triassic and Cretaceous strata are the main hosts. Cu-rich, and Pb-Zn-Au-Ag-rich Cyprus and Besshi type VMS districts occur locally in Mesozoic basins in southern and northern SSB, represented by Bavanat, Sargaz and Barika. Potential for new camps exists.

Alpine events during Cretaceous-Quaternary played significant roles in the geology of Iran. Cenozoic magmatic assemblages in UDB, LB, AA, and SZ host a variety of ore deposit types, including porphyry Cu-Mo-Au (PCDs), epithermal base and precious metals, skarn-type base metals, manto-type copper, and magnetite-apatite ores of IOCG affinity. Miocene was the most productive period for PCDs. Eocene was a time of countrywide extension, distinguished by widespread volcanism and high heat flow. Vein- and replacement-type fluorite-barite-Pb-Zn-Ag, some with MVT affinity, and Au deposits, developed in several districts and belts, mainly in Alborz, SSB and Central Iran. Zagros and Kopet-Dagh evolved in passive margin settings, with no thermal anomaly records, in Mesozoic-Cenozoic. The two belts host major hydrocarbon reservoirs.

Classic examples of red-bed copper occur in Upper Jurassic clastic series in TB and in the widespread Neogene red beds in Qom basin. Sedimentary phosphate occurs in Cretaceous strata in ZB. A potential exists for residual ores, represented by Al-rich laterites developed on Upper Triassic volcanic rocks and Ni-rich laterites developed on ophiolitic ultramafic rocks. The mountainous topography and rapid uplift and erosion have provided high potential for a variety of placer type ores; to be investigated.

The mafic-ultramafic assemblages, of presumably ophiolitic nature, across Zagros suture, in southern SSB, surrounding CI, to the northeast of DK, and in northeast Iran host chromite and magnesite deposits and merit more detailed investigation for PGE and other ore potentials, including VMS-type ores. The widespread Oligocene-Miocene collision-related marginal basins, and Quaternary playas, are host to a variety of evaporites. A wide selection of industrial minerals and rocks occur throughout the country, providing materials for construction, ceramics, glass, and several other industries. Resources are enormous and warrant more investigation on new uses and applications.


# Structure and metamorphism of a subduction mélange (Sistan, Eastern Iran): a close-up on subduction channel processes

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Suture zones preserve metamorphosed relicts of subducted ocean floor later exhumed along the plate interface and provide critical insights on subduction zone processes.

The suture zone of Sistan (Eastern Iran) formed as a result of the closure of a branch of the Neotethys separating the Lut and the Afghan continental blocks and offers privileged outcropping conditions. High pressure rocks are found in the inner part of the suture zone, called “the Ratuk complex”. This study focuses on the northern exposures around Gazik and compares them with the previously studied outcrops of Sulabest.

Field study and mapping allows the distinction of two kinds of subduction-related tectonic mélanges, a flysch-matrix mélange and a serpentinite-matrix mélange. The flysch-matrix mélange includes barely metamorphosed radiolarites and basalts of maximum greenschist-facies grade. This mélange reached a maximum temperature of 340°C.

The serpentinite-matrix mélange includes blocks of various grades and lithologies: mafic eclogites, epidote-amphibolite rocks, blue-amphibole-bearing metacherts, and greenschist-facies metabasalts. Eclogites reached peak pressure conditions at 520°C and 2.2 GPa and a peak temperature at 630°C and 1.2 GPa. Estimation of PT conditions for the other rocks are less-well constrained but suggest that they originate from at least three different depth zones in the subduction.

Very similar Ar-Ar ages of 87.5 ± 3 Ma are obtained for phengite and amphibole from fourteen eclogite and epidote-amphibolite samples from the ~70 km long serpentinite-matrix mélange. Ages in Sulabest are usually older than in Gazik, but there is little age difference between the various kinds of rocks.

These results (radiometric ages, observed structures and rock types) allow to place constraints on subduction zone dynamics, particularly on detachment and exhumation mechanisms of slab-derived rocks.

# Temporal and spatial variations in Late Quaternary slip rates along the Doruneh fault system (Central Iran)

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The Doruneh Fault System (DFS) is one of the major active strike-slip faults in the Arabia- Eurasia collision zone. Despite its geological activity, no large (M≥6.5) historical or instrumental earthquakes have been recorded along this fault system (e.g., Farbod et al., 2011; 2016). The DFS comprises three fault zones, i.e. the western fault zone (WFZ), the central fault zone (CFZ) and the eastern fault zone (EFZ), each with distinct kinematics and surface geometry (Farbod et al., 2011). However, the rate, distribution, and

behavior of slip, as well as the seismic behavior of these fault zones have been unknown.

