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# Mineralogical studies of the gemstones-bearing pegmatites of the Shigar valley, Skardu, Gilgit-Baltistan, Pakistan

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Shigar valley, located north of Skardu, is one of the most famous valleys of the Gilgit-Baltistan region of Pakistan as it is the gateway for most of the expeditions to the K-2, the second highest peak of the world. In recent years, this valley attained greater importance in regard to the gemstone occurrences. These are world class gemstones, mainly hosted by the pegmatites, which have attracted a large number of international gems dealers to this region for several years.

The pegmatites are well exposed in most parts of the northern areas of Pakistan. These occur mainly within amphibolite to granulite facies schists and gneisses. The amphibolites hosted pegmatites in the region extend from Hunza River in the northwest to Shigar River near Dassu in the southeast. Besides these, the pegmatites are also present at Garam Chashma in the western Karakoram and the Hushe and Masherbrum regions of the Karakoram metamorphic complex. The granitic-pegmatites are also exposed in the Indo-Pakistan continental plate in the Nanga Parbat-Haramosh Massif at Dache, Khaltaro, Shegus and Stak Nala. The pegmatites of different ages are also reported within the Kohistan batholith.

There are plenty of pegmatites exposed in the Shigar valley that host a variety of gemstones. Field and mineralogical studies of the Shigar valley pegmatites and hosted gemstones have been conducted to identify the processes involved in the formation of gemstones. On the basis of field features and internal structure, the pegmatites have been broadly classified into simple and complex or zoned pegmatites. Petrographically, these have further been classified into four types/classes, depending upon the presence or absence of different accessory minerals and gemstones. The occurrence of gemstones is generally restricted to the zoned pegmatites. The gemstones have been confirmed as topaz, aquamarine, tourmaline (schorl-foitite), goshenite, garnet (almandine-spessartine), epidote (zoisite-clinozoisite), quartz and fluorite by using various instrumental techniques such as X-ray diffractometer, electron probe micro-anlayzer and scanning electron microscope. Magmatic hydrothermal processes are mainly responsible for the formation of gemstones in these pegmatites. However, at places certain gemstones have metamorphic-metsomatic origin.

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# Numerical modeling of conjugate 'Riedel' deformation bands in sandstone

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Deformation bands in porous rocks are low-displacement deformed zones that increase cohesion and reduce porosity and permeability, and are commonly formed in a Riedel pattern (e.g. Antonellini et al., 1994; Davis et al., 1999). The term 'Riedel' refers to a specific fault pattern first created in clay cake models (Riedel, 1929). The pattern exhibits relatively short, en echelon fault segments of synthetic R and antithetic R' shears oriented at low- and high- angles to the main fault zone, respectively (Fig. 1).

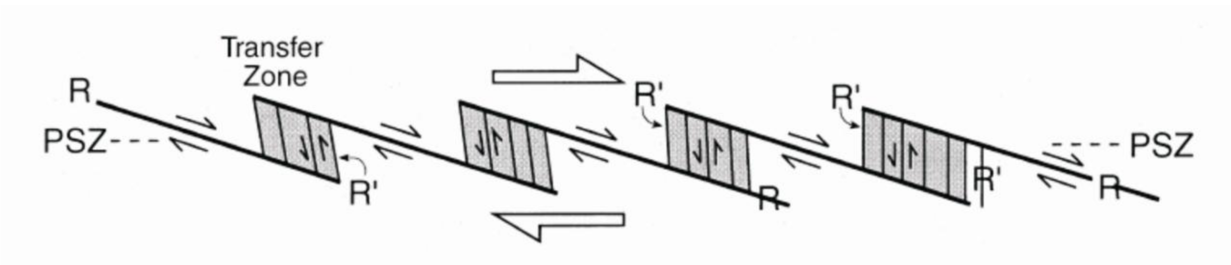


Fig. 1. Schematic sketch showing a Riedel shear zone composed of R and R' shears linked by transfer zone (after Davis et al., 1999).

Conjugate 'Riedel' pattern in sandstone has been documented in many studies (Davis et al., 1999; Fossen et al., 2007), and considerable amount of theoretical work on the development of deformation bands has been carried out (e.g. see review in Fossen et al., 2007). In this study, we have adopted numerical approach to simulate nucleation and growth of conjugate 'Riedel' deformation bands in sandstone. The advantage of numerical over other modeling techniques is that it allows user to model any particular physical/geological phenomenon and associated problem in various steps that follow sets of executable commands based on mathematical equations. The executable commands are written in a meaningful semantics that lead to answerable simulation. The results can be directly comparable to given physical process/problem at any stage with an advantage of quantitative outputs. We used Finite Difference Code (FDC) to simulate the structural evolution of deformation bands in sandstone. To generate model steps, FDC requires mechanical properties of sandstone that is an essential ingredient of the data file for execution. In this regard, the mechanical properties of sandstone are very carefully taken from the literature and used for modeling purposes (e.g. Okubo and Schultz, 2005).

We adopted Mohr-Coulomb material model with variable boundary conditions. In order to generate deformation bands, we first applied lateral shear to the mesh (strike-slip) as assumed in the theoretical models. However, surprisingly, no ‘Riedel’ geometries were formed at any stage during the given number of steps. We applied force (σ1) on top of the mesh and observed the nucleation of conjugate pattern. The pattern consists of two cross-cutting sets oriented at an acute angle to σ1. Each set consists of a zone with deformed antithetic pattern. We propose that this pattern may be the manifestation of R' shear. Our work is in progress and aimed to produce ‘Riedel’ pattern in sandstone. Based on the existing results, we can conclude that the formation of ‘Riedel’ geometry is not solely dependent on lateral shear, rather their growth is controlled by conjugate sets that are lying at an acute angle to σ1.

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# U-Pd zircon ages for the Chinglai gneiss, lower Buner, North Pakistan

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The Chinglai gneiss is a dark-colored medium-grained rock characterized by abundant augen of k-feldspar and plagioclase. It is located on the western limb of the Indus syntaxis. The Chinglai gneiss was initially mapped as part of the Ambela complex (Siddiqui et al., 1968; Rafiq, 1987). The Ambela complex was considered to be late Paleozoic on the basis of whole-rock Rb-Sr (297 ± 4, 315 ± 15) and U-Pb zircon (280 ± 15) ages from the Koga syenite (Le Bas et al., 1987 and Smith et al., 1994 respectively) and the intrusive contact of the Ambela granites with Carboniferous rock of the Jaffar Kandao Formation, where the Chinglai gneiss was also considered Carboniferous in age. Sak and Pogue (1995) and Khan et al. (1990) mapped the Chinglai gneiss as a separate body and is in contact with Ambela granite and the Ambar Formation. They considered the Chinglai gneiss to be of Cambrian age. DiPietro et al. (1999) based on texture and composition similar to Swat gneisses mapped the Chinglai gneiss and the southeastern part of the Ambela complex as part of the Swat gneisses. The Swat gneisses were previously correlated with the Mansehra gneiss that is considered to be late Cambrian on the basis of a whole-rock Rb-Sr age of 516 ± 16 Ma (Le Fort et al., 1980). Anckeiwicz (1998) obtained U-Pb zircon age of 468 ± 5 Ma from the Choga granodiorite gneiss and ca. 265 Ma from Ilam body part of the Swat gneiss to be related with late Paleozoic event.

Chinglai gneiss has abundant zircon. A sample from the Chinglai gneiss along the main road from Chinglai-Totalai section was collected for zircon separation. Zircons were separated using standard techniques of crushing, grinding and heavy liquid and magnetic separation. Zircons picked were clear euhedral grains of two morphologies, elongated prisms or stuby prisms. Analyses were performed at the Department of Earth and Atmospheric Sciences, University of Houston, using Laser ablation ICP-MS. Cathodoluminesnce (CL) images of the zircon show zoning and inherited cores (Fig. 1). In total of 17 analyses were carried out on multi grains.

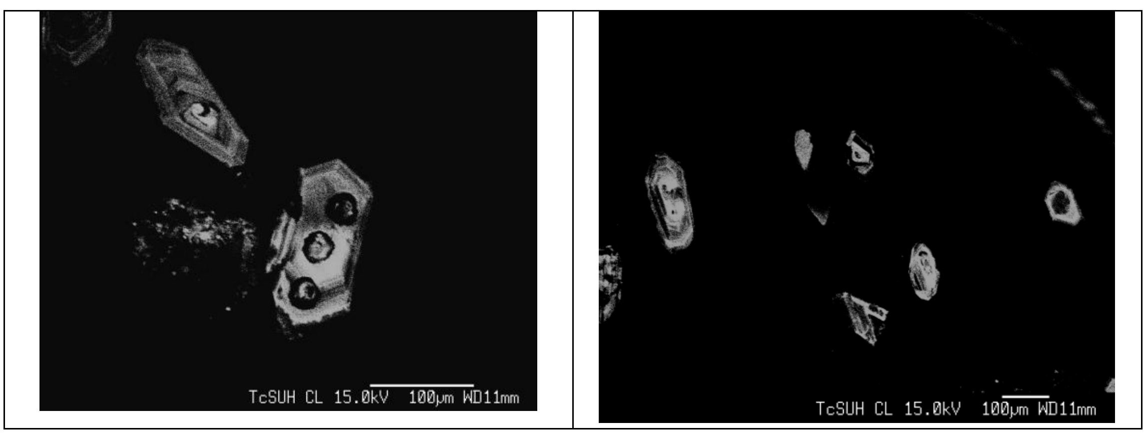


Fig. 1. CL images of the zircon from the Chinglai gneiss show zoning and inherited cores.

The analyses obtained show an upper intercept 827 Ma from the inherited core. This age is in agreement with the Black mountain complex of 823 Ma age (U-Pb zircon, DiPietro and Iscachsen, 2001) in the east of the Chinglai gneiss. The lower intercept of 456 represents a younger Pb loss and/or overgrowth associated with the intrusion in the north, the Choga granodiorite gneiss having U-Pb zircon age of 468 $\pm$ 5 (Anckiewicz et al., 1998).

The present age of 826 Ma from the inherited core and 456 Ma from the rim for the Chinglai gneiss supports the above interpretation. It constrained the age of the Gandaf and the Tanwal Formations regarded as Proterozoic and Cambrian respectively (Sak and Pogue, 1995). This also supports the argument that the Chinglai gneiss is not genetically related to the Ambela granitic complex (Khan et al., 1990; DiPietro et al., 1999).

DiPietro and Iscachsen (2001) regarded the 823 Ma age for the Black Mountain as minor Late Proterozoic intrusive event and possibly correlative with Malani magmatism which has been dated between 750 and 850 Ma on the Aravalli craton of northern India and with a ca. 870 Ma igneous suite from the Kirana Hills in Pakistan (Kazmi and Jan, 1997).

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# Site amplification factor at Mardan, Pakistan

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This paper presents site response analyses for a site at Mardan Campus of NWFP University of Engineering and Technology Peshawar. This study is a part of extensive instrumentation to be installed at Mardan campus under Pak-US Earthquake Collaborative Research Program funded jointly by Higher Education Commission (HEC) and USAID, which includes installation of two subsurface and a surface accelerometers in three boreholes connected to a common data acquisition system. The three boreholes with depth offifty (50) meters, hundred (100) meters, and fifty (50) meters are drilled at three (3) meters spacing. Geotechnical tests are conducted on the samples retrieved from these boreholes. Among other geotechnical tests, Standard penetration test, cone penetrations test, and Cross-hole test are also conducted in borehole to characterize the soil at the site. Shear wave velocities at 1m spacing are determined using cross-hole tests up to 50m depth. The site of interest has co-ordinates 34.01$^{o}$ N, 72.00$^{o}$ E. Seismic hazard analysis for the site is performed with deterministic approach using sixteen (16) faults within one hundred (100) km around the site. Peak ground acceleration for rocks is computed with shear wave velocity value 760 m/s. Boore and Atkinson Next generation attenuation (NGA) model is used to compute the peak ground acceleration values. Based on the controlling earthquake and the maximum peak ground acceleration value three real time histories are selected from the data bank of pacific earthquake engineering center (PEER). Equivalent linear site response analysis is conducted using DeepSoil software. Amplification spectrum is developed for the site and site response factors are compared with those from different International Codes.

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# New dimensions to play fairway evaluation within a sequence stratigraphic framework: Eocene carbonate play, southwestern part of the Lower Indus Basin, Pakistan

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Sequence stratigraphic methodology provides a powerful tool for subdividing the stratigraphic succession into genetically related sedimentary packages using key sequence stratigraphic surfaces. Spatial and temporal relationship of the depositional systems corresponding to each genetic package is a key to defining the petroleum play elements and documenting their extent and geological uncertainties. The methodology involves the preparation of geoseismic sections and wireline log/outcrop correlation panels at regional scale. Wheeler diagrams (Stratigraphic Charts) are then prepared and can be converted to Chronostratigraphic charts after a biometric or chronologic calibration. Subsequently, a Petroleum System is formulated based on a potential or proven source rock within the sedimentary succession of interest. Reservoir-Seal pairs are then identified to define plays and reconstruct/draw the play schematics. Lithofacies and respective depositional systems are delineated for both the reservoir and seal through an integrated use of outcrops, cores and logs to make Gross Depositional Environment Maps. These maps are the foundation of reservoir and seal distribution maps and the Common Risk Segments maps. Overlaying the reservoir, seal and source maps provide the play fairway map showing the areas of low, medium and high chances of success.

Case study of the Paleocene-Eocene Dunghan-Laki play fairway is presented from the southwestern part of the Lower Indus Basin and nearby shallow offshore region. Sequence stratigraphically, the play comprises Dunghan equivalent falling stage systems tract shelf-margin carbonate buildups overlain by the transgressive systems tract shale (top seal) of the Laki Formation. Further up in the stratigraphic section, a lack of thick shale between the thick and massive Middle Eocene Kirthar Limestone and the underlying Highstand shelf-margin carbonate buildups of Ypresian age (equivalent to the upper Laki Formation and SML of the Fold Belt) makes the Laki carbonates a high risk play. Based on limited stratigraphic information from a couple of boreholes that penetrated the relatively viable part of the play fairway, e.g., Karachi South 1A, a lack of ‘thick and regionally pervasive’ top seal (shale or marls) turns out to be the key geological risk at play level. Accordingly, the key de-risking challenge lies ahead in the form of predicting the extent and thickness of this seal element. It is possible to address this uncertainty through precise well-to-seismic tie, geological characterization of the correlative seismic reflection geometries and carrying out a seismic stratigraphic interpretation to extrapolate the sequence stratigraphic correlations away from boreholes into the tracts of Thanetian-Ypresian carbonate buildups both onshore and offshore. In this way, part-plays (geographic sectors) can be high-graded to prioritize and focus 3D seismic surveys and subsequently carry out high-resolution seismic stratigraphy to precisely demarcate different geomorphic elements and their thicknesses. Sectors of thick shale deposition and lateral carbonate-to-shale transition can be, thus, defined to map structural and stratigraphic traps that fall within the high-graded part-play.

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# A statistical approach to determine the earthquake probability, calculation of Peak Ground Acceleration for Karachi

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The city of Karachi is constructed on the southernmost folds of the Kirthar range with several faults (Surjan, Lakhni, and Jhimpir) within 125 km of the city. Karachi is close to a plate boundary and within reach of earthquakes and numerous tectonically active structures surrounding the city. Most effective seismogenic source areas were selected for this study on the basis of the past activity and slip rates. The documented historical and latest seismicity record shows the presence of various seismic zones such as Pab fault, Ornach Nal fault, Kutch fault and Surjan- Jhimpir faults. The Runn of Kutch earthquake of June 1819 was a large earthquake of 7.6Mw near Lakpat that killed about 1500 people. Similarly, an earthquake of 7.1 occured in Kutch in January 2001. Along other sources, major earthquakes occurred, with magnitudes ranging from 4.5 to 5.8Mw according to catalogs of Pakistan Meteorological Department (PMD) and Incorporated Research Institutions of Seismology (IRIS). Therefore, it is very important to remember that any devastating earthquake can strike Karachi in future due to the presence of active tectonic in its surrounding. The aim of this study is to determine the probabilities for the generation of earthquakes of specific magnitudes in Karachi in the future years using Annual Extreme Values Method of Gumbel (1958). Also, analysis of peak ground acceleration is made by using Idriss attenuation relation (2002). The Gumbel's, extreme value distribution method yielded that the probability of an earthquake occurrence of equal or greater than magnitude = 7 in 100 years is 18 percent and its return period is 500 years and 0.24g can be the maximum g value.

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# Microstructural approaches to tectonic reconstructions of the Balcooma Metamorphic Group, Greenvale Province, north-eastern Australia

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Eastern Australia has been affected by the Ross - Delamerian (520-500 Ma), an Early Ordovician (475-450 Ma), Benambran (440-420 Ma), Tabberabberan (410-370 Ma), Kanimblan (360-320 Ma) and Hunter-Bowen (Permian) Orogenies. A succession of five foliation intersection/inflection axes preserved in porphyroblasts (FIAs), sequential growth of metamorphic index minerals, spectacular inclusion trails and in-situ dating of monazite grains within porphyroblasts show that the Balcooma Metamorphic Group has been affected by 5 orogenic cycles of different intensities from ~476±5 to 408.8±8.9 Ma. The E-W trending FIA set 1 in garnet porphyroblasts indicates N-S shortening and the beginning of the amphibolite facies metamorphism around ~476±5 Ma across the Greenvale Province. The Early Ordovician N-S shortening was followed by staurolite, kyanite and plagioclase growth in a clockwise P-T-t-D path during an Early Silurian continuous crustal thickening event. The NNW-SSE trending FIA set 2 in staurolite and NNE-SSW trending FIA set 3 in staurolite, kyanite and plagioclase porphyroblasts suggest rotation of the direction of bulk shortening to ENE-WSW and ESE-WNW between 443.2±3.8 Ma and 425.4±3.7 Ma respectively. Localized E-W trending FIA set 4 in staurolite porphyroblasts indicates N-S bulk shortening by 408.8±8.9 Ma. FIA set 5 trends NE-SW and is only present in andalusite. It suggests subsequent rotation of the bulk shortening direction to NW-SE. The Balcooma Metamorphic Group is unconformably overlain by the uncleaved Emsian age (400-392 Ma) Conjuboy Formation. Constraints from FIAs, textural relationship, Emsian age unconformity and absolute monazite plus SHRIMP U-Pb ages indicate that the Delamerian, Kanimblan and Hunter Bowen Orogenies did not affect this region. FIA 1 (~476±5 Ma), FIA 2 (443.2±3.8 Ma), FIA 3 (425.4±3.7 Ma), FIA 4 (408.8±8.9 Ma) and FIA 5 (<408.8±8.9 Ma) indicate that this region was initially affected by an Early Ordovician Orogeny but was later overprinted by the Benambran (440-420 Ma) and Tabberabberan (410-370 Ma) Orogenies.

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# Petrography of sandstone of the Lumshiwal Formation from the Samana Range, Hangu, northwestern Pakistan: Implications for provenance, diagenesis and environments of deposition

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The Cretaceous Lumshiwal Formation is exposed along a road-cut in the Samana Range, situated in Hangu, northwestern Pakistan. It largely consists of sandstone with some intercalations of shale and limestone. A total of 28 samples were collected at a regular interval of 5 m from the sandstone unit of the Formation for detailed petrographic studies. The studied samples of sandstone consist of abundant quartz (ranging up to 97 %), which may or may not be accompanied by accessory amounts of feldspars (averaging ~3 %) and traces of rock fragments and a variety of heavy minerals. The heavy minerals include tourmaline, monazite, zircon, muscovite, chert, rutile and goethite. Silica as quartz overgrowth is the dominant cementing material in the studied sandstone samples. A few of the samples however contain ferruginous cement. Due to very high modal abundance of quartz, all the samples classify as quartz arenite. This feature suggests that the Lumshiwal sandstone is mineralogically mature. The moderate degree of sorting and sub-angular to rounded outlines of framework constituents however point to the texturally sub-mature character of the sandstone. The mono-crystalline quartz is much more abundant than the poly-crystalline type, and the poly-crystalline quartz grains mostly consist of two to three sub-grains. Besides, the majority of the mono-crystalline quartz grains are non-undulose or only weakly undulose. These features suggest derivation of quartz from an igneous source rock. Furthermore, the presence of alkali feldspar and heavy minerals such as tourmaline, monazite, zircon, muscovite and rutile point to a source dominated by acidic plutonic igneous rocks.

Precipitation of silica as overgrowth cement in pore spaces, presence of long and sutured boundaries, absence of concavo-convex and tangential contacts and alteration of feldspar grains to clay minerals are the prominent diagenetic modifications in the studied sandstone. These changes represent the final phase (phyllomorphic) of diagenesis, deep burial, increased geothermal gradient and pressure as is also evident from quartz overgrowths, stylolitic boundaries of some of the grains and healing of intra-granular fractures in quartz and feldspar with ore minerals. The almost total absence of matrix and abundance of framework quartz suggest the falling sea level, i.e. high energy conditions. The presence of glauconite also supports shallow marine conditions for the deposition of the studied sandstone.

