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15 – 17 November 2010

Kathmandu, Nepal

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Sixth Nepal Geological Congress

on

Geology, Natural Resources, Infrastructures, Climate Change and Natural Disasters

15–17 November 2010

Kathmandu, Nepal

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Nepal Geological Society is going to organize the **Sixth Nepal Geological Congress** from 15th to 17th November 2010 in Kathmandu, Nepal. We are confident that the Congress will be proved to be an important gathering of the prominent geo-scientists and professionals from different countries. Furthermore, the Congress will provide the participants with an opportunity to exchange their knowledge and experiences with each other. We hope that such interaction will make an important contribution towards the further development in geo-scientific fields. We express our sincere gratitude to all the valued participants and contributors for their invaluable effort.

Our sincere thanks are also due to Cairn Energy PLC, UK, DASE-France, Muktishree P. Ltd, and Caltech-USA for their generous support to organize this event. We express our sincere thanks to Mr. Sarbajit Mahato, Director General and Mr. Sri Ram Maharjan, Deputy Director General of the Department of Mines and Geology, Government of Nepal for their kind cooperation.

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An overview of the Jijal Complex, the roots of the Kohistan magmatic arc in the Himalaya of Pakistan

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Northern Pakistan comprises at least four distinct geo-tectonic domains: 1) the Hindukush terrain in the north, followed southward by 2) the Karakoram Plate, 3) the Kohistan magmatic arc, and 4) the Indian Plate. The Hindukush terrain is sutured to the Karakoram Plate along the Tirich Mir Fault; the Kohistan arc is sutured on its north to the Karakoram Plate along the Shyok Suture or Main Karakoram Thrust, and with the Indian Plate to the south along the Indus Suture or the Main Mantle Thrust. The Kohistan arc comprises a range of volcanic, plutonic, and subordinate sedimentary rocks of Early Cretaceous (~125 Ma) to mid-Tertiary (25 Ma) age. It developed as an intra-oceanic island arc that became an Andean-type margin after suturing with the Karakoram plate ~100 Ma ago. The island arc stage igneous and sedimentary rocks underwent medium- to high-grade metamorphism.

The Jijal Complex (JC) is an association of mafic-ultramfic rocks forming a 150 km^2 block in the southern fringe of the Kohistan arc along the Indus River (73ºE, 35º5´N). Because of its unusual rock association, this complex has been studied in considerable detail by a number of workers. It is composed of two principal lithological associations. The southern part of the JC in the hanging wall of the Indus suture consists of some 10×4 km slab of ultramafic rocks (pyroxenites, peridotites, dunite, minor chromitite). Overlying these is a 7 km wide belt of garnet granulites, garnetites, garnet hornblendites, some ultramafic lenses and granitic bodies, and retrograde assemblages. The ultramafic rocks have a Rb-Sr age of 117 ±7 Ma, whereas the gabbro-norite relics in the upper part of the garnet granulites have a Sm-Nd age of 118 ±12 Ma.

The garnetiferous rocks of the Jijal Complex have a range of lithologies (Table 1), which appear to have been derived from a series of gabbros, troctolite/allivalite, hornblendite, pyroxenites, and peridotites. These rocks and the ultramafic rocks underneath appear to be isotropic to layered plutonic rocks in the roots of the Kohistan magmatic arc. The geochemistry of the rocks supports a subduction-related origin. Thermo-barometry suggests peak conditions in excess of 850 °C and 14 kbar. However, the mutual relationship of the ultramafic rocks and granulites is not clear neither is the mechanism of high-pressure granulite facies metamorphism which, probably, would have been accompanied by a small degree of partial melting.

Table 1: Mineral assembleages in Jijal Granulites

1) Garnet granulite facies assemblages

Pl + Grt + Cpx + Qtz + Rt ± Hbl
Pl + Grt + Qtz + Rt ± Hbl
Pl + Qtz + Grt + Ep ± Rt
Pl + Grt + Cpx + Scp

Cpx + Grt ± Spl
Cpx + Opx + Grt ± Hbl
Cpx + Opx + Grt ± Spl

Grt + Cpx + Qtz + Ep ± Hbl
Grt + Cpx + Hbl + Rt ± Qtz
Grt + Cpx + Rt
Grt + Hbl + Ep + Rt
Grt + Hbl

Hbl + Grt + Rt
Hbl + Grt + Cpx ± Rt
Hbl + Grt + Pl
Hbl + Grt + Ep + Qtz + Rt

Vein in Grt Hbldite: Cpx + Grt + Hbl

Zo + Grt ± Cpx ± Hbl ± Qtz

3) Pyroxene granulite facies enclaves in garnet grain

Pl + Opx + Cpx ± Hbl (meta-norite)   *Cpx ± Opx + Spl (meta-pyroxenite)*
The gabbronorite to garnet granulite reaction:
Pl (An 45) + Opx (En 62) + Cpx (Mg 33.8, Fe 18.6, Ca 47.6; Al2O3 7.2%, Na2O 1.8%)+ Prg = Pl (An 48) + Grt (Mg 31.7, Fe 44.9, Ca 23.4) + Cpx (Mg 37.7, Fe 13.0, Ca 49.2; Al2O3 5.6%, Na2O 1.6%) + Rt + Qtz

2) Retrograde assemblages

Grt + Hbl + Pl + Ep + Rt ± Scp
Zo + Ky + Pg ± Crn
Zo + Qtz + Grt + Hbl + Ky + Pg
Hbl+ Ep+ Grt+ Qtz+ Pl+Pg+ Rt
Hbl + Ep + Scp
Hbl + Ep + Qtz

Am+Ep+Qtz + Phen + Crn + Rt
Pl + Qtz + Chl + Ep
Ep + Phen + Chl + Am
Ep + Chl + Am + Sph + Ab
Ep + Ab + Pg ± Act
Act + Chl + Ep ± Ab

4) Possible Protolith assemblages

Pl + Opx + Cpx ± Qtz (norite)
Pl + Ol + Cpx ± Hbl (Ol gabbro)
Cpx ± Opx ± Pl ± Spl (pyroxenite)
Pl ± Cpx ± Ol (anorthosite)

Pl + Qtz ± Opx ± Hbl (tonalite)
Pl + Ol ± Cpx (troctolite, allivalite)

Petrological, magnetic and geochemical characterization of Cretaceous-Paleogene boundary sections, Gulf of Mexico