A SBAS DInSAR analysis has been done by Pezzo et al. (2012) to estimate the interseismic deformation and for constraining the present-day kinematic of the western Doruneh fault.

In addition, sixty-seven offsets recorded by 3 successive generations of alluvial fans (Q1, Q2, and Q3) and their associated geomorphic markers displaced along the WFZ and CFZ were reconstructed (Farbod et al., 2016). We determined the ages of ~12, ~36, and ~120 ka using in *situ*-produced $^{10}$Be and $^{36}$Cl cosmogenic nuclides for the Q1, Q2, and Q3 abandonment surfaces, respectively. The combination of these ages and cumulative offsets allowed determining three sets of individual left-lateral slip rates, and consequently, describing the distribution of slip along the fault zones. The slip rates averaged over time intervals of ~36 and ~120 ka reveal that the long-term slip behavior along the CFZ, and maybe WFZ, was constant, with variable slip rates along length, but, similar slip rates at a point. A maximum rate of ~8.2 mm/yr is estimated at the mid-length of the CFZ. However, during the Holocene, the fault slip behavior appears more complex, with a maximum rate of ~5.3 mm/yr. The CFZ is divided into two ~4 km apart independent segments, with almost symmetrical slip distributions relative to a persistent boundary, which has not been ruptured over the last ~12 ka. These slip patterns are consistent with a characteristic slip model. The maximum length of independent seismogenic fault segments varies from 70 to 100 km, which could produce earthquakes with a magnitude of Mw≈7.2-7.4. The presented results emphasize the necessity of segmentation models for long strike-slip faults that may not necessarily rupture along their whole length during a single earthquake.

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# Cenozoic plutonism in the Urumieh-Dokhtar and Alborz zones, two important magmatic belts in the Zagros hinterland; Geochronology, geochemistry and isotope constraints

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Geochemical and isotopic data provided from the plutonic bodies in the most important Cenozoic magmatic belts in the Zagros hinterland including the Urumieh-Dokhtar (UDMA) and Alborz magmatic belts were investigated in order better to understand the magma sources and tectonic implications. Most of the plutonic bodies in the UDMA were emplaced during the Oligo-Miocene whereas those formed in the Alborz mostly show younger ages, mostly late Eocene-Oligocene time interval. The geochemical investigations obtained from the Middle Miocene granodiorite, tonalite, quartzdiorite and diorite assemblage show a medium-K calc-alkaline and metaluminous affinity and strong enrichment of large ion lithophile element (LILE, e.g., Rb, Ba, Sr), enrichment of light rare earth element (LREE) and depletion in high field strength element (HFSE, e.g., Nb, Ta, Ti, P). The Middle Miocene granitoids show uniform initial $^{87}Sr/^{86}Sr$ (0.7065–0.7082), a range of initial Nd isotopic ratios ($\varepsilon Nd_{(T)}$) varying from -2.3 to -3.7 and Pb isotopic composition ($^{206}Pb/^{204}Pb$) = 18.67–18.94, ($^{207}Pb/^{204}Pb$) = 15.63–15.71 and ($^{208}Pb/^{204}Pb$) = 38.73–39.01. Geochemical and isotopic data of the Middle Miocene granitoids rules out a genesis as purely crustal-derived magma and suggest mixed mantle-crustal (MASH) origin in a post-collision tectonic setting. Sr–Nd isotope modeling shows that the generation of these magmas involved ~60 to 70% of a lower crustal-derived melt and ~30 to 40% of subcontinental lithospheric mantle. Isotopic features from the all studied plutonic bodies in the UDMA suggest that the involvement of the continental crust beneath UDMA in generation of magmas increased with time from Early Eocene toward Middle Miocene.