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# Arsenic distribution and toxicity in the groundwater of Sindh, southern Pakistan

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Arsenic contamination of groundwater is well-documented in other parts of the world, for example, India, Bangladesh, Chile, Argentina, Mexico, China and Hungary. However, for some reason Arsenic contamination in the ground waters of Pakistan remains under-reported. In this study the concentration of Arsenic and its spatial distribution were determined in the groundwater of Sindh province. The Arsenic concentration ranged from 0 µg/l to alarming 500 µg/l. The spatial distribution of Arsenic in the ground water was mapped using various geostatistical methods, including kriging and nearest neighbor. It was observed that the Arsenic concentration in the groundwaters near the River Indus is higher and gradually decreases as a function of distance from the river. The results of this study were also compared with global and regional concentrations of Arsenic in groundwater. Groundwater samples collected from various sources like hand pumps, bore wells, etc., were also tested for residual chlorine, bacterial contamination and other basic water quality parameters. About 50 percent of the water samples showed bacterial contamination. Residual chlorine was missing in almost all the samples. A water quality index was used to classify the water as good, moderate, bad and very bad for human health and consumption.

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# Land degradation assessment in the southern dry lands of Khyber Pakhtunkhwa: A case study in Pezu and Tank region of Dera Ismail Khan District, Khyber Pukhtunkhwa

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This paper explores the extent of land degradation in Pezu and Tank region which is geologically characterized as a foredeep basin formed due to Main Frontal Thrust. Overtime it has filled up with silty clay, sand and gravel forming two different types of landforms: (a) piedmont deposits in the west and the centre of the basin, and (b) floodplain deposits of the Indus River. The recent alluvial fans formed in the foothills of the mountains surrounding the basin consist of gravel and boulders with intercalations of clay. The dominant drainage direction is from northwest to southeast. Most of the streams in the study area are ephemeral in nature.

Various factors, like vegetation cover, soil cover, precipitation, potential evapotranspiration, soil texture, desertification potential, land forms and land use attributes were used to identify the land degradation problems in each soil geomorphologic unit. Soil geomorphological units observed in the study area were recent alluvial fans in the foothills of Marwat Range, recent piedmont plain characterized by sandy outwash derived from Bhittani and Marwat Ranges in north-northwest, and from Cretaceous shales of Sulaiman Range in the west. Sub-recent piedmont plain characterized by loamy sands and old piedmont plain characterized by silt loam type soils are subjected to annual and biannual torrent floods. Soil orders observed in the study area were Entisols and Aridisols characteristic of arid and semi arid regions of the world. Soil sealing and crusting and soil cracking were observed as the most predominant features of the top soils in the area. Other characteristics of the soils include low organic matter content and high infiltration rates. Soil drainage varies from excessively drained in the recent piedmont plains to moderately drained in other units. The prime land use attribute recorded in the area is Rainfed fallow agriculture associated with poor quality grazing. Soils are also subject to rill, gully and sheet erosion of varying degrees. Sparse vegetation, erratic rainfall patterns and high potential evapotranspiration, scarcity of water and high potential for desertification add up to the existing land degradation problems of the study area. Agroforestry techniques, afforestation, no tillage agriculture techniques and mulching are recommended for the improvement of land and combating land degradation.

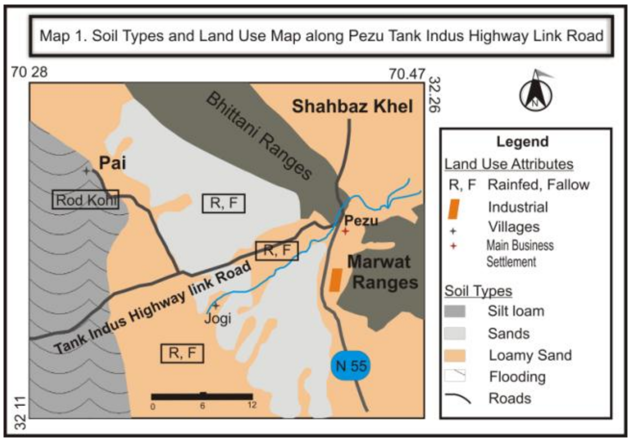


Fig. 1. Map of the study area.

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# Evaluation of activated carbon amendment for reclamation of a DDT-contaminated site in Pakistan

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DDT was produced from 1963 to 1994 in a factory in Nowshera, Khyber Pukhtunkhwa, Pakistan. The factory was then officially closed, but was still in operation for many years. The production and distribution of the insecticide resulted in a DDT polluted area of about 85 hectares. At the factory's site, covering about 550 $m^2$, soils contamination is up to 10 $\mu g\ g^{-1}$ DDT in dry soil.

To reduce DDT exposure of the environment and humans, this contaminated site has to be remediated. Therefore, the aim of this joint research project is to test a remediation strategy that substantially reduces the bioavailable fraction of the aged DDT in the soil. We propose to bind and immobilize the contaminant and its metabolites in the soil by activated charcoal (AC) amendment. AC has proven to significantly reduce the bioavailability of organic contaminants in solid matrices due to its high adsorption affinity and capacity. For this purpose, many researchers already successfully added AC to sediments. The novelty of this project is the application and thorough evaluation of this remediation technique to a field soil contaminated by sequestered DDT and metabolites.

Specifically, within the three years of the project, we plan the following actions: 1) Soils and sites will be selected to work with in the subsequent laboratory and field experiments. 2) In laboratory experiments with different soil contamination levels and different kinds of added AC (powdered, granulated, or reactivated charcoal), the bioavailability of DDT and metabolites will be assessed by depletive and non-depletive extraction methods which are Tenax® beads, a porous polymer and polyoxymethylene (POM), respectively and 3) Pilot field studies will be performed after the AC has been added to the soil according to the initial laboratory results. The chemical activity of DDT in the soil pore water will be assessed by POM and the bioaccessibility of DDT tested in the lab with Tenax® over a period of about two years. Overall, this technique presents, if it proves successful, a cheap, effective and feasible way to remediate other organically contaminated hotspots in South Asia.

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# The importance of nuclear energy in future, major uranium deposits of the world and Pakistan

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The Nuclear Energy Outlook, issued in October 2008 on the $50^{th}$ anniversary of the OCED Nuclear Energy Agency (NEA), responds to the renewed interest in nuclear power. In 2008, the International Energy Agency (IEA) projected that with current government policies, total primary energy and electricity demand will increase respectively by more than 50% and 90% by 2030, and that the great majority of energy supply remains a key issue.

Nuclear energy is an established technology, offering a reliable option to address these issues. More efficient use of energy, renewable resources and storage are important components of the response to these key issues, but no option should be overlooked. Nuclear energy is part of solution, the size of its contribution will depend as much on the capabilities of governments and the nuclear industry to address society's concerns about safety, waste disposal and proliferation concerns, as it will on its economic competitiveness. In 2008, installed nuclear generation capacity of around 372 GWe and annual production of 2700 TWh supplied about 16% of the world electricity. Using authoritative electricity demand estimates for 2030 and 2050, the NEA elaborated its own scenario of nuclear energy development. Designed to illustrate possible future contributions of nuclear energy to global supply the outcome is a range of 4300 to 10500 TWh worldwide in 2050.

The supply of uranium is required to support nuclear energy. Natural uranium resources are widely distributed around the world, including in key countries where geopolitical risks are limited. Its cost represents only a few percent of total cost of generating electricity at nuclear power plants and therefore uranium price volatility is not as major concern for nuclear power plant owners and operators as is for fossil fuel alternatives. Maintaining strategic stockpiles representing several years' consumption is also relatively easy and economic.

World identified uranium resources (5.45mt U at US$ 130/KgU, or US$50/Lb U3O8) are adequate to meet projected future high case nuclear power requirements until 2050, providing that mine production is increased significantly. Supplying uranium requirement beyond this date will require the identification of additional resources. However, recent market turmoil and declining uranium spot prices, the opaque nature of uranium market, increased regulatory requirement, scarce specialized labour and fluctuating costs of raw materials makes the process of developing mines, already demanding significant amounts of time, expertise and expenditures, increasingly more challenging. Considerable effort will be required to bring about the substantial increase in mine production required to meet future NEA projection. In addition of these challenges, uranium producer must continue developing and implementing best practices globally in order to improve public perception of uranium mining. Doing so will be necessary to develop currently identified resources to their full potential as well as to expand the existing resources base.

In Pakistan the energy mix contains 2.30% nuclear energy. The government of Pakistan has planned to increase nuclear energy from present 380 mw to 8800 mw by 2030. Mineral sector has finalized a plan to establish more then 6000 ton of Reasonably Assured Resources (RAR) of uranium by 2011 to fulfill the 1/3 requirement of fuel. Three fifty tons of yellow cake will be required annually to achieve the target of 8800 mw. At present there are two Nuclear Power Plant (NPPs) which produce 380mw of electricity, 80 mw by KANUPP and 300 mw by CHASNUPP-1. For these NPPs the Pakistan Atomic Energy Commission mineral sector is partially fulfilling the requirements of uranium. Keeping in view the distribution of world uranium deposits, further efforts should be made to explore new uranium deposits to meet the future needs.

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# Hydrodynamic analysis of Kabul River (NW Pakistan) during monsoon floods of August 2010

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The densely populated floodplains of River Kabul at Charsadda and Nowshera witness flash floods recurrently. However, the recent mega monsoon floods had catastrophic impact on the infrastructure and the communities settled along the banks of the river. A geotechnical study of the area reveals the peak flow discharge at different locations between Charsadda and Nowshera and the extent of inundation. Masses received structural and non-structural damages including roads, agricultural fields, bridges, houses and livestock. Though the hazard is very prominent and eminent, still masses keep developing the infrastructure close to the risk zone and the trend goes unchecked and least monitored.

A geo-hazard research study of the area was conducted primarily for the purpose of ‘delineation of flood plain and to study erosional dynamics as a result of monsoon floods downstream of River Kabul’. The study focuses on marking the extent of the recent flood, described as a 100 year flood, and assessment of the structural and non-structural damages and the long term impact of such recurring floods. The methodology adopted for this study involves the use of GIS whereby primary data have been collected from the field and incorporated on the standard GIS maps of the area. Available data have significantly helped in establishing the findings of primary data. They also reveal that no mechanism has ever been developed to cope with the recurring hazard. Rather developing in floodplains close to the channel on a large scale and therefore removal of trees, and at instances the natural levees has added to the intensity of the floods.

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# Active tectonics, October 8, 2005 earthquake deformation, active uplift, scarp morphology and seismic geohazards microzonation, Hazara-Kashmir Syntaxis, Northwest Himalayas, Pakistan

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The Hazara-Kashmir Syntaxis (HKS) is an active antiformal synclinal structure. It is formed by the folding of Himalayan thrust sheets in the northeast Himalayas of Pakistan. It is convex to the hinterland and concave to the foreland. The northern HKS is a tight antiformal structure whereas the southern HKS is an open structure (Fig. 1). The thin skin faults those bend around the HKS are the Main Boundary Thrust (MBT), Panjal Thrust (PT) and Barian Thrust (BT) (Wadia, 1931; Calkins et al., 1975; Baig and Lawrence 1987; Khan and Ali, 1994)). The active Jhelum left-lateral strike slip reverse fault truncates the thin skin Main Boundary Thrust (MBT), Panjal Thrust (PT), Barian Thrust {BT), Himalayan Frontal Thrust (HFT) or Muzaffarabad Fault (MF), Riasi Fault (RF}, Shahdara Thrust (ST), Hazara Thrust (HT), Nar Thrust (NT), Shah Khaki Fault (SKF), Pir Gali Fault (PF), Samwal Fault (SF) and Ratial Fault (RF). The local newly recognized faults in Shahdara, Plandri, Panjara, Sarsawa and Kotli areas are the splays of the Riasi Fault. These include Dhalian Fault, Shahdara Thrust, Manoor Fault, Nuhisarhota Fault, Godri Badshah-Kotli Fault, Chak Nasru Fault and Mandi Fault.

The active faults along the eastern limb of the HKS in Azad Kashmir-Potwar are the Muzaffarabad Fault, Riasi Fault, Shahdara Fault, Shaheed Gala Fault, Riasi Fault, Godri Badshah-Kotli Fault, Pirgali Fault and Samwal Fault (SM). However, the active faults along the western limb of the HKS are the Salt Range Thrust (SRT), Shah Khaki Fault (SKF) or Diljaba Fault (DF), Main Boundary Thrust and Chail Sar Thrust (CST). The northwest-trending and northeast-dipping Chail Sar Thrust (CST) is the extension of the Indus-Kohistan Seismic Zone in Alai Kohistan (Baig, 1990). These faults show the evidence for Quaternary deformation, deflected or offset streams, nick points, uplifted and tilted terraces and seismicity. North of Kohala, the MBT offsets Berot Nala left laterally more than I km. This indicates that the MBT is an active fault.

The thrust/reverse faults along the eastern and western limbs of the HKS are the result of southwest-and southeast-directed thin/thick skin imbricate thrusting and southwest-and southeast-verging open to tight folds respectively. The most of the thin skin faults are along the limb or core of anticlines.

The Jhelum fault runs parallel or sub-parallel to river Jhelum or along the crest or western limb of the Jhelum River anticline. The seismicity, old linear landslides, dissected spurs, nick points, deflected drainage and tilted and uplifted river terraces or nala fans show that the Jhelum Fault is an active tectonic feature (Baig and Lawrence, 1987; Baig, 2006). The northwest-southeast-trending and northeast dipping thick skin active faults in the HKS are the Chail Sar Thsust (Baig, 1990), Indus-Kohistan Seismic Zone (IKSZ) blind reverse faults wedge (Armbruster et al., 1978; Seeber and Armbruster, 1979), Bagh Basement Fault (BBF; Khan and Ali, 1994) and new October 8$^{th}$ 2005 earthquake associated reverse Kawai-Dewalian Basement Fault (KDBF). The fault on which magnitude 7.6 earthquake occurred has reverse and some right-lateral strike slip fault motion (Yeats et al., 2006; Monalisa et al., 2007). The movement on northwest-trending and northeast-dipping KDBF reactivated the pre-existing northeast-dipping active Muzaffarabad Fault and Indus-Kohistan Seismic Zone (Baig 2006; Baig *et al.*, 2008). The KDBF marks back stepping or northeast jump of Indus Kohistan Fault Zone during active Himalayan strain buildup.

The BBF is a normal passive margin fault or bending moment normal fault on the Indian plate. The BBF reactivated as reverse fault during the Himalayan collision. The reverse Shaheed Gala Fault is the exposed extension of the BBF on surface. The most of the BBF in northwest is under the thin skin thrust sheets of the HKS. The fault is between the Murree Formation and the Nagri Formation. The 10 meter thick breccia and gouge are present along the fault. The shallow earthquakes in HKS are associated with these thin and thick skin active faults.

The Muzaffarabad fault was recognized along the overturned limb of the Balakot-Muzaffarabad anticline (Calkins *et al.*, 1975; Ghazanfar *et al.*, 1986). The Muzaffarabad Fault was also called as Himalayan Frontal Thrust (Baig and Lawrence, 1987), Tanda Fault (Nakata and Kumahara, 2006) and Balakot-Bagh Fault (Yeats *et al.*, 2006). The fault was the known active fault before October 8$^{th}$ 2005 earthquake. The thrust/reverse right lateral Muzaffarabad Fault extends northwest-southeast 120 Km from Balakot to Punch, Indian occupied Kashmir (Baig et al., 2008). The fault branches into Balakot, Garalat and Sangal Bohr terminal splay faults in Balakot area. In the southeastern segment, the Muzaffarabad Fault splays into the Berpani Fault and Raikot Fault. The fault terminates into overlapping rupture zone near Chrikot and Punch areas. The Balakot Fault cuts the MBT in the northwest. The Muzaffarabad fault formed the extensive active rupture zone varying from 1-3 km. The rupture zone has normal and reveres ruptures, landslides, breccia and gouge.

The scarp morphology along Muzaffarabad Fault is controlled by warps or folded scarps, fault-related fold scarps (Nisar camp and Balakot hanging wall anticlines Baig *et al.*, 2008), imbricate scarp, compressional arc scarp, vertical scarp and overhang scarp. The local pop ups, triangle zones, pressure ridges, horst and grabben, bending movement normal faults and back thrusts at places are present along the fault. The fault forms significant pre-earthquake degraded scarp topographic front which was reactivated and uplifted along Muzaffarabad Fault up to 7.5 m during October 8th 2005 Kashmir earthquake (Baig et al., 2008). The minimum and maximum terrace uplift is measured across Muzaffarabad Fault through detail mapping of river terraces. The minimum uplift across the fault is 50 m whereas the maximum uplift is 120 m. The 120 m uplift across Muzaffarabad Fault is the result of strong multiple earthquake uplifts in Holocene.

The Institute of Geology after October 8th 2005 earthquake started seismic geohazard microzonation along Muzaffarabad Fault during 2005-2007 for the rehabilitation of the earthquake affected people of Hazara and Kashmir. However, Institute of Geology Azad Jammu and Kashmir University, Muzaffarabad voluntarily coordinated and supervised NESPAK (2006) in Seismic Hazard Microzonation of Muzaffarabad, Bagh and Rawalakot areas on the request of AJ&K government. The other areas mapped for seismic geohazard microzonation along the Muzaffarabad Fault include Balakot-Garhi Habibulla, Jhelum valley, Chikar-Bagh and Bagh-Lasdana.

The seismic geohazard microzonation along Muzaffarabad Fault is based on hazard parameters such as active faults, active rupture zone, unstable steep slopes, brittle shear zone, active old and new landslides, ground shaking, earthquake deformation, seismic amplification, seismicity and flood. The areas are classified into highly hazard, high hazard and moderate hazard zones. It was recommended that the highly hazard zone (red zone) areas be avoided for any type of construction. However, the high hazard and moderate hazard zones be used subject to geotechnical studies and earthquake resistant building codes. The active fault lines, active ruptures, active landslides, steep slopes, river-nala banks, nala courses and flood zone areas should be avoided. The seismic amplification, ground shaking, slope failure, liquefaction, structural collapse, basement failure, old buildings, structural design, asymmetric structures and building material are the causes for the damage of civil structures and loss of human lives during earthquakes. The detailed study of slip rates, uplift rates, strain buildup, hazard zonation, recurrence intervals, seismicity, seismic hazard assessment, geohazard and earthquake monitoring is needed to avoid major human loss along active faults in Azad Kashmir and Pakistan.

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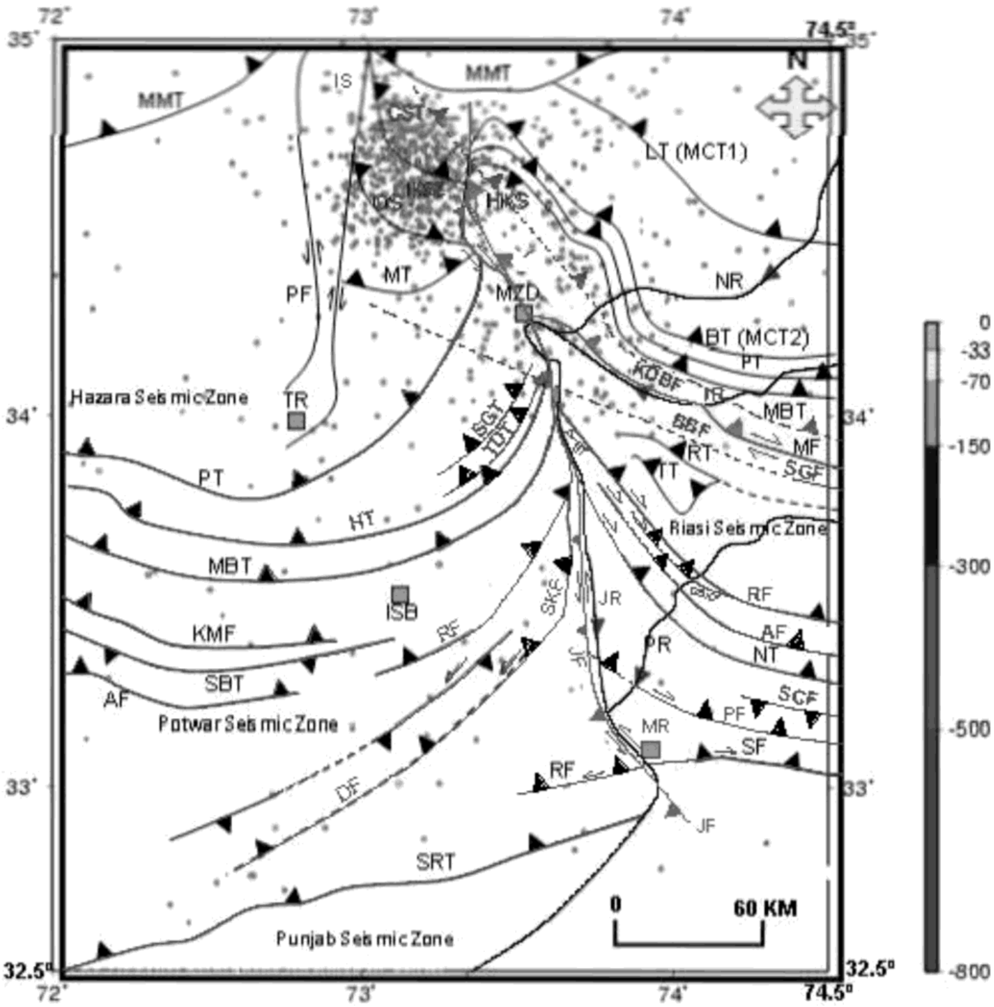

Fig. 1. Seismotectonic map of the Hazara Kashmir Syntaxis. Map shows seismicity from 1900 to present (Seismic data from U SGS 2007; modified after Baig and Lawrance, 1987; Baig 2006; Baig et al., 2008)

HKS = Hazara Kashmir Syntaxis, MMT = Main Mantle Thrust, BT = Barian Thrust, LT = Luat Thrust, MBT = Main Boundary Thrust, PT = Punjal Thrust, MF = Muzaffarabad Fault, RF = Riasi Fault, AF = Ajor Fault, NT = Nar Thrust, SF = Samwal Fault, RF = Ratial Fault, SGT = Sangar Gali Thrust, TDT = Thandiani Thrust, PF = Pir Gali Fault, SCF = Samani-Choki Fault, ST = Shahdara Thrust, SGF = Shaheed Gala Fault, BBF = Bagh Basement Fault, KDBF = Kawai-Devian Basement Fault, GBKF = Godri Badshah-Kotli Fault, SRT = Salt Range Thrust, AF = Ahmadwal Fault, SBT = Soan Back Thrust, KMF = Kheri-i-Murat Fault, RF = Rawat Fault, JF = Jhelum Fault, HT = Hazara Thrust, MT = Mansehra Thrust, OS = Ogi Shear, CST = Chail Sar Thrust, TF = Thakot Fault, PF = Puran Fault, IKSZ = Indus Kohistan Siesmic Zone, IS = Indus Syntaxis, TR = Terbela Reservoir, MR = Mangla Reservoir, ISB = Islamabad, MZD = Muzaffarabad, NR = Neelum River, JR = Jhelum River, PR = Punch River

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# Applications of Ground Penetrating Radar in Civil Engineering and Geology: case studies from Pakistan

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Ground Penetrating Radar (GPR) is widely popular these days for the assessment of infrastructure and related structures such as building walls, floors, bridges, road pavements culverts, railway tracks inspections and runways, etc. This paper demonstrates the applications of GPR in geology and civil engineering, Three case studies are presented here to demonstrate the applications of GPR, i.e., i) Motorway M1 Islamabad-Peshawar, ii) Roof floor of the buildings in Islamabad, and iii) Investigation of rupture in Balakot developed due to the 2005 Kashmir earthquake. This paper in fact reviews the operation of GPR systems together with a discussion of data processing and data interpretation techniques. In the area of Indus Bridge M1 GPR techniques have been used nondestructively to estimate the thickness of different layers, nature of cracks, voids spaces. In road structure surveys, GPR has been used to measure layer thickness, to detect subsurface defects and to evaluate base course quality, to estimate air void content of asphalt surfaces and to detect mix segregation. Similarly, the different floors of the buildings have been examined for weak zones developed due to cracks. In addition, GPR was used to measure the displacement of the large rupture produced in Balakot area by the 2005 Kashmir Earthquake. Future possibilities are described where the technique has great prospects in assisting engineers with their new pavement designs and in determining the optimal repair strategies for deteriorated roadways, and geologists/geophysicists as well to examine the hidden resources.