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We present results from petrological, magnetic and geochemical studies of El Mimbral and La Lajilla sections that span the Cretaceous-Paleogene (K-Pg) boundary in northeastern Mexico, and discuss their relationship to the Chicxulub impact and the nature, origin, stratigraphic relations and age of the impact ejecta deposits. The K-Pg boundary is preserved between hemipelagic marls and limestones of the Mendez (Maastrichtian) and Velasco (Paleocene) formations. Sections are situated about 1000 km away from Chicxulub and their K-Pg deposits are part of the proximal ejecta within complex channelized siliciclastic units, which were separated in two parts, one with a basal coarse, poorly graded spherulitic bed with 0.2 to 1 m thick and a second part with several sandstone siltstone beds. Samples were collected across stratigraphic profiles for mineral, magnetic, petrological and geochemical analyses. Detailed lithologic columns for the two localities were prepared. Magnetic measurements include susceptibility, remanent and isothermal magnetization and remanent coercivity. Magnetic hysteresis loops and IRM and back-field demagnetization were measured for samples of spherulitic bed. X-ray fluorescence analyses on whole rock were complemented with previous data obtained for the Mimbral section. Further, detailed analyses were concentrated in the ejecta material. The spherulitic bed is characterized by rich-Fe-Mg, chlorite and rich Si-Al-K glass spherules and carbonate accretionary lapilli spherules. The silicic component spherules are altered to calcite or chlorite-smectite, with some retaining glass cores. Spherules contain Fe-Mg bubbly spherules, Fe-Ti-K schlieren and micrometer size metallic inclusions documenting a compositional range of mafic to intermediate rocks, which relate to the target stratigraphy in Yucatan with the thick surface carbonate platform sediments and the granitic and metamorphic basement. Sixty individual spherules were separated from the two section beds. They display different morphologies, degrees of alteration, surface colors and sizes, with vesiculated globular spherules.

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Evaluation of the Variscan orogenic plutonic magmatism: the Greater Caucasus, Russia

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The Greater Caucasus represents a collisional orogen formed along the Euro-Asian North continental margin and connecting the European and Asian branch of the Alpine-Himalayan mobile belt. It is extended over 1200 km between the Black and Caspian seas. Two major structural stages are distinguished in its construction: Pre-Mesozoic crystalline basement complex (BC) and Meso-Cenozoic volcanic-sedimentary cover. In the Pre-Mesozoic basement complex (200 x 40 km) four structural zones (terranes), separated by regional tectonic unconformities or Jurassic depression, are identified, along with they contact each other. BC is built up of the Pre-Cambrian and Paleozoic metamorphic and magmatic rocks; Variscan plutonic magmatism plays an important role in this stage of evolution.

As a result of comprehensive geological, petrological, geochemical and mineralogical research work in BC of the Greater Caucasus, four Variscan plutonic series from south to north are distinguished: 1- Gabbro-Plagiogranite (356+15 Ma; Rb-Sr method); 2- Diorite-Adamellite (310+12 Ma; U-Pb method); 3- Plagiogranite-Granite (317+12 Ma; Rb-Sr method); 4-Granodiorite-Alaskite (300+7 Ma; Rb-St method). Each plutonic series was formed at a different geodynamic position, from different protoliths, and in each plutonic series the mechanism of magma generation was different. They have general Greater Caucasian direction (NW-SE) and notwithstanding strong horizontal movements, some tonality is still detected in their arrangement.

Based on the petrogenesis of the Variscan plutonic series and their lateral zones, we conclude that during the Variscan orogenic events northward subduction of oceanic crust (the north edge of Paleotethys) was activated. Its action in the convergent zone caused regional metamorphism and plutonic magmatism.

Sandstone petrography, heavy mineral and geochemical study of the Subansiri Formation (Middle Siwalik) in the eastern Himalaya, India: implications on provenance and tectonic setting

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Petrography, heavy mineral and geochemical study of sandstones from the Subansiri Formation, which are equivalent to the Himalayan Foreland basin's Middle Siwalik Group of Miocene-Pliocene age in and around the foothills of Arunachal Himalaya, near Gerukamukh in the border region of Assam and Arunachal Pradesh, has been carried out to infer the provenance of the sandstones, tectonic setting during sedimentation and paleoclimatic conditions prevailed in the area at the time of deposition.

Based on the framework composition, the sandstones are classified as quartzose arenite (James et al. 1986), sublithic arenite and sublithic arkose types. Petrographic studies reveal that these sandstones contain quartz, feldspars and of igneous and metasedimentary rock fragments. The modal analysis of sandstone samples (coarse gritty, medium grain size) implies a recycled orogen tectonic provenance. Moreover, petrographic data indicate metamorphic, plutonic igneous and recycled quartz-rich sedimentary parent rocks for the Subansiri sandstones. The petrographic result shows deposition of the sediments in a low to moderate relief during a humid tropical paleoclimatic condition. The sandstones are poorly cemented. Diagenetic activities in the sandstones are low as evidenced by poor cementation, less compaction, near absence of crenualated /corrugated boundaries of mineral grains, short contact along grain boundaries, and rare occurrence of bending in mineral grains and rare authigenic growth in minerals.

The heavy mineral study indicates that the sediments are derived mostly from acid igneous rock and medium grade metamorphic rock provenances. The Subansiri sandstones are mineralogically immatured.

Discrimination diagrams based on major oxides suggest intermediate igneous and felsic igneous provenance in an active continental margin and a continental island arc tectonic setting. As indicated by the CIW (chemical index of weathering) of the Subansiri Sandstone (average value of 67) their source area had moderate degree of chemical weathering.

REFERENCE

James, W. C., Wilmar, G. C., and Dividson, B. C., 1986, Role of Quartz Type and Grain Size in Silica Diagenesis of Nugget Sandstones, South Central Wyoming, Jour. Sed. Petro., v. 56(5), pp. 657-662

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Pebble analysis of the Cretaceous Fluvial Bottom Conglomerate Formation in and around Weiloi, Shillong Plateau, Meghalaya, India

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Statistical analyses of pebbles have been carried out in the Cretaceous Bottom Conglomerate Formation of the Khasi Group in and around Weiloi on the way to Mawsynram, Meghalaya to determine their characteristics and depositional mechanism along with the provenance of the sediments in the southern part of the Shillong Plateau. Pebbles have been collected by random sampling technique from the formation, which was deposited from the north as fluvial fan deposit. The proximate part is dominated by conglomerate beds with small lenses of sandstones, whereas the distal part contains relatively thick sandstone beds with intervening thin beds of pebbles. The size of the pebbles reduces towards the distal part. From the pebbles of the conglomerate beds, the three intercepts L (long), I (intermediate) and S (short) axes were measured by slide calipers. These measured data were used for statistical analyses to calculate the arithmetic mean, diameter, flatness ratio, sphericity and shape factor of the pebbles in addition to several other parameters used by different workers. The rose diagram of long axis of pebbles shows ENE-WSW orientation. The general orientation of the embedded sandstone unit is about 5º→ 220º which indicates the direction of flow of palaeo-river during the deposition of the gravels. The pebble beds were occasionally deposited by mountainous flash flood during the Cretaceous. The pebbles are composed mainly of quartzites and granites found in the Shillong Plateau indicating near source of the sediments.

The Barail sandstones of Ukhrul area, Manipur, India: a study on provenance and tectonic environment based on petrographic, heavy mineral and geochemical data

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Petrographic, mineralogical and geochemical studies have been carried out for the Barail sandstones in Ukhrul area of Manipur in the Assam-Arakan Basin to determine the nature of sediments, their sources and depositional environment. The study is based on thin-section petrographic works on the Barail sandstones, heavy mineral identification and evaluation, and also determination of major oxides of the sandstones collected from the Barail Group using XRF technique.