The plutonic bodies in the Alborz mountains, however, mostly belong to the monzonitic series including monzo-diorite, monzonite, quartz-monzonite and monzogranite plutonic assemblages. Compared to those from the UDMA, the Alborz plutons show higher $K_2O+Na_2O$ (5.5-

10.3 wt.%), higher $K_2O/Na_2O$ ratio ranging from 0.9-2.0, I-type, high-K calc-alkaline to shoshonitic alkaline features. Similar to those from the UDMA, the Alborz plutons show LILEs and LREE enrichment and HFSEs and HREE depletion analogues to the arc magmas. The Alborz monzonitic samples show variable $Sr_i$ (0.70476-0.70518) and $\varepsilon_{Nd}$ (36 Ma) (+0.39 to +2.10). The Pb isotopic ratios are ($^{206}Pb/^{204}Pb$) = 18.49-18.67, ($^{207}Pb/^{204}Pb$) = 15.58-15.61 and ($^{208}Pb/^{204}Pb$) = 38.33-38.77. The geochemical and isotopic data from the Alborz monzonitic plutons suggest that the parental magmas were mainly derived from the sub-continental lithospheric mantle source which has been already metasomatized by fluid flux and melts from the Neotethyan slab with minor crustal contribution.

In general, the comparison of geochemical and isotopic features from the plutonic bodies in the UDMA and Alborz belts suggest that the ratio of the mantle contribution in the Alborz plutonism were higher than the UDMA Oligo-Miocene plutonism. Furthermore, the higher content of alkalinity in mantle-derived magmas suggest extensional tectonic regime for formation and emplacement of the large plutonic bodies along the Alborz magmatic belt which was dominantly effect during late Eocene time. More detailed research on geochemistry and isotope characteristics of the plutonic bodies in the UDMA and Alborz belts is proposed to get more insight into the tectono-magmatic evolution of the these most important Cenozoic magmatic belts in Iran.

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# Neogene to Present paleostress field in Eastern Iran (Sistan belt) and implications for regional geodynamics

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***Key points:*** *Palostress, Neogene, Sistan, Iran*

We conducted a stress field analysis of the northern part of the ~700 km-long north-south trending, seismically active Sistan orogenic belt of Eastern Iran formed as a result of the closure of a branch of the Neo-Tethys during the early Cenozoic. Fault kinematic data reveal drastic changes in the stress regime of Eastern Iran during the late Cenozoic, with three successive directions of compression (σ1), from 90°N during the middle-late Miocene to 60°N during the late Pliocene and 25°N

during the Plio-Quaternary, thereby evidencing a counterclockwise rotation of about 65° of σ1 in less than 10 My. As shown by compilation of paleostress data, Plio-Quaternary direction of compression in Sistan coincides with the one recorded across the whole of Iran and with present-day Arabia-Eurasia convergence direction. This result suggests effective stress transfer from the Zagros collision and that Sistan is at present mechanically coupled and shortened along with the rest of the Iranian crust/lithosphere. By contrast, Miocene compression is markedly different in the Iranian hinterland (e.g., Sistan, Central Iran and Kopet Dagh) and in the Zagros orogen. This could tentatively be related to the end of Sistan collision and/or to the imprint of active deformation occurring further to the east. The intermediate late Pliocene compression (i.e., 60°N) could correspond to the progressive reorientation of the stress regime, as Sistan gets mechanically coupled to the Zagros collision.

# Application IRAT index of tectonic activities (Beshagard mountain case study of South-East Iran)

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## ABSTRACT

Morphometry status of tectonic active areas around the Beshagard mountain is as a result of the interaction of neotectonic movements,erosion and subsidence processes.Bashagard mountain contains two attached mountains (Ghale-Toh imountain and Bashagard

mountain) with an altitude of 2000 meters at the south of the Jazmurian subsidence surrounded by Quaternary and Neogene.The boundary between the north Makran and Jazmurian subsidence is a fault that located between Band-e-ziarat unit and western alluvial fan and units of Ganj, Mokhtarabad and Rameshk in the south.Tectonic activity has a significant impact on their morphometry status and drainage basin system.We studied geomorphological patterns of drainage and mountain fronts features for clear changes and high style of mountain.In this study,we studied seven geomorphological indicators for each basin including Vf,Bs,Smf,Sl,Af,RA,Hi between west and south mountain front of Jazmurian. Morphometric indexes were divided in three categories. The average of seven indicators is an index of relative tectonic activity (IRAT).The level of tectonic activity of each IRAT category was determined. Finally,tectonic activity was evaluated for each drainage basin. Results show good similarity between IRAT category and ratio of tectonic activity of the number of drainage basins.The streams profile shows the uplift movement in the western part of subsidence Jazmurian.Thus,the achievements obtained from the analysis of topographic indices,the region's river system and geomorphological evidence show the movements of uplift and movement of right-lateral strike-slip of Jiroft fault in the west and reverse faulting of Kranj and Jazmurian faults at east of subsidence Jazmurian that all indicates the diagonal tectonic movements.