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# Engineering studies of aggregate from lightweight expanded slate of Manki Formation

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With increasing trend and need for the construction of multi-story buildings, construction companies and experts are more concerned over the use of construction materials that is lighter in weight to reduce the dead load. The use of structural grade lightweight concrete reduces considerably the self-load and permits larger precast units to be handled. Lightweight aggregate concrete (LWAC) has many comparative advantages over the commonly used concrete aggregates, for example LWAC is more fire resistant due to its verification, chemical inertness and cellular structure of the product. They have increased thermal insulation and moisture resistance and make more sound proof buildings. Moreover, it is wiser to use lightweight materials in construction of buildings in earthquake prone areas because of the improved seismic structural response of lightweight material. Pakistan has a considerable terrain that is seismically active, the most recent example being the deadly earthquake of October, 2005, which caused many tens of thousands of casualties.

Bloatable (expandable) argillaceous raw materials suitable for use in making lightweight aggregate exist in large quantities in Pakistan. For the present study, Precambrian slate from the Attock-Cherat ranges has been used to study its engineering properties for use as a lightweight aggregate concrete. Chemical analyses of the samples showed that loss on ignition varies from 3.45 to 4.56 %. The high contents of iron in the form of pyrite and hematite (5.23 %) and the content of alkalies (6.6 %) are indicative of better bloating properties in slate. The samples were fired in a rotary furnace at temperature ranging from 1050 to 1150 C° to achieve maximum bloating. After bloating, physical tests were carried out according to the ASTM specifications. The results of various tests, like water absorption, bulk density, chloride content, and soundness properties, meet the ASTM specifications of concrete and show the suitability of the rocks for use as a light weight aggregate for structural purposes.

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# Geological and stratigraphical studies of dimension and cutstone around Khanu Brohi and Khadhar areas, district Jamshoro, Sindh, Pakistan

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The Geological and stratigraphical investigations of the Ranikot and Laki formations, ranging in age from upper Paleocene (Lakhra Formation) to Middle Eocene (Meting limestone), have been carried out with special emphases on the dimension and cutstones of the lower Tertiary rocks of Jamshoro district. These rocks are exposed in the Khanu and Khadhar areas between latitude 25° 25′ 24″ to 25° 26′ 06″ N and longitude 68° 11′ 05″ to 68° 09′ 10″ E, and are dominantly composed of detrital shale facies and non-detrital limestone. Three undisturbed sections from the studied areas were selected for the columnar sections and correlation of dimension stones. The limestone, mainly used as dimension stone, is of orange yellow to pinkish yellow color and is exposed above the Lakhra formation. It is very hard, compact, thick to massive bedded, and shows sugary texture. This limestone bed represents an important marker bed at the top of Paleocene and the base of Eocene formations. It is of medium quality in comparison to the dimension stones of other areas of Sindh.

Geological mapping and lithofacies variation among the sections have been studied. The possible divisions of various facies in the studied formations have also been made. Their quality has been evaluated in the context of their use as dimension and cut stones. On the basis of hardness and chemical composition, these limestones have been classified into different classes for their valuable use in decoration and construction purposes. Besides this, structural and tectonic aspects, and economic importance of the study area are also discussed.

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# Safe bearing capacity evaluation for the proposed National Testing Services building at Sector H-8, Islamabad

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Islamabad, the capital of Pakistan, is a planned city constructed since 1960 at the foot of the Margalla Hills just north of the old city of Rawalpindi. Rapid growth of both Islamabad and Rawalpindi to a combined population of over 3 million has made ever-increasing demands of shelter for residential and other purposes. It is emerging as a major business involving expert engineering.

The present research focuses on the outcome of geotechnical investigations carried out by GEOENGINEERS, Islamabad assigned by Designmen Consulting Engineers (Pvt.) Ltd. for the construction of the National Testing Services Building Sector H 8/1 Islamabad, having two basements and ten stories. The fieldwork was started on 28th July, 2009 and completed on 16th August, 2009. During the field operation, eight bore holes of varying depth (10 to 18 meters deep) were drilled to evaluate the foundation's bearing capacity of soil, over which the entire proposed building will rest. The soil samples were collected at a regular interval or at any change in the lithology of the strata observed. Selected samples were sent to the geotechnical laboratory to evaluate their index and engineering properties, and their results have been compiled.

The Subsurface soil consists of light brown lean clay (CL), followed occasionally by sandy-silty gravels (SM). The Eastern part of the studied area consists of a few meters dumped ruble material from surrounding construction sites. The standard penetration test data reveals that N-values vary from a minimum of 6 at shallow depths to a maximum of 18 at depth. Geotechnical laboratory analyses for the representative soil samples collected during the drilling of boreholes have also been discussed. Grain size analysis data exhibit that gravel ranges from 0% to 5 %, sand from 5.9% to 29%, silt 63 – 94.1%, and clay 14.7 to 33.1%. The natural moisture content ranges from 11.12% to 24.5%. The soil consistency data reveals that liquid limit for studied samples ranges from 30.7 to 39.1%, plastic limit 22.2 to 29.9%, and the plasticity index from 7.1% to 12.0%. Specific gravity for soil samples are 2.65 g/cc. The unconfined compressive strength varies from 0.91 to 1.15 Kg/cms$^3$. The evaluated dry density is 1.485 to 2.171 g/cc, whereas the angle of repose is less than 26$^o$, indicating gentle fraction. Chemical data reveal that sulfate and chloride are well below hazardous range.

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# Water quality in Derajat Legahri, Dera Ghazi Khan

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Geological and hydrogeological studies were carried out in about 1,113 square kilometers area of Derajat Leghari, Dera Ghazi Khan. These include study of various lithostratigraphic units exposed in the mountainous region, determination of chemical quality of surface and groundwater of the area, and its use for drinking purpose.

Lithostratigraphic units, which range in age from Cretaceous to Recent, have been described. The Cretaceous to Miocene age rocks are of marine environment, whereas the Siwaliks and post-Siwaliks are of continental origin. The stratigraphic succession of the area consists of Moghalkot Formation (Paleocene), and Ghazij, Laki and Kirthar Formations of Eocene age. The Nari Formation is of Oligocene-Miocene age and the Siwaliks of Pliocene – Pleistocene age, whereas the alluvium is of Recent age. The rock units described here are from Ghazij Formation to Recent alluvium. These consist of both clastic and non-clastic sediments. About 41 water samples were collected from different localities. The surface water flow through different rocks ultimately reaches the piedmont planes in the region. A hydrogeological map is prepared taking into consideration the fresh and saline zone which changes with depth of the water table. The effect of geology on ground and surface water has been recorded.

The pH value for ground and surface water ranges from 7.3 to 8.3. The calcium concentration varies between 0.4 and 17.9 m meq/l, magnesium is up to 23.0 meq/l, and sodium with potassium ranges from 1.3 to 32.5 meq/l. These values reveal that they are higher as per international drinking water standards. The carbonates and bicarbonates increase the alkalinity of drinking water in the area. Their concentration ranges from 2.6 to 17.8 meq/l. The sulphates are 0.2 to 46.4 meq/l, whereas chlorides are within international standards. The dissolved constituents range from 216 to 3600 ppm. The study shows that the water in sandy aquifer better qualifies for drinking purpose as compared to that from the silt – clay zones.

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# Water quality assessment of Mardan district with special emphasis on heavy metals contamination

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Water quality has been changing rapidly for the last few decades in developing countries. This large scale alteration in the water quality could be either due to geogenic or anthropogenic sources. Like other South Asian countries, Pakistan is also facing health-related problems due to water contamination. Therefore, assessment of water quality of an area becomes imperative before it is used for drinking purpose by the inhabitants of the area. The present study was conducted on water samples collected from different localities of Mardan district. During this study, representative water samples from different available sources (i.e., surface, shallow and deep groundwater) were collected. These water samples were analyzed for various physico-chemical parameters (i.e., such as pH, T, (EC), resistivity, TDS) by COSORT electrochemical analyzer C931, anions (i.e., $SO_4$, $NO_3$, Cl, $HCO_3$) by Hach DR2800 spectrophotometer and major cations (i.e., Ca, Mg, Na, K) and heavy and trace metals (i.e., Fe, Mn, Cu, Cr, Cd, Pb, Ni, Zn and As) by atomic absorption spectrometer equipped with graphite furnace in the Geochemistry laboratory of the Nation Centre of Excellence in Geology, Universirty of Peshawar. Bicarbonates were recorded in relatively high concentrations, while the rest of the anions were found within the permissible limits of WHO. Among the major cations and heavy and trace metals, concentrations of Ca, Na, Fe, Cu and Pb were relatively high in some water samples. However, concentrations of K, Mg, Cd, Cr, As, Ni and Zn in all the water samples were found within the permissible limits of WHO and USEPA.

Various statistical parameters and health risk assessment tools were used to evaluate health-related problems associated with the water of Mardan district. Health risk assessment for heavy and trace metals in drinking water showed almost no health risk due to low hazard quotient (HQ) and cancer risk (CR) values. However, few shallow ground water samples were having low risk due to relatively high HQ values for Fe and Cu. This study suggests that generally the drinking water of Mardan district is safe for drinking purposes.

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# Environment friendly usage of Rice Husk Ash for subgrade soil stabilization

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Soil stabilization offers a technically feasible and economically viable solution to many engineering problems, especially in highway construction. Comprehensive testing, to evaluate improvement in desired engineering properties such as strength, durability and volume stability, etc., is essential to suggest a feasible solution. Stabilizers such as lime and cement are commonly used to improve the soil strength properties. Industrial and agro-waste products, such as fly ash and Rice Husk Ash, possess pozzolanic properties and, therefore, can be used as stabilizing agents for soil.

Journal of Himalayan Earth Sciences 43 (2010) 29-29

# Petroleum geology of Loralai Formation in western Sulaiman Range

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The Loralai Formation was deposited on the northern shelf of Tethys as carbonate platform depositional product and belongs to the Middle Jurassic carbonate rocks with its wide distribution and thousands of meters of thickness in the study area due to structural duplication on the large scale continent-continent plate margin, the thin skin tectonics and the decollement provided by shales of Sembar Formation, the largest source rock. Also because the Sulaiman Basin is in structural and stratigraphic equivalence with Kirthar Basin, the reservoir potential of Loralai Formation is beyond any question. The Lithology, stratigraphy and structure of the Loralai formation here is analogous to other such producing and proven basins. The studies on the sedimentology of the formation comprised analyses of stratigraphic sections, microfacies assemblages, and diagenetic sequences. In this area the diagenetic environments of Loralai Formation are different from one another by the resultant features such as cementation and dissolution. This is an attempt to demonstrate the pronouncing possibilities of reservoir potential of this formation for petroleum in Western Sulaiman Range.

Journal of Himalayan Earth Sciences 43 (2010) 30-30

# Functions and achievements of Pakistan Mineral Development Corporation in the mineral sector development

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Pakistan Mineral Development Corporation (PMDC) was established in 1974 as a Private Limited Company with paid up capital of Rs. 10 million and authorized capital of Rs. 1,000 million. Its objectives are exploration development of mining and marketing of minerals, including export. PMDC is primarily involved in the mining and marketing of rock salt and coal in the country. It is producing over one million tons of rock salt annually and meeting 55% of the country's rock salt requirement. The coal produced is supplied to the brick kilns, cement plants and Khanot Power Plant for generation of electricity.

PMDC's role as joint venture partner and as an executing agency are: 1) MCC China for the development of Duddar Lead-Zinc deposits, Lasbella, Balochistan, 2) WAPDA and Government of Sindh for supply of coal to WAPDA's power plant at Khanot through Lakhra Coal Development Company, 3) FATA Development Authority for mining of Kurram soapstone near Parachinar and 4) Sarhad Mineral Authority for rock salt mining at Nari Panoos, Karak.

PMDC as an Executing Agency is undertaking exploratory work for coal and copper in two projects in FATA, which have been sponsored by FATA Development Authority: 1) exploration and development of North Waziristan copper with a total cost of Rs.172.722 million. The work is in progress and 2) exploration and resource estimation for coal in Shirani area, F.R.D.I Khan, costing Rs 92.772 million. Drilling work is expected to start shortly.

*Duddar Lead-Zinc Project, Lasbela, Balochistan:* PMDC, with the technical and financial assistance of UNDP (1991-94), explored the Lead-Zinc deposits of Duddar. Subsequently the work was undertaken jointly by PMDC, Balochistan Development Authority (BDA) and PASMINCO (Australia) from 1995-1998. The investigations included over 43,000 meters drilling, assaying of samples, geological, geophysical and geotechnical studies and metallurgical tests. As a result of these investigations 14.1 million tonnes of Lead-Zinc ore was proved, having 3.2% Lead and 8.6% Zinc. Additional resource of 10 million tonnes of ore was also indicated adjacent to the ore body in the North.

An Agreement between Pakistan Mineral Development Corporation and China Metallurgical Construction (Group) Corporation, for development of Duddar Lead-Zinc deposits in Balochistan was signed on 3rd November 2003. According to the agreement, the investment required for the Project was US $73 million which was to be arranged in total by MCC. PMDC will get 20-25% share in the profits which will be shared by PMDC and Govt. of Balochistan on 50:50 basis. The investment has now gone to over 111 million US$.

On completion of the formalities, the development of the project started in 2005 and the trial production of Lead-Zinc ore started in December 2008 and is still going on. During the period from Dec, 2008 till date, a total of about 90,000 tonnes of Lead-Zinc ore has been mined and over 11,000 tonnes concentrate produced and exported to China for smelting. This project is the first of its kind in the underground metal mining in Pakistan and on its successful completion, will open up new avenues for development of similar type of other deposits in the Lasbella-Khuzdar metallogenic belt.

Journal of Himalayan Earth Sciences 43 (2010) 31-31

# Investigation of limestone exploitation area and its environmental impacts using GIS/RS techniques: A case study of Margalla Hills National Park, Islamabad

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The principal aim of the current study is to investigate the limestone (LS) exploitation area and its environmental impacts on water, vegetation, soil, etc., using low cost GIS/Remote Sensing techniques. Utilization of LS in Pakistan and other developing countries has been important for cement industry, construction material for roads and buildings, etc., however, extraction of LS from the Margalla Hills National Park (MHNP) cannot be allowed further due to the environmental impacts on the Federal city of Islamabad and Rawalpindi and the resulting degradation of water, soil, vegetation cover, air, etc. Satellite Remote Sensing and Geographic Information System have been proven as a powerful tool and low cost approach for LS exploitation investigation. Four Landsat Thematic Mapper / Enhanced Thematic Mapper satellite images have been taken over a span of 17 years (1992-2009). Digital Image Processing techniques including image enhancement, image classification and change detection have been applied to determine the temporal changes of various classes. Advanced Spaceborne Thermal Emission and Reflection Radiometer and Global Digital Elevation Model have been used for topographic information extraction. According to the results achieved, LS exploitation is deteriorating the ecosystem, biodiversity, landscape, vegetation, water quality and quantity of the MHNP, established in 1980 for the protection, conservation and management of biodiversity and ecosystem. Results of the study suggest that current LS extraction in the MHNP should be stopped immediately to secure the water, soil and air quality and quantity for growing population of the Federal capital city of Islamabad (estimated present population of Islamabad and Rawalpindi is about three to four million inhabitants) and initiatives should be taken for the rehabilitation of the already LS exploited areas of the MHNP and then to suggest alternative LS exploitation sites in the near periphery of Islamabad/Rawalpindi areas with EIA restrictions to avoid long term water, soil and air degradation and pollution.

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# Climate Change and vulnerability of Pakistan

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Climate change is a stark reality, no more a fiction. It is brought about by the industrial nations but its brunt has to be borne by the developing and developed countries alike. Pakistan is particularly vulnerable to climate change because it has generally a warm climate, lies in a world region where the temperature increases are expected to be higher than global averages; its land area is mostly arid and semiarid; its rivers are predominantly fed by Hindu-Kush-Karakoram-Himalaya glaciers which are reported to be receding rapidly due to global warming; its economy is largely agrarian and hence highly climate sensitive; and the country faces increasingly larger risk of variability in monsoon rains, extended droughts and large floods. The recent devastating floods in the country are vivid examples of this vulnerability. Under the influence of all these factors the Water Security, Food Security and Energy Security of the country are under serious threat. Compounding these factors are the expected increased risks to the coastal areas (these include Karachi, Pakistan's largest city and hub of its industrial activity) and the Indus deltaic region due to sea level rise and increasing cyclonic activity, to the mountainous regions due to Glaciers Lake Outburst Floods (GLOFs) and landslides (the recent GLOF at Attabad, Hunza is a clear example of this); to the scanty (<5%) forests due to forest fire, deforestation and reduced regeneration ; to human health due to heat strokes, diarrhoea, cholera, vector borne diseases, etc.

Adaptation to climate change has, therefore, emerged an imperative and high on the development agenda of Pakistan to deal with the unavoidable impacts of climate change, manage risks and adjust economic activity to reduce vulnerability and introduce climate proofing.

Journal of Himalayan Earth Sciences 43 (2010) 33-33

# On the paleoclimate and paleogeography of Permian rocks of the Salt Range, Pakistan

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The Stratigraphic committee of Pakistan divided the Permian rocks of Pakistan in two groups; the Zaluch group comprising the Amb, Wargal, and Chidhru Formations, and the Nilawahan group comprising the Tobra, Dandot, Warcha and Sardhai Formations. Initial paleontological datation of the Salt Range was provided by Waagon 1879-1885 in his famous work on the regional geology of the Salt Range. More detailed scientific works, highlighting stratigraphy, sedimentology and paleontology were carried out by Kummel & Teichert 1966, 1973, and Balme 1970, for Permo-Triassic rocks of the Salt Range. Detailed palynological data for the Permo-Triassic rocks of the Salt Range were also carried out by PICG, Pakistan-Japon Research group in the programme, The Tetthys. On the other hand, the Early Permian rocks of the Salt Range were not systematically studied earlier with regard to paleo-climate and paeogeography. We can differentiate the Upper and Lower Permian or Early or Late Permian rocks on the basis of flora and fauna. The Upper Permian flora was mixed type of flora which normally grows in climatic condition similar to those in the Tethys. On the other hand, study carried out on the samples of Early Permian rocks of the Salt Range have shown assemblage of such type of pollens and conifers which grow in climatic condition similar to those of Gondwana existing in India and Australia.

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# Sedimentology of the Lockhart limestone (Paleocene), Changlagali area, Nathiagali-Murree Road, Hazara, N. Pakistan

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The Lockhart Limestone of Paleocene age in the Changlagali area of Galiat is studied and described. The limestone is predominantly nodular, highly fossiliferous, with thin clay interbeds and is 120 m thick. The biotic assemblage is dominated by small and large benthic foraminifers with planktonic foraminifers, gastropods, mollusks, ostrocodes and dasycladacean algae. It has conformable lower and upper contacts with the Hangu and Patala formations (Paleocene) respectively.

On the basis of detailed field and petrographic characteristics, four microfacies with distinct textures, allochem types, fossil contents and sedimentary structures are identified and interpreted. The microfacies include 1) Algal-Foraminiferal Packstone Microfacies (Inner shelf), 2) Mixed Bioclastic Packstone Microfacies (Middle shelf), 3) Benthic foramaniferal Wacke-Packstone Microfacies (Mid-Outershelf) and 4) Planktic-Benthic Foramnaiferal Wacke-Packstone Micofacies (Outershelf).