The petrographic study shows that the sandstones are mostly quartz arenite and quartzose arenite (triangular classification of James et al. 1986). There is higher degree of diagenetic changes, with poor matrix due to dissolution of the fine mineral grains. Petrographic study and heavy mineral composition indicate that the sediments were mostly derived from plutonic acid igneous rocks. The lower sequence of the Barails is mineralogically highly matured and the upper sequence is markedly immature.

The chemical characteristics of the Barail sandstones indicate that these rocks are graywacke and Fe-shale which is not reflecting the petrographic classification. It appears from the analysis that the matrix of the sandstones contains higher concentration of Na_2O, Fe_2O_3 and Al_2O_3 as compared to K_2O and SiO_2, and influence the chemical classification. The sediments were derived from metamorphic rocks of predominantly quartzose sedimentary and intermediate igneous provenances in oceanic and continental arc tectonic settings having some passive margin influence. Also palaeoclimatic condition during deposition of the sediments was mostly humid during deposition of the lower coarser sequence of the Barail sandstones and semi-humid to arid during deposition of the upper fine sandstone sequence, as evidenced by petrographic and geochemical data.

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Spatial and temporal characterization of carbon dioxide and radon gas discharge at the Main Central Thrust zone in central Nepal

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High CO_2 and associated radon fluxes have been discovered in 2005 in the vicinity of the Syabru-Bensi hot springs, central Nepal. This CO_2, characterized by an isotopic anomaly of d^{13}C of –0.8±0.03 ‰, probably originates from metamorphic decarbonation at depth and finds its way to the ground surface through preferential percolation pathways along the Main Central Thrust (MCT). As the MCT branches at depth to the Main Himalayan Thrust, the main contact accommodating the collision between India and Tibet, such gas discharges offer a unique natural laboratory to study a potential relationship between the release of geological fluids and the seismic cycle in the Himalayas. Several gas discharge zones have now been identified in Syabru-Bensi, from the main hot springs. Other gas discharges have also been discovered in the vicinity of the Timure hot spring, located 9 km north of Syabru-Bensi, and investigations are undergoing to other hot springs of the area. Several methods are used to search for gas discharges: presence of hot springs, smell of hydrogen sulphide, geological contact zones, infra-red imaging. High radon flux is systematically associated with high CO_2 flux, a fact that is rather easy to explain in a multi-layer multi-phase analytical model. These calculations use detailed laboratory measurements of radon source term, referred to as effective radium concentration, which has now been obtained with over 450 rock and soil samples from the MCT zone. Long-term monitoring of the metamorphic CO_2 can now be performed using radon probes. Preliminary time series have been obtained in Syabru-Bensi and can be used to discuss long-term perspectives. Estimating the total flux of metamorphic carbon from active orogens is also important to refine global atmospheric carbon budgets.

The P-T evolution of the Barun Gneiss (Higher Himalayan Crystallines of eastern Nepal) in the framework of the "channel flow" model

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In the Higher Himalayan Crystalline of eastern Himalaya, the structurally lowermost Barun Gneiss (Goscombe et al. 2006) is an east–west trending, 6-7 km thick, sequence of Grt-Kfs-Ky-Sil granulitic and migmatitic metasediments, laterally continuous for at least 200 km across eastern Nepal, Sikkim and Buthan.

We present new petrographic and microstructural data on the Barun Gneiss outcropping along the Arun-Barun transect toward the Nepalese Makalu base camp, in the sector between Kauma to the south and Yangle Kharkha to the north. Our aims are: (i) to reconstruct the P-T evolution of a still poorly investigated high-grade Himalayan tectonometamorphic unit; (ii) to discuss the resulting P-T evolution of the Barun Gneiss in the framework of the "channel flow" model (Beaumont et al. 2001) predicting the tectonic evolution of Himalaya.

Barun Gneiss consists of leucocratic quartzo-feldspathic domains alternating with dark biotite + plagioclase + sillimanite layers which define a more or less continuous planar foliation; in addition, garnet and kyanite are always present. At the microscope, several microstructures representing the evidence of melt-producing or melt-consuming reactions have been recognised.

Results of thermodynamic modelling suggest that Barun Gneiss experienced a clockwise P-T evolution characterized by heating during decompression up to peak-T conditions of 800°C at P=8-10 kbar followed by a nearly isothermal decompression down to 6.5-7.5 kbar, when melt completely crystallized. Our metamorphic and petrologic data match well with the expectations of the "channel flow" model (Beaumont et al. 2001), including: (i) the estimated P at peak-T (our data: 10-8 kbar at 800°C; model: 13-7 kbar at 800°C); (ii) the decreasing P structurally upward, which defines a "normal" metamorphic sequence, in contrast to the inverted metamorphic sequence occurring in the lowermost MCTZ; (iii) the nearly-isothermal exhumation, reflecting the progressive exhumation of rocks that have been entrained in the deep, high-T region of the channel, where they experience gradually declining P at nearly constant T.

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Elusive Himalayan eclogites: evidence that they were there from zircon and monazite U-Pb geochronology and trace element geochemistry

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Mafic and pelitic granulites exposed in the eastern Himalayan kingdom of Bhutan preserve textural evidence for a precursor high-pressure metamorphic event, the precise conditions of which are generally unrecoverable due to the later high temperature overprint. As high pressure metamorphism is rare in the Himalayas, especially in the eastern parts of the orogen, their thermobarometrical and geochronological evolution place important constraints on the geodynamic evolution of the Himalaya in particular and continental collisions in general. We report SHRIMP-RG trace element (REE) and U– Pb zircon, geochronological data, collected by the same instrument and on adjacent spots of the same crystal and LA-ICPMS U-Th-Pb monazite geochronological data. Combined, these data suggest that zircons crystallized at 14-15 Ma over a temperature range of ca. 705-815^{0}C. This age is interpreted to indicate the timing of HP metamorphism due to the lack of negative Eu anomaly, the depleted heavy REE signature and the low temperatures of crystallization. Monazites associated with sillimanite-grade metamorphism in granulite-hosting garnet-sillimanite-biotite migmatitic gneisses yield rim ages between 15.4 ± 0.8 Ma and 13.5 ± 0.5 Ma and core ages of ca. 550 Ma. These rocks structurally overlie older 21-16 Ma garnet-sillimanite-biotite migmatitic gneisses in which granulite-facies material is absent. The geochronological, petrological and structural data suggest that an out-of sequence thrust likely separates the two packages. We finally propose a tectonic model for the evolution of the eastern Himalaya and suggest a general model for late orogenic exhumation of the lower continental crust.

Radioactively anomalous granitoids in Narnaul area of Delhi Supergroup rocks, southern Haryana, India

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Southern part of Haryana consists mainly metasedimentary rocks belong to the Palaeo-Meso Proterozoic period of Delhi Supergroup and are exposed on the of Aravalli mountain range. In Narnaul area most of the granitoid (granite + pegmatite) intruded mainly into the quartzite but also occur within other metamorphite (granitic gneiss, schist, basic rock, calc rock, slate and phyllite). Granitoids occur as irregular mass, dyke, vein and lens. Granitoids are orientating in NNE strike direction with low dip angle. These granitoids show sharp contact with the host rocks and their dimensions are variable from few meters to hundreds of meter. The granites are pink, grey in colour, massive, medium to coarse, also very coarse grained, phyric and aphyric type. Narnaul granitoids consist of quartz (smoky, milky, yellowish brown, buff), microcline, orthoclase, albite, biotite, muscovite, tourmaline, ± hornblende, ± calcite, ± beryl, and ± garnet. The granitoids are showing varies textures like hypidiomorphic, porphyritic, graphic and perthitic.