**Keywords:** morphometry, Beshagard mountain, Jiroft fault. Active tectonic , IRAT index

# Rare earth elements geochemistry of hydrothermal gangue calcites of Ab-Bagh Sedimentary-exhalative (SEDEX-type) Zn-Pb deposit, Sanandaj-Sirjan zone, Iran

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The Ab-Bagh Zn-Pb deposit is located in the central part of the Sanandaj-Sirjan zone (SSZ), Iran and is hosted in the Upper Jurassic-lower Cretaceous sedimentary sequence. Mineralization occurs during the back-arc rifting of the continental margin of the SSZ. Based on stratigraphic position, two ore horizons can be distinguished. The vent-proximal SEDEX type ore horizon 1 is hosted by Late Jurassic-Early Cretaceous black shale and siltstone; it displays three different ore facies (stockwork, massive and bedded ores). The carbonate replacement SEDEX type ore horizon 2 occurs in lower Cretaceous carbonates and exhibits two ore facies; massive ore facies is concordant with host rock layering and is underlain by a stockwork facies. Major metallic minerals are sphalerite, galena, and pyrite with rare chalcopyrite which are accompanied by calcite and quartz in both ore horizons. Rare earth elements of calcites were determined by ICP mass spectrometry in Zarazma lab. Important host minerals for REEs are carbonates in which those elements substitute for Ca. Consequently, the abundance of REEs in carbonate minerals, is an important geochemical tool for determining the origin of ore forming fluids. The objective of this study was to find the origin of the both ore horizons using REE patterns. The REE patterns of the calcites from both ore horizons are similar except for ore horizon-1 samples presenting low REE content (233.36 ppm in average), and calcites of ore horizon-2 having high REE content (656.7 ppm in average). The chondrite-normalized REE patterns of the two types of calcite are characterized by HREE-rich shape, in which the calcites of both ore horizons shows $(La)_N>(Ce)_N>(Pr)_N>(Nd)_N$

with $Eu/Eu^{*}>1$. Positive Eu anomalies in calcites of ore horizon-1 stranger than calcites of ore horizon-2.

REE geochemistry of the two types of hydrothermal calcite is different for detrital and carbonate strata which host the ore mineralization. Various evidences demonstrates that the REE geochemistry of the two types of calcite has a tendency of continuous variations and confirms that they are products of different evolution stages of ore-forming fluids and all calcite have the same source. First pulse of ore forming fluids caused the formation of ore horizon-1 during late Jurassic-early Cretaceous, while a second phase of fluids has formed ore horizon-2 during the Early Cretaceous.

# Minor and trace element geochemistry of galena from Ozbak-Kuh carbonate-hosted MVT Pb-Zn deposit, North of Tabas block, Central Iran

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We have used ICP-OES technique to investigate the distribution of minor and trace elements in galena samples from Ozbak-Kuh deposit. The Ozbak-Kuh Pb-Zn deposit is located in 150 km north of Tabas city, in the northern part of the Tabas-Posht e Badam metallogenic belt. This deposit is part ofthe Ozbak Kuh-Eshqabad district. In the Ozbak Kuh-Eshqabad district, Mississippi-Valley-type lead and zinc occurrences are hosted by carbonate rocks of Ordovician, Devonian, Carboniferous, upper Permian and Jurassic ages. Several occurrences are reported: Qalehmadan, Goshrow, Sibzar, Ozbak-Kuh, Gushekamar, and Chahsorb, all of which are currently abandoned. The most important and biggest deposit was Ozbak-Kuh. This deposit is hosted in the Middle Devonian Sibzar Formation, which correspond to a carbonate sequence. The epigenetic Pb-Zn ore body, which is discordant with host rock layering, displays a vein-veinlet shape and is located close to the faults. Similar to other MVT deposits, the mineralogy of the ore is simple and consist of galena, sphalerite, calcite and dolomite. Galena is much more frequent than sphalerite, and commonly is the only ore mineral present. Chalcopyrite is also present in depth, together very small amounts of pyrite and arsenopyrite. Reaction between upflowing hydrothermal fluids and host rock led to extensive dolomitization halos in the ore zone.