The limestone represents deposition in a warm, low energy, restricted to normal salinity of the carbonate shelf. The cyclic repetition of the microfacies indicate changing depositional conditions as a consequence of sea level rise and fall.

The diagenetic fabric recognized in the limestone reveal mechanical and chemical compaction, deep burial-related pressure dissolution and tectonically-induced fractures with spar fillings. The nodular fabric of the limestone is mainly attributed to pressure dissolution phenomenon.

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# Hydro-chemical investigations of high altitude alpine lakes of Gilgit and Ghizar districts, Gilgit-Baltistan, Pakistan

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The present study was conducted to investigate the environmental impact assessment of water of the selected high altitude alpine lakes (i.e., Naltar wetland complex, Uttar, Hundrap and Baha lakes), and their respective streams within the Gilgit and Ghizar districts. These lakes are the major water resources of dirking and irrigation; they also have great significance in promotion of tourism in the region. Water samples were collected from the studied alpine lakes and their respective streams, and were analyzed for physical parameters, anions, major cations and trace and heavy metals by using sophisticated instruments including atomic absorption spectrometer equipped with graphite furnace and Hach DR2800 spectrophotometer in the Geochemistry laboratory of the National centre of Excellence in Geology, University of Peshawar. Water quality of these lakes was evaluated by comparing the physico-chemical parameters with permissible limits of WHO and US-EPA. The concentrations of physical parameters such as T (<8 $^oC$), pH (<7.72), EC (<165 μs/cm) and TDS (<95 mg/l), anions such as Cl (<12 mg/l), $SO_4$ (<23 mg/l), $NO_3$ (<2 mg/l) and $HCO_3$ (<187 mg/l), major cations such Na (<58), K (<4 mg/l), Ca (<40 mg/l) and Mg (<5 mg/l), and heavy and trace elements such Mn (<45 μg/l), Fe (<260 μg/l), Cu (<10 μg/l), Pb (<4 μg/l), Zn (<363 μg/l), Ni (<5 μg/l), Cr (<3 μg/l), Cd (<3 μg/l) and As (<4 μg/l) in most of the samples were found within the standard limits.

The concentration of anions and major cations in water of the study area were found in the order of $HCO_3^- > SO_4^- > Cl^- > NO_3^-$ and Ca>Mg> Na > K respectively. Therefore, the water of these alpine lakes is classified as Ca-$HCO_3$ type. Statistically, the quality of water in the study area was evaluated by using Pearson's correlations. A strong positive correlation between most of the physico-chemical parameter pairs was noticed. For health risk assessment of heavy and trace elements, the average daily dose (ADD), hazard quotient (HQ) and cancer risk (CR) were determined by using statistical means. The average values of HQ and CR were found <1 and <1per 1,000,000 inhabitants, respectively. These values were found very low as compared to USEPA guideline. It is, therefore, suggested that generally there is no chronic or carcinogenic health related risk involved as far as the water of the high altitude alpine lakes of northern areas of Pakistan is concerned.

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# Application of multivariate statistical methods to surface and ground water quality and health risk assessment of Attock Basin, Pakistan

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Attock Basin, previously known as Campbelpur Basin, is lying at the southeastern margin of the Peshawar Basin and is separated from it by the Indus River. It is generally covered with the Quaternary alluvial and fluvial sand, gravels and lacustine deposits. It is mainly drained by Haro River with its three main tributaries named as Nandna, Dhamruh and Reshi streams. Attock is the main city of the basin. For the last two decades the basin has tremendous increase in the population and establishment of industrial units. The increasing population and industrial developments in the basin have significantly affected the water resources of the basin. In order to investigate the quality of water of the basin, representative water samples from surface and ground water were collected according to the guidelines of the WHO. These samples were analyzed for physico-chemical parameters using sophisticated instruments including atomic absorption spectrometer equipped with graphite furnace and Hach DR2800 spectrometer in the Geochemsitry laboratory of the National Centre of Excellence in Geology, University of Peshawar. During this study more emphasis was given to the heavy and trace metals such as Fe, Mn, Cu, Pb, Zn, Ni, Cr, Co, CD, As and Hg. The data obtained was compared with the permissible limits of these elements set by the WHO, US-EPA and Pak-EPA for drinking water. The heavy and trace elements in most of the studied water samples were found within the permissible limits. In this study different multivariate statistical data analysis techniques were applied to find out the heavy and trace elements contamination contributed either by industrial and municipal solid waste and or by the various types of minerals of the soil of the basin. Data set thus obtained was treated using factor analysis (FA), principal component analysis and cluster analysis. FA identified four factors responsible for data structure explaining 67.04% of total variance in ground water and four factors in surface water explaining 83.13% of total variance and hence allowed to group selected parameters according to common features. Questionnaires were distributed to the individuals from each sampling unit to estimate the drinking water consumption. Exposure and risks for each individual was also determined by using health risk assessment statistical tools. This study indicated the necessity and usefulness of multivariate statistical methods for evaluation and interpretation of data in understanding the quality of water and related health risk assessment.

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# Geometry of foreland structures in the Himalayas and the Zagros

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Foreland structures are sites of the world's most prolific oil and gas fields in compressional structural settings. The structures, however, may have variable geometry with the presence and absence of a thrust fault at the mountain front. Understanding the geometry of these structures through balanced cross-sections provide solutions to many of the questions related to their evolution and hydrocarbon exploration. Regional balanced sections across the Himalayan foreland in the northern and western part of Pakistan suggest thin-skinned deformation with a mechanically weak decollement immediately above the basement. The cross-section across the central Salt Range/Potwar Plateau in northern part of Pakistan shows presence of a thrust fault, exceeding displacement of about 20 km. The thrust sheet has a flat-ramp-flat geometry extending over about 90 km and riding over a cushion of EoCambrian evaporites. The trailing edge of the thrust sheet is imbricated to form oil-field structures comprising fault-related folds, triangle zones, and pop-up structures. A section across the eastern Salt Range/Potwar Plateau exhibits a set of fault-related anticlines with relatively distributed shortening.

The Sulaiman fold belt along the western margin of the Indian plate does not show the presence of any exposed thrust at the mountain front. It exhibits folds-and-thrust structures in the form of broad detachment anticlines at the mountain front that are transformed into a passive-roof duplex geometry further north. Active seismicity along two linear belts and tectonic geomorphology in the Sulaiman fold belt is indicative of active mountain front and the out-of-sequence thrusting. Similarly, selected structures from the Zagros and its foreland are recognized to represent fold-and-thrust and duplex structures. Variation in structural geometries is influenced by the stratigraphy and mechanics of thrusting. Balanced cross-sections serve as a tool to resolve geometry of foreland structures for hydrocarbon exploration.

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# Status of Seismic Hazard Assessment in Pakistan

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For the seismic hazard assessment, deterministic as well as probabilistic evaluation methods are applied. In Pakistan both of these methods are used depending upon the nature of the project for which it is applied. Unfortunately the main parameters required for hazard analysis are very poorly defined in Pakistan. The deterministic method requires accurate definition of active faults in terms of location, type, dip and strike and length and width (or subsurface extension). The probabilistic method requires definition of seismic sources, associated seismicity, slip rate and recurrence relationship.

The definition of active faults requires detailed neotectonic studies of the faults. Paleoseismological studies of the fault scarp can identify slip rate and recurrence period of large earthquakes. Regional GPS arrays can give an idea about the slip rates across the major tectonic units. Detailed and long term continuation of these studies is required in Pakistan to refine the seismic hazard assessment.

Another important data for seismic hazard analysis is the accurate earthquake parameters i.e., location, magnitude, depth and fault rupture mechanism. Prior to October 2005 earthquake, the accuracy of earthquake parameters is low due to low density of seismic stations in Pakistan. With the recent improvement of seismic networks in Pakistan by various agencies, it is hoped that accuracy of earthquake recording parameters will improve in future, resulting in better definition of seismic sources and their recurrence relationships.

Due to scarcity of strong-motion data, attenuation equations could not be developed for the South Asian region and equations developed in other regions with similar tectonic characteristics are used for seismic hazard analysis. More and more strong-motion instruments should be installed and maintained to collect a large volume of data so that local attenuation equations could be developed.

All these studies are very important in improving the reliability of seismic hazard assessment in Pakistan. The collective effort of a number of agencies responsible for these studies is required to refine the seismicity and neotectonic data required for a reliable hazard evaluation. Therefore, it is essential that efforts be made to enhance the scope of these studies for achieving seismically safe environment.

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# Comparison of conventional and GIS/SRS based geological mapping of asbestos bearing areas in Northern Pakistan

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Geographic Information System (GIS) and Satellite Remote Sensing (SRS) technologies have recently emerged to collect, store, analyze and manipulate diverse geological information related to mineral exploration and exploitation in Pakistan. However, very limited attempts have been made so far in Pakistan for effective applications of GIS and SRS techniques to produce digital geological maps. The present study attempts to evaluate and upgrade the conventional geological map of the asbestos-bearing areas located in Mohmand and Malakand Agencies and District Charssada. During this study GPS was used to mark the precise geographic locations of asbestos-bearing deposits and mines in the study area. Various GIS and SRS techniques including Geo-referencing, False Color Composite, Principal Component Analysis and Normal Vegetation Index were applied to LANDSAT TM image of the area to compare and edit the errors identified in the existing conventional geological map of the study area. Overall this study demonstrates that GPS, GIS and SRS are the best tools to improve and upgrade the existing manual geological maps used for mineral exploration and exploitation activities in Pakistan.

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# Nature and significance of contrasting depositional systems within the late Cretaceous succession, Kirthar Foldbelt, Pakistan. Deciphering the fragmentation of Indian passive margin prior to collision

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The Late Cretaceous succession in the N-S trending Kirthar fold belt of western Pakistan is dominated by sandstones with subordinate mudstones and marls. Recent work demonstrates that these were formed in two partly coeval depositional systems. The northern system is characterised by deposits formed on a gently inclined, storm and river-flood dominated clastic ramp that can be assigned to four main facies associations, and includes excellent examples of Mutti-type shelf delta lobes. The southern system is dominated by deepwater turbidite sand-bodies formed in both channels and restricted lobes within deep slope and basin-floor settings.

The palaeoflow patterns and sandstone petrography of these two systems are also significantly different. The northern, shelfal sands display paleoflow to W and NW and appear to be sourced from the thermally uplifting Indian shield to the east, while the deepwater sands in the southern system were emplaced by N and NNW directed gravity flows but were derived from an easterly source that included volcanics. The architecture, regional distribution and vertical sequence of sand-bodies within both systems provide important clues to the physiographic and tectonic character of the Indian passive margin during its northward drift, just prior to collision with Eurasia.

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# National Mineral Policy and Disaster Risk Management in the mineral sector of Pakistan

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The first National Mineral Policy (NMP), framed in 1995 in consultation with provinces, private sector and other stakeholders has been implemented. With implementation of National Mineral Policy independence of the departments of Mines and Mineral Development has been established in the provinces. New regulatory and fiscal regime was tailored for investment friendly environment to make the mineral sector of the country more deliverable and vibrant. The new mineral concession rules are aimed at maximizing exploration and development in mineral sector by providing safety and security to mine workers. The environment related issues have been addressed by NMP to mitigate the adverse impact of mining on other sectors and make it universally acceptable. In mining sector the disaster management deals with three areas. These include safety management in mines, effect on external environments-weathering agents on mineral resources and impact of mining on environment. Mining is not only profitable profession but is also hazardous, therefore, the mining operations are regulated to ensure safety at mines under the Mine-Act 1923 and its subordinate rules and regulations. The provincial chief inspectorate of mines is responsible to ensure safety in mines in their respective areas. The role of management is to foresee all possible risks enlist them and design procedure to control them. The possible dangers in mines include roof fall, presence of noxious gases, uncontrolled blasting, and water inundation etc. The possible risk to safety in mines includes lack of supervision, absence of safeguard, and absence of protective devices and inter personnel communication. The role of management to avoid the dangers in mining includes proper planning, organizing staff and co-ordination, controlling and budgeting. The external factors disturbing mining environment include floods, glaciations /avalanches, earthquake, land sliding, public works programme etc. Very little can be done to divert the unalarmed generation of huge energy by floods, earthquakes and avalanches; however the mining operations should take into consideration the possible threats from such environments including the public works in selecting the mines location and methodology of mining. Public works should be so located to inflect minimum threats to the mining operations. To avoid the impact of mining on environment, post mining operations require rehabilitations after surface mining. The subsurface mining also has impact of vibration, sound and dust emission for which mitigating measures need to be adopted.

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# Investment opportunities in the mineral sector of Pakistan

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Pakistan is geologically a unique country where within an area of about 796,096 Sq kms almost all geotectonic zones related to plate tectonic process are developed. Precambrian shield rocks are exposed in Nager Parker area of Sindh Province, Sargodha area of Punjab Province and in Karakoram, Hindukash and Hamalayan part of Pakistan. Andian type Island arc is developed in Chagai District of Balochistan and Oceanic type Island Arc in Kohistan. Cheman-Ornach-Nal transform boundary exists between Indo-Pakistan plate and Afghan Block. Ophiolitic rocks and melanges occur along western margins of the Indo Pakistan block in Lasbela-Khuzdar, Muslim Bagh-Zhob and Waziristan while deep seated thrusts known as MKT and MBT are the suture zones between Eurasian Continental Plate, Kohistan Oceanic Island arc and Indo Pakistan Continental Plate. There are vast areas in Pakistan which have geological environment favorable for the discovery of world class mineral deposits. The significant discoveries made so far include huge coal deposits in Thar coal field in Sindh, well known copper-gold potential of Chagai-Raskoh region in Balochistan, dimension stone deposits (Marble and Granite) in Khyber-Pakhthunkhwa (KPK), Balochistan and FATA, world class gemstone deposits i.e., emerald, ruby, tourmaline, garnets in Khyber Pakhtunkhwa (KPK), Azad Jammu and Kashmir (AJK) and Gilgit-Baltistan. Private mining companies can invest in establishment of mechanize coal mines, commissioning of coal based power plants in Thar, Sonda Jherric and Lakhra coal fields of Sindh, mining and processing of dimension stone including marble granite and colored limestone, mining cutting polishing of gemstone in KPK, AJK and Gilgit-Baltistan and establishment of chemical industries based on value addition of rock salt.

Pakistan is very attractive to exploration/mining companies for a number of reasons encompassing presence of investment friendly National Mineral Policy and provincial mineral concession rules providing various incentives and facilitation to investors. Presence of favourable geology, cheap labour force, good climate, good infrastructure and communication network, availability of experienced geoscientists, technician and laboratories make Pakistan a favorable country for the investment. Geological data base of significant nature is also available for planning all future geological and mining activities.

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# Use of GIS in defining the management strategies for groundwater resources of Quetta valley, Pakistan

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Pakistan is blessed with a variety of topographic features ranging from higher mountains and steep slopes in the north, to the coastal areas in the south, including plains, plateau and deserts in between. Pakistan has plenty of valuable natural resources like lush green forests, rivers, lakes, fertile land, natural gas, and mineral deposits. These resources play a vital role in the economy of the country. Among the natural resources, water is most important for life and, being the main water source, groundwater management needs special attention. Conventional approach adopted to suggest management strategies for groundwater resources failed to provide sustainable solutions, therefore, professional approach for management and conservation of groundwater is urgently needed and required. Geographic Information System has become an essential tool for studies, where real world application is required using real time data.

This report deals with the spatial information about water table and temporal changes that occurred in groundwater regime between 1967 and 2007 in the Quetta valley of Baluchistan province. Real time data have been used in assessing the qualitative and quantitative changes in water table with respect to time and space. Results of the analysis show that water table in more than 80% of the area has gone down and in some areas it has dropped more than 100 ft. Continuous over-draft has resulted in excessive groundwater abstraction and presently only 20-30% of the farmers have reach to the groundwater. Geographic Information System is the only tool that can display “what is happening where?” in this alarming situation.

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# Thick skin tectonic study of the Hazara-Kashmir Syntaxis based on gravity data

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Gravity and geological study in the Hazara and its adjoining areas of northern Pakistan has been incorporated into interpretation of the gross crustal structure of the Hazara-Kashmir Syntaxis (HKS). In this area, continued northward migration of the Indian plate has been overridden by slices of its own northern margin, resulting in slight thickening of the crust. Two types of deformation have been observed, one is in the crystalline crust and the other in both the sedimentary wedge and crystalline crust. The crystalline crust is faulted into blocks by the Hazara Lower Seismic Zone (HLSZ), Bagh Basement Fault (BBF) and Indus Kohistan Seismic Zone (IKSZ). These faults are trending in the NW-SE direction. In the core of HKS the BBF is exposed on the surface in Shahidgala east of Rawalakot, Namanpura near Bagh and in Chatter Muzaffarabad areas. In the northwestern part between Chatter and Mansehra areas under the western limb of the HKS, this fault exists in the crystalline basement and not exposed on surface. In the south of Mansehra along the Abbottabad road, deformation in the sedimentary-metasedimentary wedge is an indication of BBF on surface. The study also suggests that the HLSZ is a blind basement fault trending in the NW-SE direction and extending up to Moho depth between Taxila and Kalar Syedian areas. In the northern part of the study area, the IKSZ was a blind basement fault before 2005 Kashmir earthquake. Due to compressional stresses, the rupture developed in 15–20 km thick sedimentary and meta-sedimentary wedge and the $8^{th}$ October, 2005 earthquake occurred in the Kashmir and Balakot areas. The study also suggests that IKSZ or Kawai fault is a thick skin fault which penetrates both the sedimentary and metasedimentary wedge and is demarcated from Kawai to Davelian and Chinari areas.

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# Microfacies and depositional environments of the Jurassic to Paleocene carbonates in the Kharzan area, Khuzdar, Balochistan

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The Kharzan area lies in the Central Kirthar Range of the Kirthar Fold and Thrust Belt. It exposes a thick Jurassic to Eocene stratigraphic sequence comprised of carbonates and clastics. The sequence is represented by Chiltan, Mazar Drik, Goru, Parh, Moru, Ranikot, Dungan, Ghazij, Kirthar, Nari and Gaj Formations in ascending order. As a part of this study, lithostratigraphic relationships of the units are recognized. Detailed sedimentology of the exposed carbonate units is based on logging and sampling of measured stratigraphic sections in the entire area. Detailed petrographic studies are carried out to identify and interpret microfacies of the sequence.

The oldest exposed sequence in the area is represented by massive to thick bedded, dark to light gray, Chiltan Limestone of Jurassic age. The limestone is measured and described from Chutok Nala and Pironi Nala in the Kharzan, district Khuzdar, Balochistan, where the base of the unit is not exposed and it is 300 and 200 m thick respectively. The top of the Chiltan is a major unconformity marked by subaerial exposure surface with karstified solution breccia. Six microfacies comprised of 1) Ooidal Grainstone, 2) Peloidal, bioclastic Packstone, 3) Dolomitic Grainstone, 4) Peloidal Packstone, 5) Micropeloidal Wacke-Packstone and 6) Dolomitic Mudstone are recognized. These microfacies are interpreted to represent deposition under a shallow shelf environments marked by sea level-induced periodic changes in energy conditions. The Chiltan deposition is followed by emergence of the carbonate platform with the development of paleokarst related solution breccia.

The Parh Limestone of Cretaceous age overly the Goru Formation and is a thick sequence of thin-bedded, papery laminated micritic limestone with planktonic foramanifers like *Globotruncana fornicate*, *Globotruncana sigali*, *Globotruncana concavata* and represent deposition in a deeper outer shelf.

The Paleocene sequence is represented by the Dunghan Limestone. The formation is 130 m thick in Chutok Nala and is comprised of two distinct lithological units; the lower unit is medium-bedded limestone with interbeds of clinoforms of massive, carbonate breccia, while the upper unit is thin bedded, fossiliferous limestone. Five microfacies identified in the Dunghan Limestone are; 1) Mixed Bioclastic, Algal Packstone, 2) Foram-Algal Grainstone Microfacies, 3) Coarse Lithoclastic Microfacies, 4) Microbioclastic Planktic Wacke-Packstone Microfacies, 5) Peloidal Wacke-Packstone Microfacies. The microfacies interpretation shows that the Dunghan Limestone represents deposition in a carbonate ramp with deepening upward trend.

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# Microfacies and depositional environments of the Kawagarh limestone, Dhamtaur-Harnoi section, Abbottabad, Pakistan

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The Kawagarh Limestone of the Cretaceous age is exposed along Abbottabad-Nathiagali Road. A section of the formation along Dhamtaur-Harnoi is measured, logged and sampled for the identification of textural constituents and faunal components for the interpretation of depositional environments. The formation is 45 m thick having lower contact with the Lumshiwal and upper contact with the Hangu Formation. It is medium to thick-bedded with local brecciated horizons and fossiliferous with predominance of planktonic forams while other bioclasts include echinoderms, ostracodes and algae.

Based on constituent composition and textures, three microfacies are recognized. These microfacies are: 1) Planktic foram Wackestone Microfacies, 2) Burrowed planktic foram Wacke-Packstone Microfacies and 3) Planktic foram Packstone Microfacies. The microfacies interpretation shows that the Kawagarh Limestone represents deposition in a low energy setting on the shelf. The lack of land-derived clastic input and preponderance of planktic foraminifers indicate deeper, mid-outer shelf environments of deposition. Sea level fluctuations of the shelf are reflected by the cyclic nature of vertical facies changes. The Kawagarh Limestone displays a number of diagentic fabric dominated by the presence of burial related pressure dissolution, stylolitization, spar-filled fractures,and secondary dolomitization.