Using portable Scintillometer, radioactivity survey was carried out. Radioactivity of the granitoids outcrop in Narnaul area varies from12 μr/hr to 30 μr/hr. On the basis of radioactivity data, the granitoids are classified into two groups (i) High Radioactive Granitoids (HRG) (20 μr/hr to 30 ìr/hr) which consist mainly of quartz, microcline, orthoclase, albite, as essential minerals. Muscovite, biotite, tourmaline occur as accessory minerals. (ii) Low Radioactive Granitoids (LRG) (12 μr/hr to 20 μr/hr) which comprises mainly quartz, albite, orthoclase, microcline as essential minerals and tourmaline, actinolite, calcite as accessory minerals. Hence the HRG consists essentially of K-feldspar (microcline, orthoclase) and biotite. The LRG consists of quartz, Na-feldspar (albite), orthoclase and calcite. The modal composition (in vol. %) of (HRG) granitoids of the study area are plotting in the granite, alkali granite and alkali syenite fields of QAP diagram (Streckeisen 1973) and in the alkaline and peralkaline and field of granitoid generated by crustal fusion process (Lameyre and Bowden 1982). The modal composition of (LRG) granitoids are plotting in granodiorite and quartz rich granitoid fields of the calc-alkaline-granodiorite series. Observations of sharp contact, chilled margins and graphic texture in these granitoids suggested the evidence in favour of magmatic origin. HRG are derived due to the selective U enrichment activity whereas the less mobile Th probably segregated in the LRG.

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Crystallization conditions of the Palaeoproterozoic basement rocks in Bangladesh: an evaluation of biotite and amphibole mineral chemistry

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The Palaeoproterozoic (~1.73 Ga) basement rocks from Maddhapara, Bangladesh, a remnant of Columbia supercontinent (Hossain et al. 2007), show a large range of chemical variations (e.g., SiO_2 = 50.7–74.7%), including diorite, quartz diorite, monzodiorite, quartz monzonite and granite. Amphibole and biotite, dominant ferromagnesian minerals, have been analysed with an electron microprobe for major elements. We sampled a variety of rock types, ranging from diorite, quartz diorite and monzodiorite.

In biotite, the most pronounced variations are in Al^{vi} contents (0.13 to 0.25 pfu) and $Fe^{2+}/(Fe^{2+} + Mg)$ values (0.39–0.47). The biotite is classified as phlogopite in the biotite quadrilateral (annite–siderophyllite–phlogopite–eastonite). In the Mg-(Al^{VI}+Fe^{3+}+Ti)-(Fe^{2+}+Mn) ternary diagram for the classification of trioctahedral micas by chemical and lithological affinity, most biotites from basement rocks in Bangladesh plot in the “Mg biotites” field, which includes Mg dominant trioctahedral micas. Biotite is a very good sensor of oxidation state of the magma from which it crystallised (Wones and Eugster 1965). The studied biotites generally plot between the QFM and HM buffers in the Fe^{2+}-Fe^{3+}-Mg ternary diagram. The trend of decrease in Fe^{3+} and increase in Mg in the biotite of more evolved phases suggest very minor change in oxygen fugacity. Ca-amphibole in the examined samples has a wide compositional variation in X_{Mg} = Mg/(Fe + Mg) = (0.50–0.66), Si (6.35–6.71 pfu), and $Fe^{3+}/(Fe^{2+} + Fe^{3+})$ = 0.10–0.45. Most of them are compositionally magnesiohornblende based on the classification of Leake et al. (1997), while some pargasite, magnesiohastingsite, edenite and tschermakite are also present. Compositions of amphiboles in diorite, quartz diorite, and monzodiorite are generally indistinguishable. Application of hornblende-plagioclase thermometer to calculate the temperature of crystallisation of the basement rocks are 680–725ºC and Al-in-hornblende barometry results yielded a pressure range 4.9–6.4 kbar at 680–725ºC (Hossain et al. 2009). The occurrences of Mg-rich pargacite, magnesio-hornblende and Fe^{2+} biotite in dioritic rocks suggest relatively oxidized magma (Tahmasbi et al. 2009). Wones (1989) made quantitative estimation of fugacity based on the equilibrium expression:

$$\log fO_2 = -30930/T + 14.98 + 0.142(P-1)/T$$

Where, T is temperature in Kelvin and P is pressure in bars.

Temperature (T) and pressure (P) estimated from hornblende-plagioclase thermometry and aluminium in hornblende barometer of the Palaeoproterozoic basement rocks were used in these calculations. The sample analysed using maximum P-T, have $\log fO_2$ is about -15 bars that show the magma crystallised in high fO_2. Oxygen fugacity estimates suggest that the basement rocks probably crystallised under oxidizing conditions. The biotites compositions show an apparent calc-alkaline trend of differentiation. The study suggests that the trend of oxidized magmas is commonly associated with convergent plate boundaries.

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Material properties of the moraine of the glacial lake and the examination about the outburst of dam of glacial lake for the hazard assessment

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In this paper, the material properties about the moraine of the glacial lake are shown. An approach and its needed data for the evaluation of outburst that the assessment for the disaster caused by the glacial lake outburst flood are described.

At first, the physical and the mechanical properties of the moraine of the glacial lake of Nepal and Bhutan are examined, and they are compared. In Nepal, sample was obtained at Imja Tsho glacial lake, and in Bhutan, two samples were obtained at two glacial lakes which developed in the basin of Mangde chuu. The properties are the specific gravity, the grain size distribution and the shear strength.

Subsequently, the overflow was assumed as the provoking causes of the outburst, and it was shown that the DAMBRK model was suitable as the analytical model in 10 models suggested as the failure model of the fill dam similar the moraine dam.

And, the simulation of the outburst was worked out using the DAMBRK model and the obtained data about the properties of the moraine, and the evaluation of the outburst was examined based on the simulation results by a view point of the hazard assessment. As a result, the border of the outburst and the static erosion were obtained and it was made clear that the water balance of the glacial lake influenced it. Finally, as the data that we should get for the prediction of outburst, the data about the water balance such as the amount of the lake water, the inflow from the upstream, and the outflow from the lake are suggested.