Pure galena samples from Ozbak-Kuh deposit were separated with hand picking under binocular microscope and then analyzed with ICP-OES in IMPRC lab. Galena from this deposit is characterized by high concentrations of Sb and Cu. The mean Sb content in galena was 850 ppm, with range from 685 to 984 ppm. In general, substitution of antimony into galena represents a well-characterized example of solid solution and galena can contain variable amounts of Sb. The mean Cu content in galena is 360 ppm, with minimum and maximum content of 105 and 593 ppm. High Cu concentration is justified by chalcopyrite inclusions in galena. Arsenic contents of galena from Ozbak-Kuh deposit range from 10 to 39 with average of 25 ppm. In addition to the presence of arsenopyrite, this suggest that ore forming fluids were relatively rich in As. If Sb and/or Bi are present, significant amount of silver can be added to the galena structure. But despite high Sb content , galena do not display high silver content (4.8 ppm in average) and refers to the low amount of silver in the natural ore forming environment. According to high concentration of some elements such as Sb in studied samples and some very small unknown ore mineral inclusions in galena, further complementary study are necessary to explore the trace element potential of this deposit.

# The late Jurassic Dash-Aghol stratiform iron deposit; Northern Sanandaj- Sirjan Zone of Iran

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The Dash-Aghol iron deposit is located 13 km northeast of Bukan city, western Azarbaijan province, northwestern part of Sanandaj-Sirjan zone (SSZ) in the Zagros orogenic belt of Iran. Iron mineralization in Dash-Aghol deposit is hosted within a Jurassic volcano-sedimentary sequence, which deposited in an extensional back-arc basin. The Dash Aghol deposit occurs stratigraphically on top of sandstone with interbedded shale, beneath tuffaceous limestone. The main host rocks include sandstone, tuffaceous limestone and carbonate. Oxide mineralization occurs as a sheet-like and tabular shape within the ore horizon. The stratiform ore predominantly consists of massive to semi-massive and banded oxides (mainly hematite) and chert that define a lens 70-100 m long and up to 2-4 m thick, approximately. The silica-rich bands (chert) represent the stratiform geometry and are exposed mostly in the upper part of sequence. Geometry of the ore bodies in these reserves is layered, lenticular and irregular. Their texture is disseminated, laminated or massive. Iron minerals in these reserves consist of magnetite, hematite, limonite and goethite and disseminated pyrite. Gangue minerals are chlorite, calcite, quartz and feldspar. Average iron grade in the stratiform ore are 55-65%. The presence of banded, layered, semi-massive and disseminated textures indicates that the ore was a primary facies of synvolcanic-syndepositional hydrothermal activity, similar to those formed in modern seafloor environments and in exhalative deposits. Two ore types are distinguished based on geometry and shape of ore bodies. Primary mineralization occurs parallel and concordant with the layering of the host rocks. Ore textures of this type include massive, laminated and disseminated forms and are found in chert, limestone and tuff. Vein- type mineralization associated with faults display brecciated or vein to veinlet texture; it occurs in sandstone and tuffaceous limestone. According to the geodynamic setting, stratigraphy, ore geometry, texture, paragenetic sequences, ore bearing chert-carbonate- tuff facies and mineralogy, the iron ores of the Dash-Aghol area are stratiform carbonate-sandstone host rocks deposits which were precipitated in a back arc shallow marine environment within a sequence equivalent to that of Jurassic age during sedimentary-exhalative process.

# Structural analysis and tectonic evolution of the Golpaygan-Mahallat metamorphic-magmatic core complex

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The present research investigates deformational history of the Golpaygan-Mahallat metamorphic complex and its relationship with regional tectonic evolution. The results suggest presence of four stages of deformation and three main episodes of metamorphism. The first stage of deformation (D1) and associated structures developed during prograde regional metamorphism under amphibolite facies, probably due to the steep slab subduction of the Neotethys Ocean beneath the Central Iran. Later D2-D3 deformational stages and associated structures were formed by a regional shortening event and exposure of metamorphic rocks in shallower levels of crust during Cretaceous flat slab subduction. At this time,

metamorphic minerals of the first generation were replaced by a lower temperature secondary paragenesis, characteristic of a retrograde metamorphism. The relevance of oblique convergence is clearly supported by dominant shear component determined by vorticity analysis of structures which developed during D3 deformational stage. Extension and thinning of the overriding plate due to the slab rollback during Paleocene to Eocene times caused decompression melting of lithospheric mantle and formation of magmatic and metamorphic core complexes in the study area. Intrusion of the resulted magmatic bodies caused a contact metamorphism of Buchan type, and crystallization of new minerals in the metamorphic and sedimentary host rocks. This regional extension and related magmatism is accompanied by development of D4 extensional shear zones and normal faults that resulted in exhumation of different metamorphic rock types in the Golpaygan-Mahallat area.