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# Mercury and health-related problems in gold extractors, Gilgit-Baltistan, Pakistan

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This study was conducted to investigate mercury (Hg) exposure and health-related problems in the local people who are extracting gold by the Hg amalgamation method from the stream sediments in the Gilgit-Baltistan Province. Urine and blood samples of occupational and non-occupational persons were analyzed for total Hg, while blood's fractions, including red blood cells and plasma, were analyzed for total Hg and its inorganic and organic species. The concentrations of Hg in urine and blood samples were significantly ($P$<0.01) higher in occupational persons as compared to non-occupational and exceeded the permissible limits set by World Health Organization (WHO) and United State Environmental Protection Agency (US-EPA). Furthermore, the data indicated that numerous health problems were present in occupational persons involved in extraction of gold in the Gilgit-Baltistan province.

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# Investigating levels of selected heavy metals in surface water of Shah Alam River, Khyber Pakhtunkhwa

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Over the last few decades fresh water contamination has become a matter of concern. Among other organic and inorganic pollutants, our aquatic systems may extensively be contaminated with heavy metals. Heavy metal contamination of aquatic system has attracted the attention of several investigators both in the developed and developing countries of the world. The fact that heavy metals cannot be destroyed through biological degradation and have the ability to accumulate in the environment make these toxicants deleterious to the aquatic environment and consequently to humans who depend on aquatic products. The most common heavy metal pollutants are arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), mercury (Hg) and Zinc (Zn). Their source of entry into the aquatic system could either be a single, identifiable or dispersed (and often difficult to identify). Industrial wastes create a potential source of heavy metal pollution in the aquatic environment.

Pakistan is one of the countries facing fresh water pollution mainly due to untreated discharge of industrial wastes into rivers. Here only 1% of industrial waste is treated before its discharge to the rivers. River Kabul is an important river of Khyber Pakhtunkhwa province; it receives 80000 $m^3$ industrial effluents every day. River Shah Alam branches off river Kabul that receives all the sewage from Peshawar, as well as from 30 surrounding villages. It also receives effluents from Sugar mills, distilleries, paper mills, tanneries, ghee mills and textile mills in that area.

The purpose of this study was to investigate the levels of heavy metals (Cd, Cr, Cu, Mn, Ni, Pb and Zn) in the surface water of the Shah Alam River. The surface water samples were collected at five sampling sites, selected on the basis of upstream and downstream industrial and domestic sewage discharge locations. Surface water samples were collected from each site in a six month period, from December to April. The elements Cd, Cr, Cu, Mn, Ni, Pb and Zn were assayed using an atomic absorption spectrophotometery and the results are given as mg of heavy metal/L of fresh water sample (mg/L). The order of heavy metal concentration was Mn $\geq$ Ni $>$ Zn $>>$ Cu $>$ Cd $\approx$ Pb $>>$ Cr. The concentrations of Ni were 20 -30 times higher than the permissible World Heatlh Organization (WHO) limits for water, Cd levels were 10 times, whereas Mn and Pb were 2-3 times higher than WHO limits. The levels of Cu, Cr and Zn were within those limits.

Although a weak correlation existed between metal concentration and temperature increase, but since the temperature change was only within 2-3°C over the sampling period, therefore, we could not deduce concentration dependence on water temperature. Except for the Mn, no strong correlation existed between water pH and metal concentration. Although metal concentration has been reported to increase with decreasing pH, in our studies no such correlation existed (except for Mn). The absence of such correlation could be due to the dilution factor that occurs after river Naguman joins river Shah Alam. The concentrations of almost all metals detected were higher in all downstream locations. Declines in those levels occur at site where Naguman River joins river Shah Alam. Metals could accumulate in sediments and can become bioavailable to aquatic fauna (bottom feeders). An investigation into the concentrations of heavy metals in river sediments is needed for better assessment of heavy metals bioaccumulation in fish.

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# A review on Radon monitoring for geological exploration

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Radon is a naturally occurring radioactive alpha particle emitting colorless, odorless and tasteless gas produced by radioactive decay of uranium and thorium. It plays a dual role in man’s life, being a fatal health hazard to mine workers and common people living in their homes on one hand and a very useful geological tool on the other hand. As a geological tool, radon monitoring technique can be used in uranium and hydrocarbon exploration, earthquake prediction, study of active faults and geothermal energy sources. With this technique, fault zones have been recognized with fairly good precision worldwide. The technique can also be effectively used in hydrologic research, when studying the interactions between groundwater, streams, and rivers. It has found limited use in geothermal prospecting. As an enemy, the presence of high level of radon concentration in the indoor air of the houses and in the air of underground mines constitutes a serious health hazard, being a major cause of lung and stomach cancer.

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# Mathematical modeling of blasting and analysis of crack propagation in fractured and faulty rock by PFC-3D

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Detonation of explosives to fragment rock remains central in mines, quarries and civil excavations. Whenever fractured and faulty rocks are blasted, much of the explosive energy is lost in the incompetent zones, resulting in blocky fragments. In this study circular rock models with a single central source of explosive were simulated using the Particle Flow Code 3D (PFC-3D) for the prediction of formation behavior. Using PFC-3D, we model the movement and interaction of spherical particles by the distinct element method. From the analysis of rock blasting simulations it is found that results of blasting in fractured rocks is dependent upon fracture orientation, fracture width and on the material filling the fracture. On the basis of detailed study, it is suggested that the explosive be concentrated at the competent rock portion while the fractured and incompetent zones be stemmed. The investigation also confirms that the use of high specific charge cannot solve the problem, but may cause fly rock.

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# Geochemistry and petrogenesis of the Nagar Parkar Igneous Complex, Tharparkar, Sindh

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Covering 480 $km^2$, the Nagar Parkar area in southeastern Sindh is part of the Thar Desert adjacent to the Runn of Kutchh. The area is occupied by a variety of magmatic rocks referred to as the Nagar Parkar Igneous Complex. At least six phases are recognizable: 1) basement rocks (oldest), 2) riebeckite aegirine grey granite, 3) biotite-hornblende pink granite, 4) acid dyke, 5) rhyolite “plug”, and 6) basic dykes (youngest). Of these, the last three are insignificant in volume. Radiometric dates are lacking but the grey and pink granites are petrographically comparable to the Siwana and Jalore plutons, respectively, emplaced in the Malani volcanic series. Based on these similarities and proximity, it is thus suggested that the phase 2 to 6 bodies in the Nagar Parkar may belong to the Late Proterozoic (720 – 745 Ma) Malani magmatism that covers large areas in western Rajasthan. Khan et al. (2007) have reported a 745 ± 30 – 755 ± 22 Ma UThPb age on monazite from the pink granite.

The basement comprises deformed and epidote-amphibolite facies metamorphosed rocks ranging from mafic to granodioritic composition. They appear to be the products of crystallization differentiation of calc-alkaline magma of island arc affinity. The phase 2 to 5 rocks, forming stock-size plutons to minor dykes, range from peralkaline (most common) to peraluminous granites, microgranites, rhyolite and trachyte. They display very similar trace element characteristic and classify as typical within plate, A-type granitoid. Their trace element patterns are akin to those of Mull (Scotland), Skaergaard (Greenland), and Sabaloka (sudan) granites, which are emplaced in attenuated to normal continental crust.

The basic dykes are divisible into hornblende-bearing (dioritic/lamprophyric) and pyroxene-bearing (doleritic) types. Both are alkaline and show some chemical resemblance to continental alkaline basalts. Significantly, the mantle-normalized diagrams of the basic dykes are similar to those of the main granites except for relatively lower concentrations of trace and rare earth elements. This similarity provides a strong argument in favaour of derivation of the parent magmas of phase 2 to 6 rocks from the upper mantle. However, during ascent, the magmas that produced the granitic rocks were contaminated with crustal material. In terms of tectonic evolution, the Nagar Parkar region appears to be a composite terrane that developed initially as an island arc. It was accreted to other terranes to constitute a Precambrian continental crust. During the collision it may have experienced deformation and metamorphism in epidote-amphibolite facies. During the Late Proterozoic, the terrane played host to continental magmatism related to epeirogenic uplift (doming) and extension.

Reference:

Khan, T., Murata, M. and Oto, A., 2007. Internat. Assoc. Gondwana Res. 4, Conf. Series, 92-93.

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# Biostratigraphic studies of the Eocene succession on the basis of Pelecypods and Gastropods around Thano Bula Khan area, Sindh

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The Biostratigraphic study of pelecypod and gastropod fauna of Eocene in Thano Bula Khan have prominent position in biostratigraphy of Sindh. On the basis of these fauna the Eocene rocks of Sindh are correlated with other Eocene strata of Pakistan and worldwide.

The Biostratigraphic study consists of ten species of pelecypod and eight gastropod species. There is no common specie in Sindh, Punjab, Khyber Pakhtunkhwa and Baluchistan; except three species of pelecypod (*Clementia cf. C. papyracea, Lucina metableta, Cardium inaequiconvexum)* and one specie of Gastropod (*Velates perversus)* which are common in Sindh, Punjab and Khyber Pakhtunkhwa. Single specie of pelecypod and gastropod is common in Sindh, Punjab and Balochistan. While seven species of pelecypod and six species of gastropod are common in Sindh and Punjab.

The Eocene pelecypod and gastropod fauna of Pakistan has a well-marked affinity with that of Albania, Bulgaria, Burma, Egypt, England, France, Hungary, India, Indonesia, Iran, Italy, Jamaica, Russia, Saudi Arabia, Somalia, Soudan, Spain, Srilanka, Switzerland, Tibet and Turkey. A brief account of the age of various formations based on paleontological evidence is also assigned to the succession.

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# Advances in Earthquake Engineering

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Seismic hazard of moderate to high levels of are present throughout Pakistan, and the numerous building collapses caused by the 2005 Kashmir earthquake verified the seismic vulnerability of building types present throughout the country. The overall capacity of the Pakistani academic, public, and private sectors to assess seismic vulnerability, to identify potential seismic mitigation measures, and to strengthen vulnerable essential buildings is currently limited. There is a pressing need to develop a critical mass of knowledgeable professionals, strengthen existing faculties and their earthquake research programs.

There exists a huge stock of buildings through out Pakistan which are either not designed for earthquake resistance or have problems with respect to seismic resistance. In order to mitigate the seismic threat to the existing building stock a detailed and comprehensive three tier procedure has been developed for existing buildings in Pakistan. This paper presents the three tier seismic vulnerability assessment procedure and also discusses gaps in between information needed and available regarding seismology and earthquake engineering.

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# Equivalent linear earthquake site characterization of layered soil deposits at Shakardarra and Muzaffarabad

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The present work deals with the test of the adequacy of site response analyses (e.g., strain-dependent normalized shear modulus and equivalent linear damping curves) to predict the effects of soil deposits on site responses during earthquakes. The selected sites are Shakardarra (in Kohat) and Muzaffarabad (Azad Kashmir). For this, the site responses at the vertical strong motion arrays at the Shakardarra and Muzaffarabad were analyzed prior to occurrence of any earthquake. The site response analysis program, which is based on the Equivalent linear hysteretic soil model (EERA), has been used for the purpose. The site response models were constructed using different borehole profiles, shear and compression wave velocity profiles, and the available geotechnical data of CPT and SPT. Two site-response analyses were carried out for two input ground accelerations 0.07 g and 0.1. Based on the EERA analysis results, the Muzaffarabad site was found to have comparable responses over a wide range of earthquake motions while at Shakardarra there is relative small range of earthquake motion results. At Shakardarra site, EERA predicts site amplification of 3.83 (clay), 3.84 (Dry sand), and 3.89 (wet sand) for acceleration up to 0.07 g, and attenuation of surface acceleration for higher levels of accelerations. While at Muzaffarabad EERA predicts site amplification of 9.35 (sandy gravel) and 10.51 (clay) for acceleration up to 0.1 g. The results are beneficial for both the researchers and engineers alike.

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# Geophysical modeling of a part of Potwar (Missa Keswal) area by using seismic and well data

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Geophysical modeling of a part of Potwar at Missa Keswal (Qazian Anticline) has been carried out in the present work (Fig. 1) The 2-D seismic data consisting of ten seismic lines (GNA-09, GNA-10, GNA-11, GNA-13, GNA-14, GNA-15, GNA-16, GNA-19, MN-20 and GNA-21) were re-interpreted for the purpose. The well data of Missa Keswal-01 was used for the confirmation of the reflector identified through synthetic seismogram and also to confirm the depth of the interpreted reflectors. Structural interpretation depicts two broad types of fault sets namely, thrust and back thrust faults. These faults together give rise to pop up structures in the study area, and are also considered responsible for many structural traps. Structural interpretation includes time and depth contour maps of Chorgali Formation, velocity modeling, fault modeling and kinematic analysis of faults. The results show that the fractured carbonates of Chorgali Formation and Sakesar Formation are the major producing reservoirs in Missa Keswa area. It is hoped that the present work would help in better understanding of the variations in the subsurface structure and stratigraphy of the Missa Keswal area.

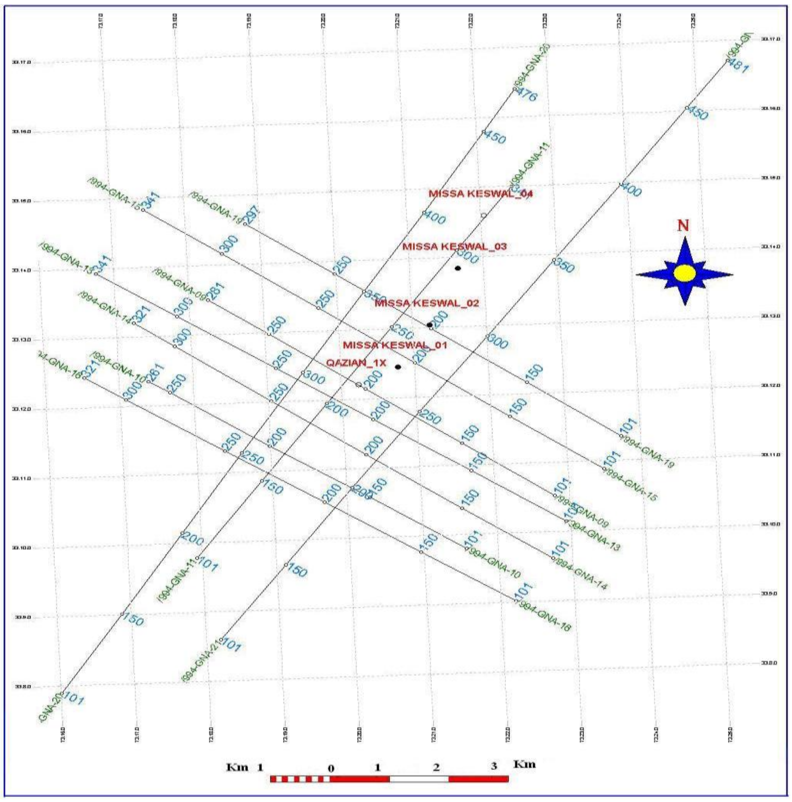


Fig. 1. Base map of the study area.

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# Structural interpretation of carbonate mounts in Indus offshore, Pakistan using geological and geophysical data integration

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The present study deals with the structural interpretation of two major carbonate mounts M2 and M1 covering more than 200 sq. kms areas. The 2D seismic data consisting of a total of eight seismic lines of up to the time column 10-12 second acquired in deep offshore Indus fan system at water depth ranging from 1700 m to 3100 m in year 2000, has been utilized for the purpose (Fig.1). M2 structure was selected as the primary target to be drilled. An exploratory Well is located in the south of Karachi, in the Arabian Sea (northern tip of the Indian Ocean), across the Sommath Ridge at water depth 2712 m. Velocity analysis, High Density Velocity, and pressure evaluation, based on the available data and cross checked with analogues indicate a rather hydrostatic regime. Down to 3,700 m and 3,900 m the pressure is predicted hydrostatic.

The interpretation of the seismic, corroborated to the High Density Velocity, use of the previous regional study and knowledge of delta systems provide a general description of the sediments corresponding to the seal above the G2 structure. The analogues and previous work done on other delta apparatus help to confirm the tentative lithological facies attribution to the seismofacies and petroleum system. The series of reflectors were marked on seismic section, called Base Detritics, defines a buildup. This build-up is further divided in three units from bottom to top: The first unit is volcanic, the second unit is made up of volcanoclastics, and the last unit comprises the carbonate buildup. These sub-units correspond to the main back-steps of the platform.

Analogy to various carbonate buildups and previous work done on other isolated carbonate platforms of Tertiary age, after identification of the leeward versus windward side of the buildup on the seismic data, allows describing tentative lithological facies with respect to the seismofacies. Stress was put on the potential hazard identified as a specific chaotic seismofacies that can be related to karst event before drowning.

On the geological and geophysical analysis of the exploratory well, it is suggested that the M1 structure is suitable to drill and confirm the presence of hydrocarbon in the carbonate buildups. The limitation in the present work is the usage of the seismic grid of 5x5 km for a structure size of 15x18 km. This grid does not allow an accurate and reliable mapping of the seismic facies. A thickness resolution of the seismic data between 25 to 50 m due to the frequency spectrum centered on 40 Hz is quite acceptable for overall definition.

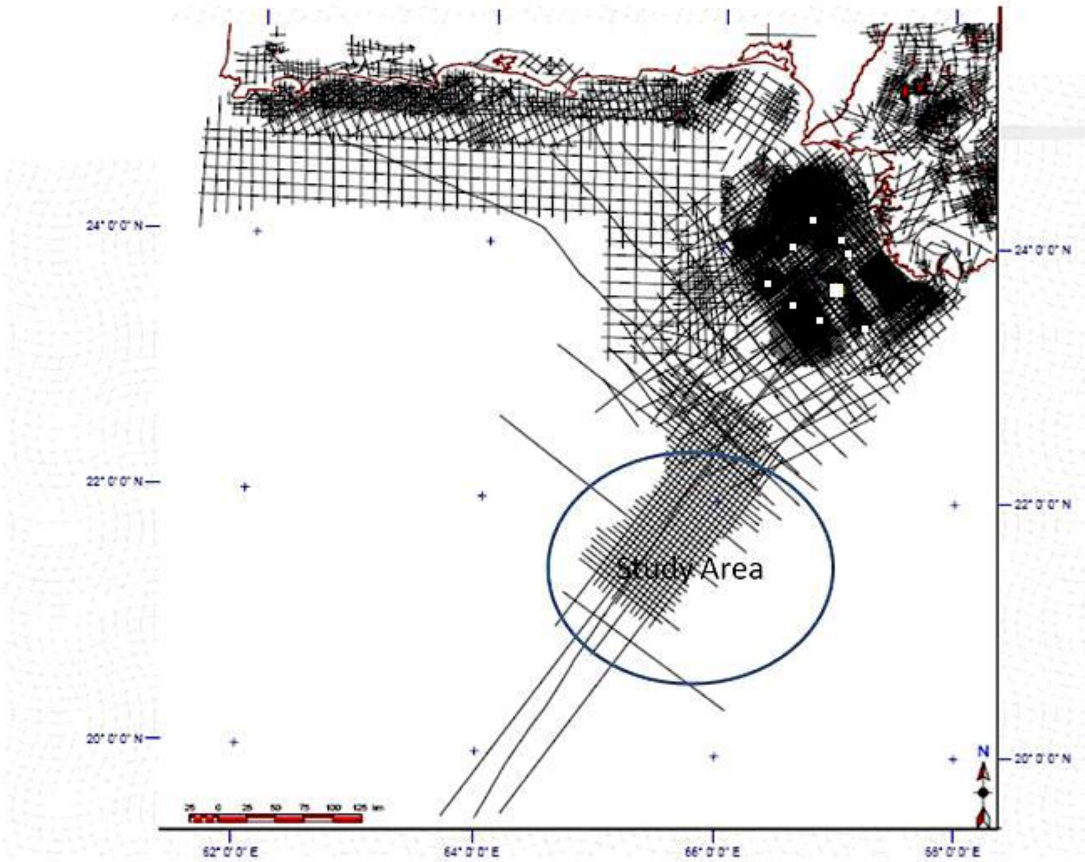


Fig.1. Base map of the study area showing the locations of the seismic data used in present work. White squares are the locations of Wells.

Journal of Himalayan Earth Sciences 43 (2010) 59-61

# Sheikhupura (northern Punjab) earthquake of August 08, 2010: Preliminary investigation

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A shallow focus earthquake (3.8 km in depth, according to Pakistan Meteorological Department) occurred on the noon of August 08, 2010 near Sheikhupura (31$^o$ 41′ 24″ N, 73$^o$ 52′ 48″ E). This was a relatively low magnitude (ML 3.8) earthquake and no associated damage has been reported, however, the shaking has been felt in Lahore, Kasur, Gujranwala and Gujrat.

Northern Punjab plain is tectonically located to the south of the Salt Range. The area around the epicenter of the Sheikhupura earthquake is occupied by alluvium no more than 350 m thick; underneath lies a Precambrian basement that is seismically active. It is characterized by shallow focus, moderate level earthquakes caused due to steeply dipping strike-slip and extensional faulting (Kazmi and Jan, 1997). Named as the Punjab Seismic Zone, it seems to extend from the Sulaiman to Lahore and Delhi. No prominent surface structure have been reported by previous workers in this part of the Punjab Plain, except the NW-trending strike-slip faults some 160 km WNW and the EW-trending normal fault 25 km to the south of the Sheikhupura earthquake epicenter (Fig.1). The nearly EW-trending fault plane with steep dip (71$^o$ N) in the presently analyzed Focal Mechanism Solution for the earthquake is in agreement with the longitudinally EW-trending extensive lineament shown by Seeber and Armbruster (1979) in their Fig. 3.