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Exhumation history of the deepest central Himalayan rocks, Ama Drime range

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The Ama Drime range located at the transition between the High Himalayan range and south Tibet is a N-S active horst that offsets the South Tibetan Detachment System (STDS). Within the horst, a paragneissic unit, possibly attributed to the upper Himalayan crystalline series, overly the lower Himalayan crystalline series (Ama Drime orthogneissic unit) containing large metabasite layers and pods that have experienced pressure=1.4 GPa. Combining structural analysis with new and published pressure-temperature (P-T) estimates as well as U-Th/Pb, 39Ar/40Ar and (U-Th)/He ages, the P-T-deformation-time (P-T-D-t) paths of the main units within and on both sides of the horst are reconstructed. They imply that N-S normal faults initiated prior to 11 Ma and have accounted for a total exhumation =0.6 GPa (22 km) that probably occurred in two phases: the first one until ~9 Ma and the second one since 6 to 4 Ma at a rate of ~1 mm/yr. In the Ama Drime unit, 1 to 1.3 GPa (37 to 48 km) of exhumation occurred after partial melting since ~30 Ma until ~13 Ma, above the Main Central Trust (MCT) and below the STDS when these two fault systems were active together. The switch from E-W (STDS) to N-S (Ama Drime horst) normal faulting between 13 and 12 Ma occurs at the time of propagation of thrusting from the MCT to the Main Boundary Thrust. These data are in favor of a wedge extrusion or thrust system rather than a crustal flow model for the building of the Himalaya. We propose that the kinematics of south Tibet Cainozoic extension phases is fundamentally driven by the direction and rate of India underthrusting.

Differentiated exhumation/cooling history of the Lesser and the Higher Himalayan units in the Kullu-Kinnaur area, Himachal Pradesh, India

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In the Kullu-Kinnaur region of Himachal Pradesh, the Main Central Thrust tectonically juxtaposes Lesser Himalayan very low- to medium-grade metamorphic Proterozoic metasediments and meta-igneous rocks of the Larji-Kullu-Rampur Window (LKRW) against medium-high-grade metamorphic metasediments and Ordovician granitoids of the High Himalayan crystalline slab.

E of Beas River near Kullu, in the Malana-Parbati area, called as Bajaura nappe forms a distinct element between the low-grade metamorphic LKRW-Berinag quartzites in the footwall and the crystalline nappe in the hanging-wall. Metamorphic grade within the crystalline increases from bottom to top, from δ” 500 °C (Ms-Chl-Bt-schist) to ε” 650 °C (Grt-Ky-Sil gneiss). Sm-Nd garnet ages at 40.5±1.5 Ma from pegmatoid probably mark local melting during initial decompression, in line with inverse element zoning in synkinematic garnet. Ongoing exhumation in ductilely deformed assemblages is constrained by Sm-Nd garnet ages at 28.5±1 Ma, white mica Rb-Sr ages around 23-20 Ma, while Bt Rb-Sr ages indicate a drop of regional metamorphic temperatures below 300 °C between 15 and 12 Ma.

In the southeastern LKRW, the deep Sutlej gorge exposes medium-grade paragneisses and Proterozoic granite-gneisses (i.e. the Lesser Himalayan crystalline unit), overthrust by the High Himalayan units. These were later displaced towards NE, along the younger Karcham Normal Fault (KNF). Marked young extrusion of Lesser Himalayan crystalline units resulted in differentiated exhumation/cooling of more frontal parts of the orogen. Very young ductile deformation in the Lesser Himalayan crystalline units (near Wangtu) is constrained by Sm-Nd garnet and Rb-Sr muscovite ages at 6.8±2.1 and 5.3±0.3 Ma from late pegmatite intrusions. Apatite FT ages down to 0.6 Ma further underline accelerated diachronous sub-recent exhumation of different parts of the orogen, the counterpart of this extensional exhumation being reflected by NE normal faulting of Higher Himalayan units along the KNF and the STDZ, and extensive uplift-related Plio-Pleistocene fluviatile-lacustrine sediment accumulation in the Transhimalayan headwaters of the Sutlej, in Western Tibet.

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Review of detrital zircon ages and Sm-Nd isotopic data from Himalaya–support to the Mesoproterozoic formation of east Gondwana

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Detrital zircon ages and Sm-Nd isotopic data from Himalayan Orogen (DeCelles et al. 2000; Myrow et al. 2003; Gehrels et al. 2006) suggest that the Lesser Himalayan Metasediments (LHM) might have received material from the Northern Indian Craton, while the Higher Himalayan Gneisses (HHG) mostly from the Circum-East Antarctic Orogen (CEAO) including western Australia and east Antarctica, and partly from the LHM and the Arabian Nubian Shield (Yoshida and Upreti 2006). The original material of the Tibetan Tethys Sedimentary Sequence is considered to be mostly derived from the HHG and partly from the CEAO and only small amount on the western area from the Arabian Nubian Shield (Yoshida et al. 2005). The above results do not support the isolated block of the Indian craton during the Neoproterozoic apart from other crustal blocks, but suggest the juxtaposition of the Indian Craton with the Mesoproterozoic CEAO during the Neoproterozoic, and thus Mesoproterozoic or earlier formation of the East Gondwana. In examining the temporal and spatial polarities of detrital zircon age populations from geologic units with different ages, we assumed that the LHM, HHG, and the TTS are more or less continuous sequence deposited in more or less similar sedimentary basin at the northern margin of the North Indian Craton.

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Granitoid magmatism in Mongolia: evolution in time

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Granitoids in Mongolia occupy ~30% of the country and comprise a large part of the Central Asian Orogenic Belt (Altaids). The Altaids have been variously interpreted as consisting of (1) volcanic arc rocks, (2) early Caledonian, Hercynian and Indocinian complexes accreted to the Siberian Craton, and (3) Caledonian crust incorporating juvenile arc rocks and Precambrian microcontinents. The oldest dated rocks include diverse granitoid rocks that yield Proterozoic ages (2.8-1.6 Ga).The character of Early Paleozoic magmatism varies across the country. In contrast to alkaline rocks in northern Mongolia, batholiths to the west comprise 500-460 Ma old, arc-related granitoid rocks; some granitoids in this area and to the south, however, formed in an oceanic environment and are associated with ophiolite sequences. Extensive accretionary belts formed during the Silurian-Devonian are characterized by subduction related rocks in Mongolian Altai, where calc-alkaline granitoids are associated with post-orogenic rift-related alkaline rocks. Alkaline plutons in this area are interpreted to have formed by hot spot activity. In southern Mongolia, Devonian arc-related monzodiorites host large porphyry Au-Cu deposits. During the Late Paleozoic (Carboniferous-Permian), calc-alkaline arc-rocks formed during coalitional events that formed Trans-Altay zone and Mongolian Hercynides. The Permain Khangai batholith in central Mongolia, however, is interpreted as an intraplate intrusion.

Early Mesozoic granitoid magmatism occurred in the Mongol-Okhothsk belt that stretches over 3,000 km from Central Mongolia to the Pacific. Magmatism in this area is zonal, being cored by calc-alkaline granitoid batholiths flanked by numerous high-K postorogenic plutons including highly evolved, Li and F-rich granites. Similar granitoids, including their subvolcanic analogues (ongonites) were also emplaced during the late Mesozoic. Alkaline rocks including carbonatites are spatially associated with rifts in southern Mongolia. Late Mesozoic granitoids in this belt are represented by relatively small plutons formed by quartz diorite-granodiorite-granite and leucogranites with Li-F granites, namely their subvolcanic analogous ongonites. Along large faults in South Mongolia rifts formed with alkaline magmatism with carbonatites.