# Earthquake geology of the largest instrumental Seismic event of Persia: North Saravan seismic event (Mw= 7.8) of April 16, 2013 (SE Iran)

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The North Saravan quake of April 16, 2013 (Mw= 7.8) occurred at 10:44:17 UTC within Sistan-Baluchestan province, SE Iran. The instrumental epicenter of the event given by IRSC is 28.04° N, 62.03° E; located north of Saravan city with 82 km in depth. The epicenter of this event is located within a fault zone trending mainly NW-SE, north of Makran E-W trending subduction zone. The fault zone contains however some secondary ~E-W and N-S structural trends. Generally, the NW-striking Saravan fault system seems that formed as a resultant of N-S major dextral faults of East Iran and E-W, mainly thrust faults of Makran subduction zone. This earthquake felt in a far distance to the epicenter because of deep focus. Considering the epicenteral location of the earthquake, the seismic event could be caused beneath the Saravan fault system. The fault is a major NW-striking active fault zone (length ~ 250 km) in SE Iran. According to Normal mechanism of ~ENE-WSW faulting (N 60°-70° E) presented in focal solutions and depth of the event (more than 50 km), it could be potentially caused by extension-brittle deformation concentrated in slab zone of the Makran subduction zone. Makran subduction zone contains one of the largest accretionary wedges on the globe, formed by the convergence between the Arabian and the Eurasian Plates. It is characterized generally by a shallow subduction angle. According to historical (e.g. events of; 1765, 1851 AD) and instrumental seismicities (e.g. events of; 1945, 1983), Makran region is known as an active seismic zone. In General view, the western and eastern portions of the zone are located in Iran and Pakistan territories, respectively. Seismologically, strong earthquakes within Makran have long return periods, especially in Iranian portion. Review of earthquakes mechanism's occurred within Makran could be show two different types of reverse-shallow (in coastal portion, to the south) and mainly Normal-deep seismic events (in northern parts). Based on preliminary field observations, we found however just a short surface geological feature trending NW-SE along the Saravan fault as a reactivated structural trend. The pattern of this secondary surface feature is En-echelon left-stepped with a steep normal component. During the seismic event, it is however southern block which has been uplifted.


# Lake Urmia basin (NW Iran) during the Late Pleistocene and Holocene: climate and environmental changes inferred from the lake deposits; preliminary results


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## Abstract

The ongoing changes affecting Lake Urmia (NW Iran) and its area are revealed by the important lake water level decrease (7 m in the last 15 years), desertification and formation of dust storms threatening the health conditions of millions of people at a regional scale. That presents an ecological problem promptly highlighted [1-3] and directly impacting on the society development and is the object of the Iranian government preoccupation. Water level drop was attributed to the decrease of rainfall estimated to be 10% lower than before and to the anthropogenic causes, principally the construction of numerous dams on rivers supplying the lake. Nevertheless, even if the overexploitation of water is evident, the role of individual natural and anthropogenic factors influencing the state of the lake is still not well identified. Indeed, the lack of the detailed record of climate and environmental evolution in the past, limits the understanding of actual and future processes and the capability to develop integrated management of this water resource.

The French-Iranian bilateral project, the first step of which is the Gundishapour PHC program that started in 2016, aims to obtain a reliable and accurate high temporal resolution records on past environmental and climate changes in the Lake Urmia basin for the Late Pleistocene and the whole Holocene. The interpretation of environmental data will be done with reference to modern hydrogeochemical and geological systems[4]. A hydrogeological mass-balance model will be established if necessary (mean residence time of lake water, hard water effect, deep dissolved gases, etc.). All this is indispensable since the main problem encountered for

paleoclimatic reconstructions using various proxies at a global scale from cored lacustrine sequences remains the establishment of a reliable 14C time-scale. The process integrates geophysical, hydrogeological, hydrological and lake sediments studies.

During the fieldwork in May 2016, a sediment core has been obtained from recently dried out part of the lake close to the city of Urmia, and sampling of the lake water, as well as water from 4 wells and a river has been done. Sediment obtained from core (~14 m thick) is not yet dated, nevertheless, according to previous works [(5-7)] it presents the most probably the latest Pleistocene and Holocene. The sequence consists on sandy and clayish/silty deposits characterised by different magnetic susceptibility values. That indicates changes in sources of detrital material and/or different lake water level. At the bottom, the very hard crust of evaporites resembles to that from the top and indicates the as actual low state of the lake. The conductivity of sampled water (lake, river, wells) shows various values, but always indicating its very high mineralisation.

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