The location of the event on the Bouguer gravity map of Kadri (1995) is shown in Fig.2. It coincides with the zone of high gravity anomaly reflecting igneous intrusions(s) or structural disturbances. We prefer to associate the Sheikhupura earthquake with the extensional faulting as indicated by the geophysical data (gravity survey), along with the focal mechanism solutions of earthquakes of the present study and those of Seeber and Armbruster (1979).

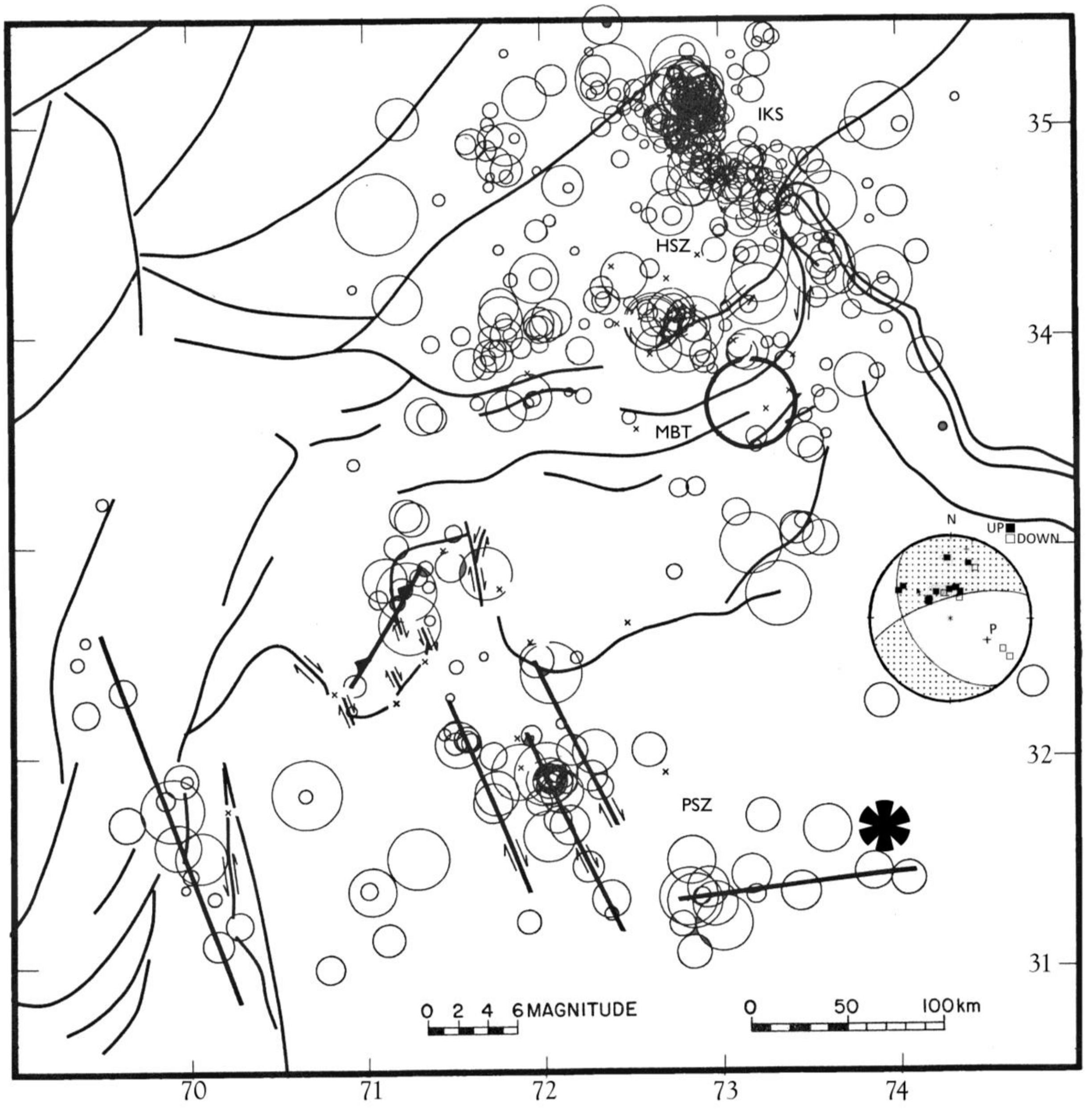


Fig. 1. Seismicity in and around Hazara Arc and northern Punjab (modified after Seeber and Armbruster, 1979), along with location (*) and Focal Mechanism Solution of the Sheikhupura Earthquake. IKS: Indus Kohistan Seismic Zone, HSZ: Hazara Lower Seismic Zone, MBT: Main Boundary Thrust, PSZ: Punjab Seismic Zone.

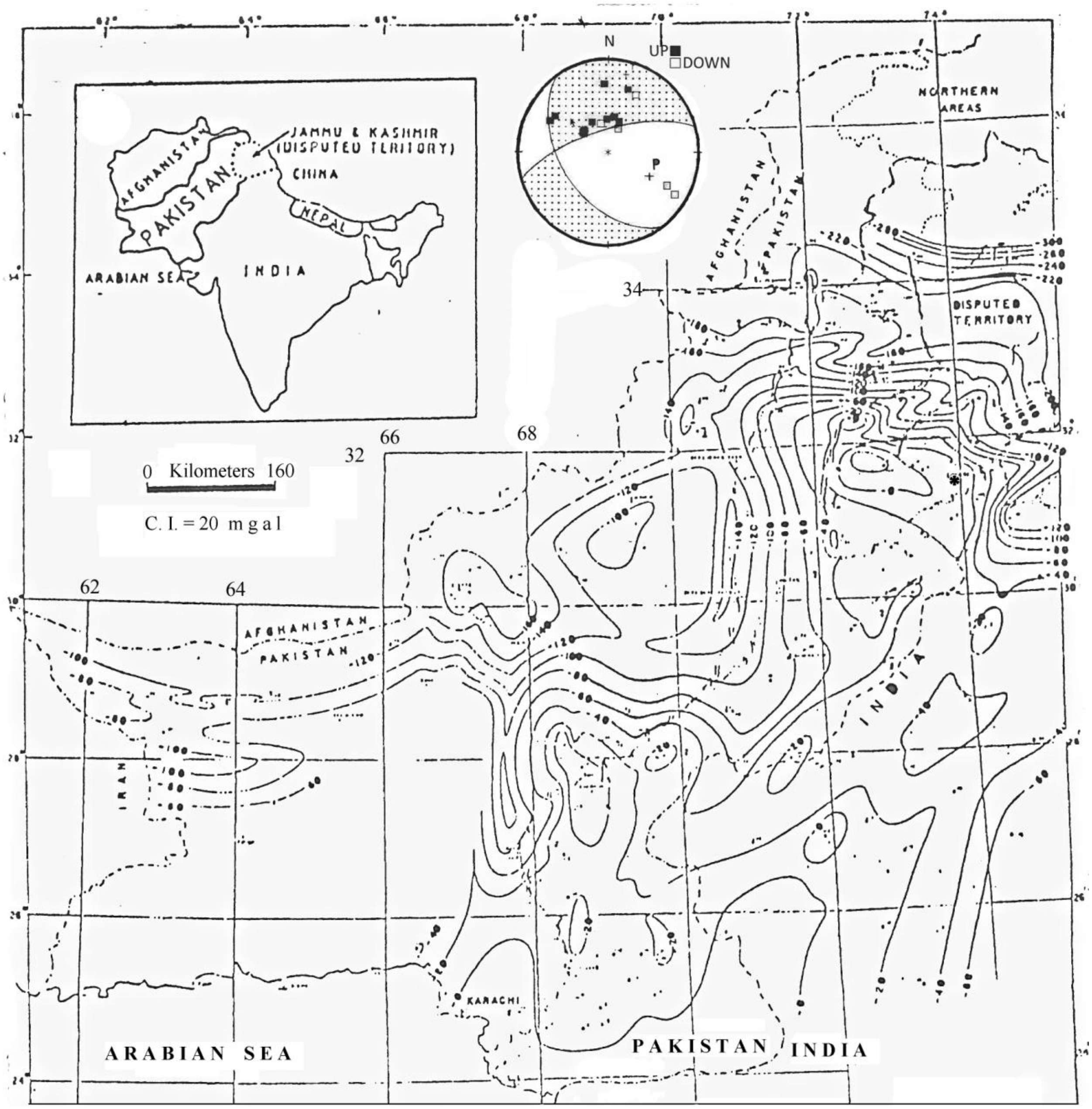


Fig. 2. Bouguer gravity Anomaly map of Pakistan (Kadri, 1995), with location (*) and Focal Mechanism Solution of the Sheikhupura Earthquake.

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# Thin skin tectonic study based on gravity along the western limb of Hazara Kashmir Syntaxis, Muzaffarabad and adjoining areas, Sub Himalayas, Azad Kashmir, Pakistan

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The Hazara Kashmir Syntaxis is an antiformal structure formed by the folding of thin skin thrust sheets. These sheets are bounded by the Main Boundary Thrust (MBT), the Panjal Thrust (PT) and the Kashmir Boundary Thrust (KBT). These thrusts are displaced by the left-lateral Jhelum strike-slip fault. Gravity study based on geological and gravity data delineates the thickness of crust and thin skin faults of the area. Computed gravity model demonstrates the thickness of the crust, sedimentary/ metasedimentary wedge and depth of faults. The thickness of the crust varies from southwest to northeast 14 km to 15.5 km, respectively. In the study area, the MBT lies west of Jhelum fault. The Hazara Formation is thrust on the Murree Formation. The Murree Formation is trapped as horse block between the Hazara Formation and the Carbonates. Geophysical study delineated the KBT (Muzaffarabad Fault) near Nisar Camp between the Cambrian Muzaffarabad Formation and Miocene Murree Formation and joins the thick skin Kawai Fault or Indus Kohistan Seismic Zone. Gravity study shows that the KBT is a thin skin structure within the cover sequence of the Indian plate. It is a reverse fault dipping at an angle of 48° NE and penetrates up to a depth of 8.63 km. This fault was reactivated during October, 8th 2005 Kashmir earthquake. A 3 m net slip has been calculated along this fault which extends from Balakot to Bagh. The crystalline crust dips 5° NE from Chattar in the southwest to Ghori in the northeast in Muzaffarabad area. The model depicts the Jhelum left-lateral strike-slip fault between Precambrian Hazara Formation and Miocene Murree Formation. It dips at an angle of 75° SW and penetrates up to a depth of 14.7 km in sedimentary/metasedimentary wedge and does not displace the crystalline basement in the Muzaffarabad area.

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# Health risk assessment of drinking water consumption along Indus Suture Zone, Kohistan region, northern Pakistan

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The study was conducted to determine the concentrations of physico-chemical parameters in drinking water (surface water and groundwater) of Kohistan region, northern Pakistan. Water samples were collected from the streams, springs and Indus River and analyzed for physical parameters (i.e., pH, EC and TDS) by COSORT electrochemical analyzer C931, anions (i.e., $NO_3$, $SO_4$, $PO_4$, Cl and $HCO_3$) by Hach DR2800 spectrophotometer and heavy metals (i.e., Cu, Pb, Zn, Ni. Cr, Co, Cd, Mn, Fe and As) by atomic absorption spectrometer equipped with graphite furnace in the Geochemistry laboratory of the Nation Centre of Excellence in Geology, Universirty of Peshawar. All the physical parameters and anions and majority of the heavy metals (HMs) concentrations were found within the permissible limits set by world health organization (WHO). However, Pb, Zn, Cd, Ni and As showed higher concentrations than their permissible limits in 29%, 6%, 7%, 2% and 2% water samples, respectively. Heavy metal concentrations were evaluated for non-carcinogenic risk such as chronic daily intake (CDI), hazard quotient (HQ) and cancer risk (CR). The non-carcinogenic risk HQ were <1 for all the HMs except As. This level of contamination revealed a low chronic risk and medium cancer risk when compared with US-EPA guidelines. Furthermore, the statistical analysis such as univariate (one-way ANOVA, inter-metals correlation) and multivariate analysis (i.e., cluster and principal component analysis) results revealed that geogenic and anthropogenic activities were major sources of water contamination in Kohistan region.

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# Glacier advancement hazards and its effect on local community: A case study of Hussaini, Hunza

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Hussaini is a small village of Gojal (Upper Hunza) in the Northern Areas of Pakistan. It is situated on the both banks of Hunza River. The old main village is on the western-bank and at the lateral moraine of Hussaini glacier and below Borith Lake. The newly irrigated land, called Zarabod, is on the left bank. The total population is 679 souls, living in 90 households (2007). Hussaini is 145 km North of Gilgit and 45 km from Ali Abad in Central Hunza. Hunza River flows in to the east while the Karakoram Highway (KKH) passes to its west. Hussaini Village is situated on 74°52'23.42" East longitude and 36°25'29.14" North latitude at an altitude of 2556 meters (Source-GPS) above sea level. South of Hussaini is Gulmit (the headquarters of Gojal magistracy - tehsil), Ghulkin is to the southwest, while Passu is in the north with famous Batura glacier. Hussaini glacier is located to the west with famous Shisper peak, 7611 meter.

Recently we observed with apprehension the glacial lake outburst flood (GLOF), last time in Passu and, now, in Ghulkin. The floods caused by these GLOF pose a great risk to these villages. The risks, however, can be minimized by employing modern technology. With the help of RS and GIS technology, these glacial lakes can be identified through Satellite images and Aerial photographs and after field verification and ground realities the sites can be observed and assessed in their early stages when the lakes are developing. Using proper techniques, the water can be released, not allowing the formation of dams which have the potential to annihilate human settlements and agricultural establishments. RS and GIS technologies can also be utilized in the region for the purpose of hazard mapping, land sliding, GLOF, soil erosion, glacier advancement etc.

Some glaciers are located within the vicinities of the villages and people, routinely, walk by or across them for one or the other reason. The people need to be vigilant and look for any unusual changes taking place in the glaciers. The changes, as and when observed, should be communicated immediately to the relevant public and non – governmental organizations. The area should be observed after February when the glaciers start melting and due to fluctuation and movement the streams block the natural gullies and make glacial lakes.

There is a disastrous situation in Hussaini village due the glacier advancement for the last many decades, resulting in much suffering of the local community Both for drinking and irrigation water, the people of Hussaini ware working on the glacier 8 to 12 hours on daily basis for many years now.

A glacier is located in the west and the Khunzhrav River is flowing to the East of the village but due to lack of resources there is no water in the village. A drought like situation hovers on the village for many years. As the glacier is advancing very fast toward the Khnzhrav River and

KKH - located at a distance of some 254 meters, the four channels dug out from the snout of the glacier have been destroyed and now the temporary solution was obtaining insufficient water through a vulnerable pipeline from the southern glacier's originated stream to the northern snout channels. This pipeline was also washed away by the recent flood and next GLOF is, again, in an alarming position.

The villages located along the Khunzhrav river and below the glaciers are in high risks specially in Gojal valley, Shimshal, Passu, Hussaini, Ghulkin, Gulmit are at risks of river flood, and GLOF can wash them out if proper protection is not taken. The communities, volunteers and scouts should be ready to handle these disastrous, terrible and very challenging situations.

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# Microfacies assemblages and diagenetic framework of the Lower Eocene Sakesar limestone, Karoli area, Central Salt Range, Sub-Himalayas of Pakistan

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A detailed study has been done to establish the microfacies assemblages, diagenetic framework and biostratigraphy of the Lower Eocene Sakesar Limestone from the Karoli area in the Central Salt Range. The limestone is composed of bioclastic microfacies only. Bioclastic wackestones and bioclastic packstones have been recorded with repetition at different stratigraphic levels and with various ecological associations of biota. The microfacies are mainly comprised of shells and fragments of different foraminiferal species. While, shells and bioclasts of Brochiopods, Gastropods, Pelecypods, Echinoderns, Broyozoa, Sponges, Corals, Blue-Green Algae and Red Algae are also present in these microfacies. Based on ecological associations, 13 lithofacies have been identified. Biostratigraphical investigations revealed that the limestone is host of a number of biostratigraphically important benthonic larger foraminiferal species belonging to the genera: Nummulites, Assilina, Lockhartia, Alveolina and Opercolina. The diagenetic framework has also been elucidated and dissolution, replacement, alteration, dolomitization, micritization, various cement morphologies, micritic envelopes, open and filled fractures (calcite veins), stylolites and solution porosities have been recorded. These investigations led towards the conclusion that the Sakesar Limestone was deposited mainly in the subtidal and inertial zones of open shelf. However, a small part of it was deposited in the restricted shelf environment.

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# Salt tectonics of the Karoli area, Central Salt Range, Sub-Himalayas, Pakistan

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The paper focuses on of the salt tectonics characterization of the Karoli area, Central Salt Range, Sub-Himalayas, Pakistan. The study area falls in the zone of Himalayan Frontal Thrust. Its architecture was mainly developed in the typical compressional tectonic settings. The study area was lithostructurally mapped at the scale of 1:10,000. The differential erosion at various places in the study area has lead to the loading and unloading of overlying relatively higher density rocks. This resulted in the upward movement of plastic and low density salt of the Salt Range Formation and caused the phenomenon of valley bulging. The interpretation of structural data manifested overprinting of extensional tectonics due to salt diapirism and was displayed by a number of normal faults. Certain well exposed sections showing the outcrops of normal faulted contacts were documented by field photography. A salt diapiric dome was documented as well, not reported by any previous worker. Only one thrust fault was recorded in the mapped area. The presence of normal faults is contrary to the tectonic environment of this area and is the result of structure overprinted by salt diapirism. The subsurface presence of salt marl of the Pre-Cambrian Salt Range Formation is the cause of this structural overprinting. The salt marl moved upward and pierced through the overlying strata. As a result the Salt Range Formation is exposed in the core of dome and at a number of other locations in the investigated area. These investigations led towards the conclusions that the originally developed structure in the compressional tectonic settings was modified by the plastic and diapiric nature of the Pre Cambrian rock salt and features of extensional tectonics have been superimposed on those of compressional tectonics. The presence of newly discovered dome, normal faults and frequent exposures of the Salt Range Formation in the investigated area characterize an environment of salt tectonics.

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# Study of seabed and subsurface channels using high resolution 2D seismic data, Indus fan, Pakistan

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The study is carried out on high resolution 2D seismic data from the offshore Indus Fan, Pakistan. The Indus fan is located off the passive continental margin of Pakistan-India and is bounded by the Chagos – Laccadive Ridge in the east, by the Owen–Murray Ridges in the west, and by the Carlsberg Ridge in the south. The area lies in one of the tectonically active regions of the world with Makran accretionary complex lying at the convergent margin between the Arabian and Eurasian plates.

As a result of the collision between Indian and Eurasia Plates, about fifty million years ago, the Himalaya and other mountain ranges have been formed by under-thrusting and uplift of Indian and Asian crust. This uplifting has derived a high flux of sediment load transported through Indus river system and subsequently dumped into the Indus fan. The analysis of 2D seismic data of Indus fan reveals extensive gravity flow depositional elements like turbidity-flow leveed channels, channel over-bank deposits and debris flow channels that can be identified on the basis of its unique seismic signature.

The seismic data obtained from the upper part of the Indus fan reveals Holocene channel system on the sea bed. These data are evaluated along with the GLORIA sidescan sonar data to identify the channel migration, channel avulsion patterns and to compare the positions of the channels. Six seabed channels of different length and width were identified on the seabed. The flow direction of the channels is from North to South-west. These channels were identified on the basis of their erosional down cutting of the previously deposited sediments and their meandering and straight plan form. Knickpoint (reaches of anomalously steep gradient) evaluation was carried out for all the channels observed on the sea bed to further evaluate any major changes that occurred during the Holocene times, hence providing important information about the prevailing channel environments in the region.

The mapping of the channels and levees at three different locations (moving SW from the present day Indus Canyon) revealed a marked decrease in the number of channels and levees. Possible influences on the number of channels are discussed.

Finally laterally migrating and aggrading channels (identified by their U-V shaped high amplitude reflection) were observed in some of the seismic lines. These aggrading channels show interesting stratigraphy apparently caused by four to five cycles of channel infilling and re-entrenchment. A simple kinematic reconstruction was carried out to discuss the probable cause of formation of these aggrading channels.

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# Numerical modeling and tsunami inundation for potential earthquake at Makram subduction zone, Pakistan

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According to the historical seismic importance of Makran Subductin Zone (MKZ), it has the potential for future large earthquakes and tsunamis. This study is based on numerical modeling of tsunami propagation by taking Gwardar coast as focal area which has geographical and economical importance for Paksitan and had been extensively affected by tsunami generated in 1945 Makran earthquake. Simulation for tsunami propagation and inundation at Gwadar coast was carried out a moment magnitude Mw 8.5; 5.26 m rupture slip due to this earthquake and fixing the source area within Makaran Subduction Zone i.e. 120 km away from the coastline. The results show maximum flow depth of 5m and maximum inundation up to 1.46 km on Gwadar coast . Numerical simulation reveals that any future Makran Subduction zone earthquake with M2 8.5 can generate a destructive tsunami.