Proterozoic granitoids are interpreted to have been formed from Archean source rocks. Paleozoic granitoids have comparatively juvenile compositions and evidently formed above subduction zones. Mesozoic intrusives have a mixed juvenile and crustal source.

New data on the geological setting of the Nepalese Kanchenjunga area

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Structural and petrographic studies were performed at the western flank of the Kanchenjunga massif in far-eastern Nepal, across the northern and north-eastern flanks of the Taplejung tectonic window where the Lesser Himalayan Sequence (LHS) is exposed as a regional antiformal structure beneath the Main Central Thrust Zone (MCTZ) and the Higher Himalayan Crystalline (HHC).

In the studied area, the upper structural levels of the LHS comprise quartz-sericite and chlorite-sericite schists, quartzites, and intercalated augen gneisses. Moving upwards, the MCTZ is a few km-thick sequence characterized by a typical inverted metamorphism, passing from the structurally lower garnet-kyanite-staurolite two-micas schists to the structurally upper two-micas, garnet and kyanite-bearing migmatitic gneisses. Above the MCTZ, the HHC is exposed over more than 40 km up to the Tibetan border and may be divided in: (i) a lower portion, consisting of garnet-K-feldspar-kyanite-sillimanite anatectic paragneisses with minor intercalations of impure marbles and calc-silicate gneisses; (ii) a middle portion, consisting of similar anatectic paragneisses devoid of kyanite and rich in cordierite; (iii) an upper portion, consisting of sillimanite-bearing anatectic orthogneisses intruded by tourmaline- and/or andalusite-bearing leucogranites.

The main foliation dips from N-NE to the W. Meso- and micro-structural data support the occurrence of a several km-thick, ductile to ductile-brittle shear zone centred on the MCTZ, although an intense mylonitic deformation also occurs in the upper portion of the LHS and in the lower portion of the HHC. Deformation in the upper portion of the LHS produced phyllonites, mylonitic schists and mylonitic augen gneisses with strong flattening and stretching of the K-feldspar porphyroclasts. In the MCTZ, kinematic indicators show a consistent top-to-south sense of shear, related to the juxtaposition of the HHC over the LHS. The lower portion of the HHC shows evidences of pervasive ductile shearing (folding and meso-scale shear zones with top-to-south sense of movements). In the middle portion of the HHC, ductile high-strain is concentrated in discrete, top-to-south metric to decametric shear zones. In the whole area, two late phases of folding, characterized by roughly N-S and NE-SW trending axes, developed under low-grade metamorphic conditions. These folds are likely associated to the final exhumation stages and their geometrical interference is inferred to control the present day regional antiformal shape of the LHS beneath the HHC.

Magnetic susceptibility as a potential tool for geological differentiation of the Lesser Himalayan rocks in central Nepal

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Magnetic susceptibility (MS), one of the physical properties used in mineral and oil exploration, has been popular recently for rapid assessment of quality and quantity of material in land, water and air systems in natural media or even for assessment of pollution/contamination level, e.g., by heavy metals, due to anthropological activities. This has become possible due to portable MS-meters, which allow rapid differentiation of geological medium (rock formations and soils) at varying state of weathering and posing difficulty for accurate mapping in the natural outcrops.

Variation in MS has been measured in roadside rock outcrops in Central Nepal along the Kathmandu-Mugling-Jugedi and Mugling-Pokhara-Ramdighat-Kerabari routes. A pocket–sized MS meter (SM-30 by ZH Instruments, Czech Republic) was used to measure MS *in situ* on the smooth surfaces of rocks that belong to the formations mapped as Nawakot Complex, Kathmandu Complex, Sirkot Group, Kaligandaki Supergroup and Tansen Group in the inner and outer parts of the Nepalese Lesser Himalaya. Site mean MS data (averages of 15 readings at each site) reveal: (i) a wide range of (-0.003 to 5.1) x 10^{-3} SI; (ii) Lowest MS (<0.1 x 10^{-3} SI), for quartzite, quartzose sandstone, limestone, dolomite, which are predominantly composed of diamagnetic minerals (quartz, calcite and dolomite); (iii) Intermediate range of (0.1-1.0) x 10^{-3} SI for most shales, diamictites, slates, phyllites, sandstones, schists; and (iv) high values (1.0–5.1) x 10^{-3} SI for amphibolite schists, metasandstones, sandstones with volcanic detritus, hematite-rich sediments and trachytic volcanic rocks in increasing order. MS has good potential for fine-scale discrimination of formations characterized even by similar lithologies, composed of quartz or carbonate minerals, inability of whose objective identification has led to proliferation of formations, uncertainties in local and/or regional correlation and therefore confusions in their age assignment.

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Metabasites petrology and P-T evolution in the Lesser Himalaya, central Nepal

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Petrological study was carried out for the first time on the metabasites of the Lesser Himalaya in central Nepal. The metabasites are mostly tholeiitic basalts emplaced in the clastic sediments as supracrustal dikes and sills, and later metamorphosed together with the host rocks. They contain almost a constant mineral assemblage of Ca-amphiboles + plagioclase + biotite + quartz ± epidote ± chlorite + (Fe-Ti oxides). Amphiboles in the form of porphyroblast show chemical zonation with actinolite/magnesio-hornblende cores, tschermakite/ferro-tschermakite rims, and magnesio-hornblende margins. The cores of porphyroblasts are pre-kinematic and were probably formed prior to the Tertiary Himalayan orogeny. The porphyroblast rims and the matrix amphiboles are syn-kinematic and were formed during the Upper Main Central Thrust activity in the Tertiary. The compositions of both the porphyroblast rims and matrix amphiboles change from actinolite in the chlorite zone to magnesium-hornblende in the biotite zone and to tschermakite/ferro-tschermakite in the garnet zone. The systematic changes in amphibole compositions as well as petrographic characteristics of metabasites confirm the classical concept of increasing metamorphic grade structurally upwards towards the Upper Main Central Thrust in the Lesser Himalaya. Application of hornblende-plagioclase thermobarometry shows a coherent prograde P-T path in zoned amphiboles. The cores of amphibole porphyroblasts were formed at average peak temperature of ~540ºC and at pressure of ~3 kbar. The porphyroblast rims and matrix amphiboles were recrystallized at average peak temperatures of ~570ºC in the biotite zone and ~630ºC in the garnet zone at pressure of ~6 kbar. The metabasites petrology is in favor of the tectono-metamorphic models that relate the inverted metamorphism with thrusting along the Upper Main Central Thrust and coeval inversion of isotherms. It is suggested that published amphibole cooling ages from the Nepalese Lesser Himalaya based on simple, homogeneous mineralogy should be reinterpreted in view of the presence of polygenetic amphiboles with heterogeneous composition.

Petrology of granites in Siner areas, Siwana Ring Complex, northwestern Peninsular India

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The Neoproterozic Malani Igneous Suite (MIS) constitute the largest acid magmatism in the Indian subcontinent. It has been spreaded over an area of about 55,000 sq. km. in northwestern Peninsular India including at Nagar Parkar and Kirana areas of Pakistan. The rocks exposed in the Siner areas are the part of southwestern portion of Siwana Ring Complex (SRC) in Trans-Aravalli Block (TAB) of Rajasthan. SRC is the classical representative of MIS and displays important features viz. volcano-plutonic structure, anorogenic acid volcanism and has shown potentials for rare earth, rare metals and radioactive mineralization.

The rocks of SRC define bimodal, felsic dominant magmatism with characteristic ring dyke intrusions along the periphery of a collapse caldera. Based on detail geological mapping and field studies in Siner areas, the exposed rocks are grouped into three different phases. They are as follows: (1) Extrusive phase: basalt, trachyte, rhyolite. (2) Intrusive phase: gabbro, pink granite, pink porphyry granite, coarse grain grey granite, pegmatite. (3) Dyke phase: basalt, rhyolite and microgranite.

The Siner area consists mainly of acid plutonic rock with their volcanic equivalents. Contact between the intrusive and extrusive rocks is sharp. The Siner granite is massive, grey and pink colour, medium to coarse grained rock. It consists of megacryst of alkali feldspar (perthite + orthoclase) (hypersolvus) enclosed in a groundmass of alkali amphiboles (arfvedsonite and riebeckite), quartz, orthoclase including minor amounts of iron oxides. Siner granites show hypidiomorphic, granophyric and spheluritic textures (represented by arfvedsonite). Quartz is coarse grained, and shows anhedral shape, first order grey interference colour and wavy extinction. Perthite is coarse grained, subhedral and at places shows hydrothermal alterations viz. sericitization and kaolinization. Arfvedsonite is coarse grained, prismatic and greenish black colour. The Siner granite has an average modal mineral proportion (6 samples) of 35% quartz, 39% alkali feldspar, 24% alkali amphibole and 2% iron oxides (heamatite and magnetite). Modal data of Siner granites e fall in the alkali granite field of Quartz - Alkali feldspar-Plagioclase diagram (QAP) of Streckeisen (1973) and fall in alkaline and peralkine series of Lameyre and Bowden (1982). These present work exemplifies the features of anorogenic, A-type of magmatism in the Trans-Aravalli Block of northernwestern India.

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Second generation glaciers mapping and inventory of Nepal

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Rapid melting of glaciers resulting subsidence, shrink and retreat of glaciers in Nepal Himalaya is prominent in recent decades. The retreat rates of glaciers vary from basins and, in some instances, has doubled in recent years compared to early 1970s. Given these contexts, it is of utmost important to document the present status of glaciers to understand the dynamics of cryosphere and its impact. The use of remote sensing data and geographical information system are providing to be one of the most effective means of updating glaciers database.

The second generation glaciers mapping and inventory of Nepal are based on the semi-automatic mapping method using the landsat images of 2007 ± 2 years and SRTM DEM (Table 1). The Glacier ID is given as of GLIMS standard and the glacier attribute parameters like area, elevation, aspect, slope, thickness and Ice Reserve are derived automatically. The mapped glacier area covers about 4241 km^2, which is about 2.9% total land surface of Nepal. The number of glaciers in the inventory has increased but the total glacier area has been decreased drastically compared to 1970s.

Table 1: Second generation glacier inventory of Nepal

Basins		Glaciers		Elevation of Glaciers (m asl)		Ice Reserve (km^3)
Name	Area (Km^2)	Number	Area (km^2)	Highest	Lowest	
Koshi	21598	843	1180	8437	3977	120.15
Gandaki	26171	1339	1829	8093	3273	155.98
Karnali	36753	1461	1120	7515	3631	67.51
Mahakali	4741	167	112	6850	3695	7.13
	89263	3810	4241	8437	3273	350.77

Geochemistry and U-Pb ages of the Nardanda pegmatite of the Kathmandu Crystalline Nappe and Gulbhanjyang augen gneiss of the Gosainkund Crystalline Nappe, central Nepal Himalaya

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An E-W running Nardanda pegmatite (15 km long) belonging to the Kathmandu Crystalline Nappe (KCN) is exposed at the northern margin of the Kathmandu valley near the contact with the Gosainkund Crystalline Nappe (GCN), a southward extension of the Higher Himalayan Crystallines (Rai 1998). A coarse-grained augen gneiss from Gulbhanjyan area belonging to the GCN, about 6 km north of Kathmandu valley is well exposed in the central part of the nappe.

The pegmatite of the KCN is very coarse grained and consists of quartz, potash feldspar, plagioclase, tourmaline and muscovite with accessory kyanite, garnet and beryl. The augen gneiss of the GCN is composed of coarse-grained quartz, potash feldspar, plagioclase, biotite and muscovite with accessory apatite, zircon and opaque minerals. Fibrolite sillimanite and kyanite are locally present. Chemically the Nardanda pegmatite is aluminous, quartz rich, leucocratic and potassic, and the Gulbhanjyang augen gneiss has similar signatures with mesocratic appearance. The gneiss is probably ancient stock of granitic vein.

The monazite and xenotime from the Nardanda pegmatite of the Kathmandu Crystalline Nappe (KCN) and zircon from the Gulbhanjyang augen gneisses were dated by U-Pb method at the Laboratory of NERC, Isotope Geosciences Centre, UK. Monazite and zenotime from the pegmatite show Miocene ages (25±1 Ma) (Rai 2001). These ages correspond to the crystallization age of the pegmatite. These ages appear to be slightly older than those of the leucogranites of the Higher Himalaya (24 to 17.2 Ma; Daniel et al. 1987) situated 60 km to the north of the study area. An Early-Ordovician (486±9 Ma) U-Pb age is obtained on zircon from the Gulbhanjyang augen gneiss (Rai 2001). This U-Pb age is very close to the ages obtained from the augen gneiss of the Higher Himalayan Crystallines in the root zone (Rb-Sr whole age of 513±30 Ma; Le Fort et al. 1986). These two augen gneisses may be considered as the contemporaneous magmatic events during Ordovician.

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Sedimentology, microfacies analysis and diagenesis of the Lower Eocene the Sakesar Limestone, central Salt Range, Pakistan

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The sedimentology and the foraminiferal biostrtigraphic studies of the Early Eocene Sakesar Limestone have been undertaken from of Khajula, Tatral, Badshah Pur and Karuli areas, Central Salt Range, Pakistan. A total of 65 thin sections have been studied for detailed microfacies and micropalaeontological analysis. The Sakesar Limestone is extremely rich in benthic larger foraminifera, the important genera are Nummulites, Assilina, Alveolina and Lockhartia. The red and green algae are also present in it. Based on the field observations, five types of the lithologic variations recorded in the Sakesar Limestone from bottom to top; limestone interbedded with very thin shale, limestone interbedded with marl, nodular limestone, massive bedded nodular limestone and massive bedded cherty limestone. The prominent microfacies observed in the Sakesar Limestone are mudstone, wackestone, wackestone to packstone and packstone. The diagenetic features represents freshwater (meteoric), marine and burial environments setting of the Sakesar Limestone. The prominent diagenetic features are stylolisation, calcitisation, nodularity, dissolution and fracturing. The presents study also diagenetic process which creates the secondary porosity in the formation. Overall the on the basis of larger benthic foraminifera and detailed microfacies analysis the depositional environment of the Sakesar Limestone is inner neritic.