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# Threat of glacial lake outburst flood to Tehsil Gupis from Khukush lake, District Ghizer, Gilgit, Pakistan

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Glacial lake outburst flood (GLOF) is a powerful natural phenomenon which is very active in the Karakuram Himalayas of Pakistan. In these areas, most of the villages are settled along the banks of the rivers on the debris fan deposits. These debris fans are the product of repeated debris flow events in the main channel to which a number of interconnected creeks contribute their material. These interconnected creeks originate from huge glaciers and glacial moraines at the upper catchments. These glacial deposits form a complex topography with multiple depressions at places. These depressions then change into lakes after getting filled by water from glacial meltdown. As the amount of water increases the pressure on the dam also increases. When the pressure exceeds the holding capacity of the dam, it bursts out which causes flooding in the lower catchments. In most of the cases glacial moraine acts as a barrier or natural dam. This hazard can be handled and controlled by keeping a proper check on the situation of the natural dam which acts as a time bomb with random time adjustment. By calculating the strength of the dam and seasonal fluctuations of water level in these remote lakes, we can build a relationship between the strength of the dam and the volume of the water whose pressure the dam can sustain and retain itself. The other thing which can be done is to increase the preparedness of the community which is settled on the areas lying low along the valley through which water from outbursting lake will ultimately flow. Preparedness can be increased by providing the community with various sets of information about GLOFs including the map marking out the areas which would be inundated from possible outburst of remote lake. This paper aims to create flood attenuation model for Tehsil Gupis and to create a flood map for the areas of greater commercial and economic importance. This paper will target the Khukush Lake and would address the methodology used to create peak flow attenuation model for Tehsil Gupis.

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# Multi hazard risk assessment and mitigation plan for marble mining operations in Chitral

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Goals of hazard identification and risk mitigation plan for marble quarry operations are to identify potential hazards by examining quarry operations, and observing the tasks performed by workers, offer general advice regarding hazard control measures and SOPs. The study reveals that the impact of marble quarry operations is within safe limits of national environmental quality standards, but there is a need of; 1) hazard control measures to reduce the potential of exposure to hazards, 2) a hazard communication program, 3) geotechnical assessment of quarry for slope stability analysis, 4) formulating report form for daily inspection of quarry and working faces, 5) frequent safety audits and training sessions relating occupational health and safety, 6) Environmental control measures to prevent future environmental degradation and 7) include information, in quarry design (cultivation plan), on how to leave the quarry in safe condition before ceasing operations

All existing quarry operations should be observed in detail for any further aspects or exceptions.

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# Pakistan monsoon floods: climate change or geological rundown?

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The July-August 2010 floods in Pakistan brought havoc and misery that is unprecedented in memorable history. Various estimates put the humanitarian crisis to be larger than the combined effects of the three worst natural disasters: Asian tsunami, Kashmir and Haiti earthquakes. In flood science, such a catastrophe is known as a once-in-a-century flood. The question is: Are these floods caused by regular geological processes or by climate change? The answer is not simple.

Although Himalayan glaciers feed the Indus River but the bulk of its flow is due to summer monsoon that triggers floods. Counting, dating and correlating the flood-laden sand beds on a flood plain help develop a time-series of flooding events that shed light on the monsoon system. Analysis of some of these beds near Sukkur and Bahawalpur by a group of scientists indicate that around 4000 BC, a warm period existed that fed heavy monsoon rains into the Indus. Then by 2000 BC the climate cooled with no monsoon rains, turning a large part of the Indus valley into desert. However, the cause(s) of these thousand-year cycles of Indus drought and flood is contentious. To some, geological records reveal that thorough out the Holocene the monsoon activity was pretty much a geological rundown at least on a 1000-year cycle. Others think that climate change may be the reason as their models predict that the monsoon intensity is sensitive to the surface temperature of the Indian Ocean. During times of cooler climate, less moisture is picked up from the ocean, the monsoon weakens, and the Indus river flow is reduced. Whereas, some have found a clear correlation between human action, climate and monsoon activity.

While there is huge uncertainty regarding exact correlation between global warming and intense monsoon activity, the fact remains that that the distribution of monsoon rains has become more uneven i.e. total rainfall stays the same, but it comes in shorter, more intense bursts. Such as in the July-August 2010, more than half of the normal monsoon rain fell in only one week instead of its typical spread over three months. Rivers just cannot cope with all that water in such a short time. This uncertainty entails lack of planning and preparedness and, thus, the future may hold more flood misery for the people of Pakistan.

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# Morphometry of alluvial fans and its relation to debris flow hazards in Chitral valley, N. Pakistan

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The Chitral district of N. Pakistan lies in the eastern Hindukush Ranges at the south-western limb of the Pamir Syntaxis. The Chitral River traverses across the district as a predominantly U-shaped valley formed in response to Late Quaternary ice-age glaciations. Remnants of landforms formed during these glaciation stages and subsequent fluvial regimes, locally preserved on trunk-valley flanks are superimposed by debris-flow dominated alluvial fans associated with the tributary streams. On one hand these fans are the sites of habitation because of their flatter surfaces, fertile soils and access to water, on the other their proximity to steep valley slopes renders them prone to mass-movement hazards especially the debris flows.

As a part of this study, morphometric analysis of the drainage as well as depositional basins of more than 95 prominent tributary stream fans, stretched along the north-south axis of the Chitral river has been carried out. The morphometric studies including stream attributes like drainage basin area, stream profile, gradient, depositional basin area, stream pattern are measured using Arc GIS 9.2. Based on the morphometric analysis supported by field observations, it is determined that the ephemeral streams i.e., talus cones and debris fans have high hazard potential. These streams having shorter lengths and a limited catchment area, have hyper-concentrated flows resulting in active deposition on fan surface. On the contrary, the high-energy perennial streams, carve through the landforms they traverse including the alluvial fans they formed in their earlier history, leading to an efficient discharge of the debris load into the trunk river rather than on the fan surface. Whereas the ephemeral-stream fans are prone to debris-flow hazards, on average, every three to five years, the landforms associated with the perennial streams face debris flow hazards in exceptionally large events with return periods of recurrence >30 years. The study has utility for quick assessment of vulnerability to debris-flow hazards, based on simple observations about the nature of the feeder tributary stream and its associated alluvial fan.

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# Sedimentologic studies of upper sands of lower Goru Formation based on well cuttings and wireline logs from wells of X Field in the subsurface of Sindh Monocline, Southern Indus Basin, Pakistan

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Detailed studies of lithologic successions of upper sands of Lower Goru Formation in the subsurface of X Field of Sindh monocline were investigated by zoom stereo binocular examination and thin section study of well-cuttings in conjunction with the wireline log studies to understand the depositional environment. The gamma ray log response and sonic (DT) logs have been used to identify and successfully correlate the sand bodies with lithologic logs prepared from well-cuttings analysis.

The detailed sedimentological studies of the well cuttings samples of each of the main bodies resolved various lithofacies of meter scale thickness based on their textural signatures (grain size, shape, and sorting). Within the sand unit B a number of distinct coarsening and fining upward sequences can be identified which reflect frequent sea level fluctuations. Textural investigations, particularly of those samples composed predominantly of sand size fractions, show that the mean grain size in the study area is fine to medium grained and vary between 1.8φ and 2.5φ. The samples are moderately- to well-sorted and well-rounded to sub-angular in shape. Mineralogically, the samples comprise mostly of 60-85% quartz grains and only occasionally contain any feldspar grain. Only the fine-grained sandstones of the study area exhibit a slight increase in the amount of feldspar. A few grains of dark colored minerals can occasionally be seen in thin sections. The results further indicate that the sandstones are fairly mature.

The presence of a number of coarsening and fining upward cycles indicates frequent shift in the depositional environments influenced by the sea level changes. Based on overall results, it can be interpreted that the upper sands of the Lower Goru Formation of Lower Cretaceous age in Sindh monocline were deposited in moderate to high energy nearshore sedimentary environment largely influenced by frequently fluctuating sea level.

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# Field features and petrography of igneous rocks from Utla (Gadoon), NW Pakistan: Preliminary investigation

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The igneous rocks around Utla in Gadoon area, NW Pakistan are considered to be a part of the Peshawar Plain Alkaline Igneous Province (PPAIP), which extends from Tarbela in the east to Pak-Afghan border in the west. The rocks of the Utla area most probably represent the eastward extension of the Ambela granitic complex. Some of the previous workers, however, group them with the granitic rocks of Swat and Mansehra.

Field observation and detailed petrographic studies of representative samples suggest that the Utla area largely consists of granitic rocks having intrusive contact with the Late Proterozoic Tanawal formation. At places, green to greenish black and black dykes of apparently basic composition cut across the Utla granite. Texturally, the granitic rocks are predominantly mega-porphyritic. At place, however, foliated and fine-grained varieties also occur, particularly along shear zones. Furthermore, the equigranular fine-grained varieties occuring as small patches within the mega-porphyritic granite.

The Utla granites contain phenocrysts of zoned and saussuritized plagioclase, perthitic alkali feldspar, including both the orthoclase and microcline varieties, and quartz. The frequently large size of the phenocrysts makes them visible in the outcrop even from some distance. The extent of albite exsolution is variable, most probably because of difference in the composition of the original homogeneous alkali feldspar grains and/ or degree and rate of their undercooling below the crystallization temperature. The groundmass predominantly consists of alkali feldspar and quartz, minor to accessory amounts of tourmaline, biotite and muscovite, and accessory to trace amounts of apatite, andalusite, zircon, monazite, sphene and garnet.

Among the mafic minerals, tourmaline is the most common and abundant. Most of the tourmaline grains display irregular zoning and variable degree of alteration. The flakes of biotite and muscovite mostly occur in close association and are particularly abundant in the foliated/ gneissose varieties of the granite where they may wrap around the megacrystic feldspars. Textural relationship suggests that some of the muscovite might have formed at the expense of biotite. In some of the studied samples, muscovite is intergrown with quartz. An appreciable amount of sphene occurs in most of the studied samples. Associated almost exclusively with biotite, it occurs as small discrete grains as well as thin rims or broader zones around small grains of an opaque ore mineral.

The markedly different modal mineralogy suggests a two-fold division of the dykes that intrude the Utla granite: (i) basic and (ii) intermediate. The former appear to be much more abundant and are further distinguished into two subgroups on the basis of their textural and mineralogical characteristics. Dykes from one of the subgroups essentially consist of plagioclase laths and clinopyroxene and display ophitic to sub-ophitic texture and, thus, appear to be dolerite. The clinopyroxene gives a pinkish/ violet color in plane light, and hence may contain a significant amount of Ti. The grains of clinopyroxene show variable degree of alteration to chlorite and amphibole. Besides, brownish hornblende also occurs as discrete grains in some of these dolerite dykes. These rocks also contain accessory amounts of other minerals, including biotite, sphene, epidote, apatite, ilmenite and rutile. Like that in the host granite, sphene in the dolerite dykes occurs both as discrete grains and thin rims or zones around opaque ore grains forming corona texture.

The other group of basic dykes largely consists of plagioclase and amphibole. The subordinate amount of clinopyroxene present in these rocks occurs either as relics within, or totally pseudomorphed by, green amphibole and chlorite. The amphibole also occurs as discrete grains displaying brown color and partial alteration to chlorite and biotite. The occurrence of appreciable amount of epidote and zoisite together with green amphibole and chlorite after clinopyroxene indicates metamorphism of these rocks under greenschist to epidote amphibolite facies conditions. Some of these rocks also display a certain degree of preferred orientation. The more or less commonly occurring accessory phases in these rocks include sphene, rutile, ilmenite, calcite and apatite. Corona texture of sphene around opaque ore mineral is a common texture present in these rocks as also observed in the dolerite dykes described above.

The dykes of intermediate composition are characterized by porphyritic texture with phenocrysts exclusively of brown amphibole. These phenocrysts are replaced by chlorite along cleavages and fractures. Simple twins are also observed in some of the amphibole grains. The groundmass consists mostly of fine-grained chlorite, epidote-clinonzoisite/ zoisite and sphene. Like their basic counterparts, these dykes also contain sphene as thin rims to broad zones around grains of an opaque ore.

The intrusion into Tanawal formation, distinctly porphyritic character, and the more or less common occurrence of appreciable amount of tourmaline are some of the features of the Utla granites which make them resemble the granitic rocks from Mansehra and Swat. Furthermore, like the Mansehra rocks, some of the samples from Utla granite also contain andalusite. On other hand, the Utla rocks, especially the dykes, display opaque ore-sphene corona textures, which is a characteristic feature of the granitiods from Ambela.

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# Biostratigraphy of Sakesar limestone, Rikhi-Burikhel area, Western Salt Range, Pakistan

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The Sakesar Limestone (Lower Eocene) is exposed along the northwestern side of the western Salt range along Rikhi-Burikhel track where it is 29.5 m thick. As a part of this study, 16 samples were collected from the outcrop at regular intervals. Petrography of 32 thin sections was carried our for detailed microfaunal studies. Nine species of age diagnostic larger forminifera are recorded including five species of Alveolinids. *Alveolina canavarii* is recorded for first time from the Sakesar Limestone. Based on the fauna, the age of the Sakesar Limestone is Ilerdian (SBZ 7-8) of the Lower Eocene.

Journal of Himalayan Earth Sciences 43 (2010) 78-78

# Biostratigarphy of the Paleocene-Eocene succession of the Tarar area, Southern Hazara, North Pakistan

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A 200 m thick, Paleocene-Eocene succession, comprised of Hangu, Lockhart, Patala, Margalla Limestone, Chorgali and Kuldana Formations occurs in stratigraphic order in a well-exposed section in Tarar area of southern Hazara. Based on the detailed biostratigraphic studies (100 thin sections), 13 age diagnostic species of larger foraminifers are recorded. The present study reveals that the Paleocene-Eocene boundary occurs within the Patala Formation.

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# Temporal evolution of surface rupture deduced from coseismic multi-mode secondary fractures: Insights from the October 8, 2005 (Mw 7.6) Kashmir earthquake, NW Himalaya

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Detailed rupture–fracture analyses of some of the well-studied earthquakes have revealed that the geometrical arrangement of secondary faults and fractures can be used as a geological tool to understand the temporal evolution of slip produced during the mainshock. The October 8, 2005 Mw 7.6 Kashmir earthquake, surface rupture provides an opportunity to study a complex network of secondary fractures developed on the hanging wall of the fault scarp. The main fault scarp is clearly thrust-type, rupture length is ~75±5 km and the overall trend of the rupture is NW–SE. We present the results of detailed structural mapping of secondary faults and fractures at 1:100 scale, on the hanging wall of the southern end of the rupture in the vicinity of the Sar Pain. Secondary ruptures can be broadly classified as two main types, 1) normal faults and, (2) right-lateral strike-slip 'Riedel' fractures. The secondary normal faults are NW–SE striking, with a maximum 3.3 meter vertical displacement and 2.5 meter horizontal displacement. Estimated total horizontal extension across the secondary normal faults is 3.1–3.5%. We propose that the bending moment and coseismic stress relaxation can explain the formation of secondary normal faults on the hanging wall of the thrust fault. The strike-slip 'Riedel' fractures form distinct sets of tension (T) and shear fractures (R′, R, Y) with right-lateral displacement. Field observations revealed that the 'Riedel' fractures (T) cut the secondary normal faults. In addition, there is kinematic incompatibility and magnitude mismatch between the secondary normal faults and strike-slip 'Riedel' fractures. The cross-cutting relationship, and geometric and magnitude incoherence implies a temporal evolution of slip from dip- to strike-slip during the mainshock faulting. The interpretation is consistent with the thrust fault plane solution with minor right-lateral strike-slip component.

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# Comparative analysis of the National Disaster Management plan of Pakistan in the regional context

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The geopolitical location of South Asian nations has exposed people of these countries to a variety of natural and man-induced disasters, like earthquakes, floods, tsunamis, etc. To face the threats associated with these disasters, there is a need to develop proactive collaborative disaster management plans at national and regional levels. Pakistan has recently developed a National Disaster Management Plan, which provides a framework for managing disaster-related issues at gross root levels. However, the plan still requires implementation in true spirit. In this paper, the National Disaster Management Plan has been reviewed and compared with the Disaster and Emergency plans of other South Asian countries, like India, Bangladesh and Sri Lanka. The comparative analysis shows that Pakistan needs to develop a collaborative network with other South Asia countries for effective implementation of the disaster management plan.

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# Exploring opportunities of rain water harvesting in the urban areas of Pakistan

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Pakistan is facing severe water crisis for the last few decades. The climate change, regarded one of the main reasons for such crises globally, has also affected the local weather in Pakistan to a considerable extent. The changes in the pattern of rainfall and its distribution, governed again by climatic change, have led to a severe water shortage in the urban areas of Pakistan. The recent draught led to the depletion of ground water and there is a tendency of continuous drop of the aquifer in the major cities, like Karachi, Lahore, Islamabad and Peshawar. To overcome the challenges of water scarcity in the country, water conservation strategies are needed to be implemented at grass root levels. Rain water harvesting in the urban areas of Pakistan is one of the emerging opportunities available for harnessing the water for re-use. In this paper the opportunities of rain water harvesting in urban areas have been discussed with special reference to Pakistan. It has been shown that if harvested for re-use, the rainwater can provide some long term solution for the water crisis in these cities.

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# Removal of chromium (III) from aqueous solutions by the Organic Ion Exchangers

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Soil and water contamination by heavy metals like Cr, Cu, Pb, Mn, Hg, and Cd in soil as well as in water arising from the discharge of industrial effluents is one of the important environmental problems. Due to the greater stability these heavy metals cannot be degraded and removed from the environment. Their presence in aquatic life causes harmful effects to living organism. Chromium, one of the above-named heavy metals has two stable oxidation states, Cr (III) and (VI). The presence of strong oxidants in soil and water can change Cr (III) to harmful Cr (VI). Therefore Chromium (III) removal on three cation exchangers Amberlite.IRC-50($Na^+$), Amberlite.IR-120($Na^+$) and Amberlyst.15($H^+$) is studied as a function of time and concentration at different temperatures(293K-333K). The kinetic and equilibrium studies proved that affinity of these cation exchangers towards Cr(III) removal followed the order as Amberlyst.15($H^+$) > Amberlite.IR-120($Na^+$) > Amberlite.IRC-50($Na^+$). The pH is observed to increase during exchange on Amberlite.IR-120($Na^+$) and Amberlite.IRC-50($Na^+$) and decrease during exchange on Amberlyst.15($H^+$).

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# Classification and genesis of sandstone-type uranium ore bodies in middle Siwalik rocks, eastern Sulaiman Range and Bannu basin, Pakistan

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The sandstone-type uranium ore bodies have been discovered in middle Siwalik rocks in Sulaiman Range and Bannu Basin. These ore bodies were probably developed from single origin, later tectonic developments created different environments, shaping their present mode of occurrence and genesis. It is assumed that initially, braided paleo-Indus river eroded the uraniferrous material from primary rocks in the north and west and deposited the material in foredeep basin and developed conventional paleo-channel type uranium ore bodies. Later reworking shaped the present forms of the ore bodies.

During the first stage, conventional paleo-channel ore bodies developed in braided river system. These ore bodies are affected least by orogeny and buried beneath sedimentary cover. Since no contact of the ore body and air has occurred, hence no leaching phenomenon has been activated. During the second stage, paleo-channel related ore bodies, passing through tectonic episode, got tilted, and rose above the surface of erosion. The above surface part of the ore body has been oxidized and enriched the already existing ore body below the water table. This body is termed as complex paleo-channel cum ground water leached type of sandstone deposits bounded by clay bed on lower side. During the third stage, these re-enriched ore bodies were further uplifted, and the above-surface part of the ore body was oxidized which further re-enriched the existing ore body below the water table, resulting in development of horizontal as well as inclined ore bodies. In the fourth Stage, uranium ore bodies developed as a result of complete leaching of pre existing paleo-channel ore body. These were then re-precipitated horizontally below the surface exposure of anomaly in reduced zone below the water table.

World wide, on the basis of mode of occurrence, three types of ore bodies, i.e. tabular horizontal, tabular inclined, and roll front, are identified in sandstone, while in Pakistan tabular horizontal, horizontal-inclined and tabular inclined are identified. On the basis of origin, these ore bodies are classed as sedimentary precipitated uranium ore bodies, and on the basis of genesis the ore bodies are classed as paleo-channel and reworked ore bodies.

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# P-T pseudosections and garnet isopleth geo-thermobarometry from the Malakand and Loe Sar Dome, NW Himalaya

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P–T pseudosection is a mineralogic map of stable mineral assemblages in a P–T space (White et al., 2008) and reveals complex arrangement of multivariant reactions that a rock records through metamorphism (Sayab, 2006). Pseudosections are typically constructed based on a fixed bulk XRF composition of a given rock sample. In this study, we performed calculations using latest version of THEMOCALC (ver. 3.33; Powell and Holland, 1988; updated 26 October 2009) with an internally consistent data set of Holland and Powell (1998; data set tcds55, updated 22 November 2003).The pseudosections have been constructed in the chemical system MnO-$Na_2O$-CaO-$K_2O$-FeO-MgO-$Al_2O_3$-$SiO_2$-$H_2O$ (MnNCKFMASH). Garnet isopleths ($X_{Fe}$, $X_{Mn}$, $X_{Ca}$) are used for geothermobarometry. Isopleths for each of the compositional variables ($X_{Fe}$, $X_{Mn}$, $X_{Ca}$) are based on the electron microprobe analysis from the garnet core and plotted in divariant fields using THERMOCALC.

Sample M22 was collected close to the Malakand tunnel. The sample contains garnet, biotite and muscovite in addition to quartz and opaque minerals. The garnet core is estimated to have grown at 4.6–4.9 kbar/510–515$^{o}$C (Fig. 1). The P–T estimates between garnet core and far median (inner core) regions were calculated using the intersection isopleths technique. The garnet median and inner rim regions have estimated at 5.0-5.1 kbar/522-524$^{o}$C and 5.4-5.5 kbar/530-533$^{o}$C, respectively (Fig.1). Sample Z23, collected from the eastern limb of the Loe Sar Dome contains garnet, biotite, muscovite and zoisite in addition to quartz. The garnet core compositional isopleths intersect at 4.0–4.1 kbar/508–511$^{o}$C.

These estimates are tightly constrained and are different than those previously published in the Swat region (cf. DiPietro, 1991). Our work is in progress and we aim to link these new estimates with micro-structural (FIA: Foliation Intersection Axes) observations (see Sayab, 2006).

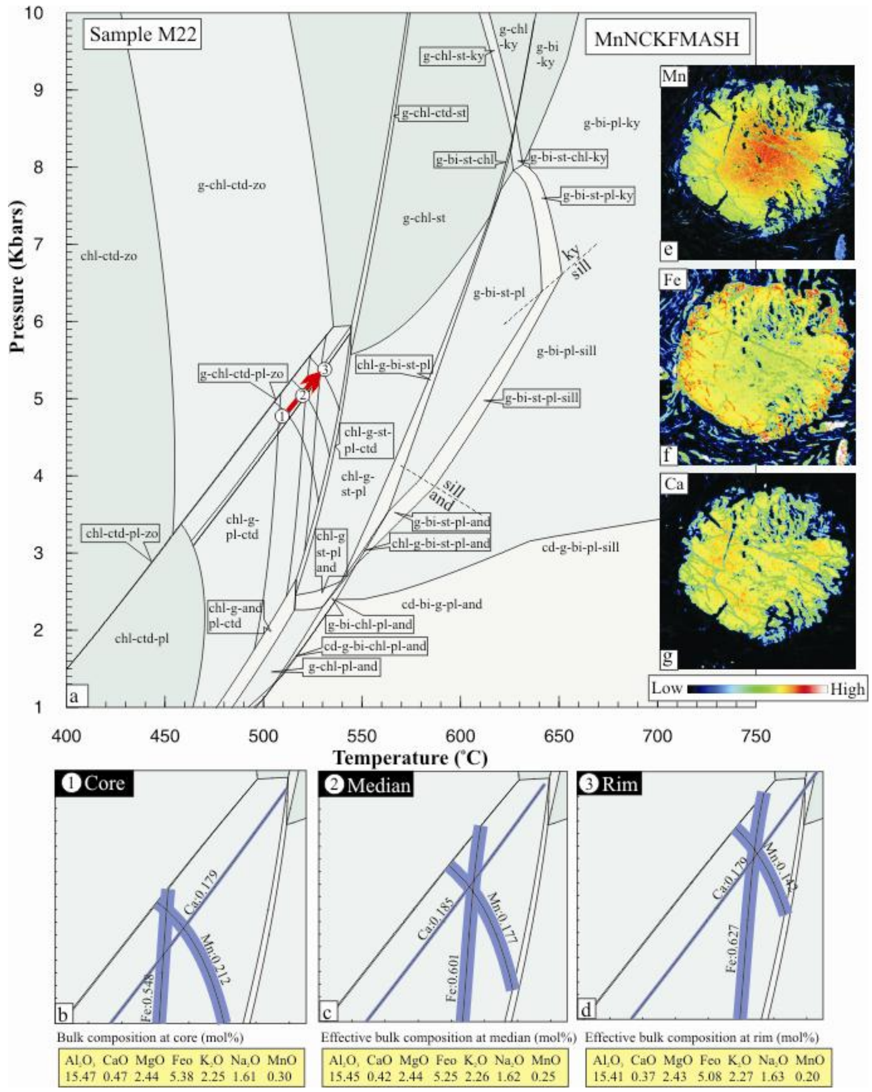


Fig. 1. P-T pseudosection for sample M22 in MnNCKFMASH

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# Functions and achievements of FATA DA in the mineral sector development

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FATA, DA, Peshawar

The tribal belt spread over an area of about 27,220 $km^2$, out of which preliminary geological survey of about 85% has been completed. Geological investigations reveal the presence of various types of sedimentary, igneous and different grades of metamorphic rocks in age from Precambrian to Paleocene in the region. The area is characterized by the presence of variety of alteration zones. The presences of these geological features designate FATA with most suitable geological environments as compared to the rest of world where mineral deposits of economic grade have been established. These include metallic, energy minerals, precious/dimension stones and different rocks of industrial use. Resultantly, world-class deposits of marble, soapstone and potential resources of copper, manganese, chromite, coal and gemstones have been discovered in the tribal belt.

Preliminary geological studies during the past indicate the presence of 20 difference minerals out of which twelve have been explored in detail. The available geological information provides ample evidence that FATA has fairly good mineral potential as exist in similar geological environments elsewhere in the world. This mineral potential can be well utilized for sustainable socio-economic development of local population in particular and the region in general. It is important to point out that despite technological/financial constraints of the private sector and the prevailing geopolitical conditions in the region; there is a tremendous growth in mineral production from FATA. The average annual growth rate of mineral production during the last five years has been 40%.

In order to further enhance the mineral development potential of FATA, FATA DA has initiated a number of mineral exploration, infrastructure development and private sector facilitation projects which on successful completion will provide sound basis for planning mineral sector activities on scientific lines. This will further promote confidence building of private sector for investment in FATA, resulting in generation of enormous employment opportunities in the mineral-bearing areas and supply of indigenous raw material for consumption of local industry.

Geological exploration under two different projects resulted in identification of more than 28 manganese prospects and two emerald-bearing areas in Mohmand and Bajaur Agencies. After successful manufacturing of Ferro-manganese alloy on pilot plant scale, based on raw material from FATA, the same has been offered to private sector investors for commercial production which will serve as import substitute. To identify additional coal clusters, investigations in Shirani area, FR DI Khan have been initiated. For further enhancement of copper reserves (8 million tons) at Shinkai area, North Waziristan Agency, subsurface investigations including geophysical survey and drilling are being taken in hand. In order to confirm extension of sulphide mineralization in the ophiolite belt extending through South Waziristan Agency, geotechnical studies are being started shortly.

As a result of geological investigation in collaboration with NCEG, University of Peshawar, the southern sedimentary belt of FATA, stretching from FR Peshawar in the north to FR DI khan in the south, has shown encouraging hydrocarbon potential and based on these studies, Oil & Gas development companies have shown interest in further detailed exploration. Besides, laboratory scale R & D work for producing smokeless coal briquettes from FATA coal has successfully been completed, while, studies for pilot plant scale production and feasibility for establishment of commercially viable coal briquetting plant are being conducted. FATA DA established a Mines Rescue/Safety and Welfare Centre of Orakzai Agency, which is the first of its nature in the region. Its achievements have been appreciated at both national and international level. In addition to the above, to facilitate and attract the private sector investors for investment in mineral sector activities, constructional of about 160 km roads has been planned in different mineral- bearing areas out of which more than 100 km have been completed, while the rest are in different stages of completion.

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# Activities of Directorate General Mines and Minerals, Government of Khyber Pakhtunkhwa

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The province of Khyber Pakhtunkhwa (KPK) with an area of 74,521 $km^2$ is endowed with almost all varieties of mineral resources which can be categorized as: 1) dimensional stones, 2) gemstones, 3) industrial rocks and minerals, 4) metallic Minerals, 5) fuel minerals / coal and 6) ordinary stones. The Directorate General Mines and Minerals (DGMM) is responsible for the management of these mineral resources of the province. This also includes the exploration and development of these resources through implementation of ADP and PSDP funded schemes. So far, more than 12 developmental schemes / projects have been implemented while 10 other developmental projects are proposed to the provincial government. Apart from these activities, the DGMM is also managing grant of mining concessions (prospecting licenses, exploration licenses and mining leases) on various categories of minerals in the province. A cadastral system record is maintained for mineral production, royalty and excise duty. DGMM also perform welfare of mining community, safety of mine workers, enforcement of mining labor laws, conduct of competency examinations of mine supervisors and workers, collection of excise duty on minerals and training of mine workers. The DGMM owned a well equipped Mineral Testing Laboratory at Hayatabad, Peshawar which is playing a major role in facilitating the investment in mineral sector in chemical evaluation of the mineral commodities and also provide facilities for gemstone testing. In order to strengthen the Exploration Wing, a Resource Mapping section has recently been established in the DGMM where GIS/RS based digitized and geo-referenced geological and mineral resources maps of the Khyber Pakhtunkhwa province are being prepared and processed for the dissemination of information to the general public and national and international investors. In this respect the DGMM has very important role in up-grading the economy of the country.

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# Discovery of uraniferous calcretes in Tharparkar, Pakistan

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Detailed geological work revealed that the calcretes in the Tharparkar desert have been formed in a variety of settings, including the piedmonts, sheetwash aggraded plains, regolith, playa plains and interdunal plains, while sand dunes and sandy plains have weaker development of calcretes. The better developed calcrete horizons occur in piedmonts and interdunes or in areas that have sufficient groundwater at depths of 80 to 120 meters. In some areas, uraniferrous calcretes have been discovered. Sections in the region show phases of pedogenic calcrete development in aeolian sand. The extensive sheetwash plains have mature calcretes. These calcretes can be correlated with the Indian side of Thar which has calcretes of similar characteristics and date to mid-Pleistocene. The calcretes of northern, central and north-eastern part of Tharparkar were surveyed and sampled. Radiometric checking in different areas alongwith geological mapping has been undertaken. More than 300 calcrete and kaolicrete samples were analysed for uranium. These calcretes are classified Pedogenic, non-pedogenic valley calcretes, soft calcrete, hard calcrete, nodular calcrete, honey comb calcrete, sandy mix calcrete, kankar, caliche, gypcretes, halcretes, silcretes and ferrocretes. Some 46 calcrete bodies have been discovered and sampled in different parts of the desert for the first time. At some places uranium content is more than 40 ppm with a maximum value of 159 ppm at Khagia near Chachro. The surface/near surface gradients originating from the northeast and east towards west and south also support the possible transport of U, V, and K through shallow ground waters to the distal parts of the Thar desert and the potential non-pedogenic calcretes in the desert may host uranium mineralization. Preliminary studies show that a number of calcretes contain anomalous U content, i.e., >50 ppm. Our studies indicate that these calcretes represent a hybrid process, where carbonate enrichment of the originally calcareous host occurred due to periodically raised groundwater, and its differentiation into nodules occurred under subaerial environment, i.e., after recession of groundwater. Nodules display a multiplicity of carbonate precipitation events and internal reorganization of calcitic groundmass. The important source was probably provided by the pre-existing calcretes in the sheetwash aggraded plains and detrital carbonate in the aeolian sediments. The original source of carbonate in the region, however, remains unresolved and will need further investigations.

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# Trace elements distribution in the soil profiles of Peshawar

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Twenty two soil profiles derived from piedmont (shales), alluvium, loess and re-deposited loess underlain by Quaternary sediments in Peshawar district were sampled and analyzed for total Cd, Cr, Cu, Mn, Ni, Zn, and Pb using Atomic Absorption Spectrophotometer. There was no significant difference in total content of Cu in all soils. In contrast, the total content of Cd, Cr, Mn and Zn was found to be significantly greater ($p<0.05$) in piedmont soils than alluvium and loess soils. Similarly, Ni and Pb were significantly greater ($p<0.05$) in loess soils than piedmont and alluvium soils. In addition to that, Cr, Pb and Zn were found to be significantly greater ($p<0.05$) in the A horizon of piedmont and alluvium soils than B horizon. The total content of all trace elements, except Cd and Ni, was found to be at their typical concentrations for normal soils. There was no significant difference between total trace elements content except for Cd and Ni between soils and parent materials. All metals were evenly distributed and derived from similar parent material of sedimentary origin.

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# Depositional environments and diagenetic fabric of the Margalla Hill limestone Kohala-Bala area, Haripur, Hazara, Pakistan

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This study deals with the microfacies and depositional environments of the Margalla Hill Limestone (Eocene) from the Kohala-Bala area, Haripur, in the southern Hazara Fold and Thrust belt. The stratigraphic succession of Hazara ranges in age from Pre-Cambrian to Holocene. In this study, Margalla Hill Limestone (Early Eocene) of Kohala Bala in southern Hazara is measured, sampled and described.

The Margalla Hill Limestone is 136m thick limestone with thin interbeds of clay/marls, and has conformable lower and upper contacts with Patala Formation and Chorgali Formations of the Eocene age respectively. The Margalla Hill Limestone is characterized by a wide variety of faunal and floral assemblages. These include larger benthic forams, planktic forams, echinoderms, mollusks and dasycladacean algae. Three microfacies identified include; 1) Miliolid *Lockhartia* Mud-Wackstone Microfacies, interpreted to have been deposited in a low energy, restricted circulation with slightly higher than normal salinity in a lagoonal environment of the inner shelf, 2) Nummulitic Wack-Packstone Microfacies, representing deposition in a subtidal conditions of the carbonate shelf, 3) Benthic Foraminiferal Wack-Packstone Microfacies, interpreted to have been deposited in the middle shelf area relatively offshore. These microfacies are repeated several times in the section reflecting fluctuating sea level conditions.The diagenetic overprinting of the rocks includes compaction, aragonite to calcite transformation, pressure dissolution, stylolites, vein-filling spar and development of nodular fabric.

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# Evaluation of liquefaction potential of sandy and silty soils of Defence-Clifton areas of Karachi and mitigation measures

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One of the most common causes of ground failure during earthquakes is the liquefaction phenomenon which has produced severe damages so far all over the world. Many factors govern the liquefaction process for in situ soil and the most important are intensity of earthquake and its duration, location of groundwater table, soil type, soil relative density, particle size gradation, particle shape, depositional environment of soil, soil drainage conditions, confining pressures, aging and cementation of soil deposits, historical environment of the soil deposit and building/additional loads of these deposits. Areas that may be prone to liquefaction hazard are those that may be subjected to moderate to very strong ground shaking, have young alluvial deposits consisting of sand and silt, and have shallow ground water (within 50 feet of the ground surface). Young deposits would be of Holocene to late Pleistocene in age. Determination of liquefaction potential of soil deposits due to an earthquake is a complex geotechnical problem since many factors including soil parameters and seismic characteristics influence this problem. There are two approaches to mitigate against liquefaction, soil improvement and foundation based mitigation. This paper summarizes results of some specific factors that control development of liquefaction of soil such as Standard Penetration test (SPT), grain size distribution of the soil mass, relative density of the soil deposits, depth and thickness of different soil strata, depth of groundwater table, etc. Tests were carried out on sandy and silty soils collected from different sites of the study areas because these areas may be prone to liquefaction due to having loose sand beach deposits, shallow ground water and a lot of construction over landfill deposits. The potential for liquefaction of these soils and its mitigation techniques are presented.

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# Peak-Flood Inundation Map of the Western Peshawar Plain (Peshawar, Charsada, Nowshera Districts): Implications for Flood Disaster Preparedness Plans

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Flood Inundation Map (FIM) is one of the most essential prerequisites for any flood management plan. FIMs provide information on the spatial extent and depth of flood waters in a given area. Since these provide spatial distribution of floods in an event, they clearly define which cities, towns, villages, roadways, streets, buildings, airports, etc., are likely to be impacted by floodwaters. They serve two purposes. In pre-event settings, they form the basis of preparedness plans through structural and non structural measures. For instance, if a town or important infrastructure is located within the flood zone, structures like embankments, spurs, gabions, water diversion channels, draining channels etc can be built to avoid flooding from the water source. Likewise, the inhabitants at such locations may be made aware of the flood hazards and may be drilled through well coordinated evacuation/rescue plans. In the event of flooding, the same maps make basis for organizing warning, rescue, response and relief operations.

Pakistan has been subject to flood hazards on regular basis throughout its history. Flood management has been a focus since 1970s when floods caused extensive damages along the major river courses in Punjab and Sindh. However, entire emphasis has been on structural measures involving construction of embankments, spurs and bunds, and that too, mostly in the Punjab and Sindh plains. Pakistan ignored development of flood inundation maps, which are crucial not only for preparedness against flood hazards but are also most important tool for rescue/response phase during flooding. The result is that in 2010 when floods of unprecedented volumes hit Pakistan, it was not clear which population centres and infrastructures (especially roads) were most endangered and which routes be used to conduct rescue and response operation.

Using Peshawar, Charsadda and Nowshera districts in western Peshawar basin as a case study, a peak flood inundation map has been prepared based on peak flooding conditions as witnessed in end July-early August 2010. A two-fold methodology has been adopted. Firstly we have conducted a field survey delineating the extent of flooding on either sides of the rivers draining into the western Peshawar basin. Height of flood levels have additionally been measured at several points within the flooded areas. For a regional overview of the peak flood inundation, we have used an August 4, 2010 satellite image taken by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA’s Terra satellite. The combined dataset thus acquired was superimposed on the 0.6-2.5 m resolution satellite images of the Peshawar Plain freely available on Google Earth. Further we superimposed 15-30 meter resolution DEM based on ASTER onto the dataset in ArcGIS, to find the spatial distribution of topography in the studied region.

The resulting FIM for the western Peshawar basin is the first attempt on flood zoning in the western Peshawar basin. Major results from this study include:

1. Western Peshawar basin is endangered by both riverine as well as flash floods. The riverine floods are caused by high discharge in seven rivers. The major rivers of Swat and Kabul as they enter Peshawar basin are divided into distributaries, which include Jindai and Khiali (Swat River), Sardaryab, Naguman and Shah Alam (Kabul). Other notable rivers include Kalapani from north of Mardan and Bara from south of Peshawar. Except for Kalapani and Jindai rivers, rest of these distributary rivers converge into main Kabul River within an area of 5 $km^2$ immediately upstream the Kabul River bridge on M1 Motorway. Bara River joins the Kabul River immediately past the M1 Kabul River Bridge while Jindai and Kalapani join the Kabul River further downstream near Nowshera. Therefore within a stretch of about 15 km between M1 Kabul Bridge and Nowshera, Kabul River is primarily a confluence area for 7 major river courses, which not only makes this region most vulnerable to flood hazards, but is supplier of an influx of flood water for Nowshera city and district.
2. During the 2010 peak floods, the outward inundation by these 7 rivers flooded a total area of >300 $km^2$, 10 times more compared to the area of their normal river course.
3. A stretch of 8 km wide area between Shah Alam River in the southwest and the Jindai River in the northeast on either side of the M1 Motorway was most heavily flooded. It is highly likely that the M1 Motorway in this stretch blocked the normal flow in rivers and associated distriburaries, resulting in widespread inundation in the Charsadda district. The Jindai River Bridge with a span of ~70 m, far less than the span of the floodway in the Jindai River (i.e., 120 m), definitely contributed to ponding along the northern embankment of the motorway. Motorway drains for at least three streams occurring between the Kabul and the Jindai bridges are too narrow for peak flood conditions. A redesigning of the Jindai bridge and drains in this 8 km stretch of the M1 Motorway is crucial for controlling future flood hazards in the Charsadda district.
4. The FIM produced based on peak flood conditions in 2010 should form basis for future development projects in the western Peshawar Basins to avoid losses through future flood disasters in this region.

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# Earth system studies and geo-engineering: Challenges and opportunities for Pakistan

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The past 10,000 years have witnessed the growth of homo-sapien population from about a million to a staggering 7 billion at present. This exponential increase in number has also been accompanied by unidirectional and largely irreversible changes on the earth's surface in the realms of farming, mining and excavation, industrialization and urbanization. So far the earth's natural regulatory system has been able to keep everything from the climate to the supply of water and other resources inside narrow comfortable zones. The demands of these 7 billion souls for fresh air, clean water, healthy food, restful shelter, cheap energy and other material and aesthetic pleasures have now stretched the capacity and the capability of the earth system to a certain breaking point – a stage where the humanity's own survival and that of other species which co-habit this planet has become a big question mark.

On a global scale, the recognition of these human-induced fatalities and the initiation of remedial actions to partially offset, if not totally reverse these changes has begun belatedly, half-heartedly and to some extent without adequate studies and enough political will. The victim is none else but the Earth System with its major constituting components of atmosphere, lithosphere, hydrosphere and biosphere. The remedy being suggested recently is called geoengineering. It is a newly emerging field but is controversial from its very outset. It aims to fix the climate regionally, if not in the beginning globally.

Can a country like Pakistan, small in area, large in population and home to a multitude of natural and man-made hazards, derive enough developmental space to envision a better, prosperous, and more equitable future for its people? This paper looks into these possibilities in the overall context of the interconnectedness of earth system, geoengineering, and development economics that could result in evolving sustainable growth strategies ensuring water, energy, mineral, and food security for Pakistan. In the backdrop of this holistic, but hitherto neglected, approach, it offers some practical and cost-effective suggestions to make policies and programmes which should be knowledge-based, people-centric and environment-friendly. Proper understanding of the earth system operating within and on the lithospheric crust of Pakistan is the surest and safest way to turn calamities into opportunities and potential into assets. However, to benefit from all that nature has endowed Pakistan in abundance, the pre-requisite is to overcome the institutional inertias reflective of a non-progressive political mindset and outdated organizational structures and procedures.

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# Alkali Silica Reaction (ASR) potential of sand and gravels from NW-Himalayan rivers and their performance as concrete aggregate at three dams in Pakistan

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Concrete aggregates derived from the river bed materials of many of the streams originating from the NW-Himalayan region and draining into Pakistan are found reactive in terms of Alkali-Silica Reaction (ASR). This paper describes the long term ASR related performance of concrete at three dams i.e., Warsak, Tarbela and Mangla where material from such streams has been used as concrete aggregates. On Warsak an aggressive and at Tarbela a mild ASR has been detected while at Mangla dam ASR free concrete is reported. The anomaly of occurrence and non-occurrence of ASR in concrete manufactured using aggregate derived from the same provenance has been described.