Use of remote sensing and GIS tool in glacial lake mapping and monitoring of Nepal Himalayas

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Glaciers and glacial lakes are sources of fresh water as well as potential threats to downstream communities. In the past, many glacial lakes had been formed, enlarged and some of them burst out in Nepal claiming many lives and properties. Thus mapping and regular monitoring of glacial lake has become essential for mitigation of GLOF (Glacial Lake Outburst Flood) risk. Little information is available on the growth and potential threats from glacial lakes in the Himalayas. Due to remoteness, difficult terrains, wide geographical coverage, use of remote sensing data and GIS tool is applied for the mapping and monitoring of glacial lakes in the Nepal Himalaya.

Multispectral with medium spatial resolution remote sensing data of Landsat TM and ETM+ satellite images of narrow temporal range were used for the mapping of glacial lakes. Prior to the present mapping, data of different dates and sources were used which include maps, aerial photographs and satellite images. Different image processing techniques were used to delineate glacial lakes. One of the main techniques used is Normalized Difference Water Index. It highlights water bodies from other land cover features which facilitate for mapping of glacial lakes. Shuttle Radar Transmission Mission Digital Elevation Model (SRTM DEM) was used to extract elevation and orientation information. High spatial resolution multispectral images (such as ALOS AVNIR 2 PRISM, Quickbird, IKNOS 2) and microwave data of Terra SAR X and ASAR radar images were also used to see the growth trends of some of the prioritized lakes. Google Earth has also been used for better visualization of snow covers and shadow parts of lakes. Considering the unusually challenging accessibility of the Higher Himalayas of Nepal, application of remote sensing technique has proved to be inevitable for glacial lakes mapping and their monitoring for GLOF risk management.

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Basic rocks of Manipur ophiolite in the Indo-Myanmar Hill Ranges, NE India and the petrotectonic significance

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The basic rocks of the Manipur Ophiolite Mélange Zone generally occur as sporadic dykes (in ultramafics and pelagic sediments), sills (particularly in chert and cherty shale) and pillow lavas. These rocks are also found as exotic blocks floating on pelagic shale. The dykes are generally 5–8 meters thick while the sills range approximately between 1 and 8 meters thickness. These basic rocks constitute much less than 10% of the ophiolite sequence. Mineralogy and mineral chemistry of the main phases of the basic rocks indicate that they have undergone incipient thermal metamorphism of greenschist facies under hydrostatic stress conditions leading to the formation of spilites. Since hydrothermal circulation doesn't extend beyond 2–3 km depth, gabbroic rocks usually do not become spilites. As no coarse-grained basic rocks have been encountered so far and any basic rock having calcic plagioclase unaltered to albite and epidote could be explored, the Manipur Ophiolite is either devoid of or extremely rare of ideal gabbros. As the dyke and sill rocks are uralitised and the ultramafics have dykes within, diapirism of Manipur Ophiolite must have emerged out almost to the surface; and, therefore, the oceanic crust must have been very thin.

The basic rocks of the Manipur Ophiolite show alkali basalt lineage and at the same time, even if contaminated by chert, some samples could still have normative nepheline as high as about 15%. From the Harker-type variation diagrams and other major oxides data, it is found that the basaltic rocks have not experienced considerable fractional crystallization and subsequent operation of crystal-liquid separation. Therefore, no large magma chamber must have been formed and hence, the Manipur Ophiolite must have been developed in a slow spreading center. Considering the normative olivine percentages of the basic rocks and fitting other relevant data in the experimentally determined partial melting characteristics of enriched lherzolite source, the P-T conditions of magma generation is found to be 8–18 Kbar and 1185–1400^{0}C. Hence, the melts could have been generated at depths of about 25–50 km.

Concentrations of trace elements like Cr, Co, Zr, Ba, Sr. and low Mg/(Mg + Fe^{+2}) imply that the melts must have derived from metasomatised mantle rocks. The plot of Ce versus Nd of samples of basic rocks against predetermined standards generally reveals partial melting range of approximately within 3-20 %. When compared the trace element and REE variations of the basic rocks of the Manipur Ophiolite for signature of contamination, with those of upper continental crustal rocks, lower continental crustal rocks and MORB with 15% contamination by upper crustal rocks, it is found that the melts of the basic rocks of the Manipur Ophiolite must have been contaminated by upper continental crustal rocks. Considering the field setting, mineralogy, mineral chemistry of the essential phases, bulk rock geochemistry in terms of major and minor element oxides and trace and REE's, it could arrive at a conclusion that the melts of basaltic rocks of the Manipur Ophiolite were derived from differential partial melting of enriched upper mantle continental rocks at a slow spreading tectonic regime similar to that of the passive rifting of continental margin, where no considerable magma chamber has been formed leading to the absence or rare occurrence of ideal gabbroic rocks.

Geology of the Lesser Himalaya along the Gorkha-Narayangarh section, central Nepal

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Geological mapping, structural analysis and petrographic study were carried out along the Grokha-Narayangarh section of the Lesser Himalaya in central Nepal. The area is comprised of the Kuncha Formation, Fagfog Quartzite, Dandagaon Phyllite, Nourpul Formation, Dhading Dolomite, Benighat Slate and the Robang Formation of the Nawakot Complex. There is an unconformity between Dhading Dolomite and the Robang Formation and the Malekhu Limestone is missing in the area. The Nourpul Formation is clearly divisible into at least three members, i.e., the Purebesi Quartzite, Amdanda Phyllite and the Bhut Khola Dolomite.

The area lies in the western closure of the Jalbire synclinorium and is characterized by a complex thrusting and folding. The Seti Thrust is one of the major thrusts passing through the area. Folds are generally tight and overturned. Preliminary petrographic study shows that the area can be divided into three metamorphic zones, i.e., chlorite zone, biotite zone and the garnet zone from south to north, respectively. Biotite isograd lies at far southern part (Anbu Khaireni) than previously reported.

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Geology of the Trishuli Valley from Betrawati to Rasuwagadhi, central Nepal

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Geological mapping, structural analysis and petrographic study were carried out along the Trishuli Valley from Betrawati to Rasuwagadhi, central Nepal. The area is covered by the rocks of the Lesser Himalaya to the south and the Higher Himalaya to the north of Syaphrubensi, respectively. The Lesser Himalaya is divided into the Kunchha Formation (including Mailun and Thanjet augen gneiss), Ronga Carbonates (siliceous marble, calc-schist, graphitic schist and white marble), Brabal Schist, Syabrubensi Gneiss, Wangal Quartzite, Syaphru Gneiss and Schist and the Phenglung Khola Quartzite. The Higher Himalaya is divided into the Gosaikunda Gneiss, Rasuwagadhi Migmatite and Sillimanite Gneiss with Quartzite.

The Lesser Himalaya forms a huge anticlinorium (Gorkha-Kunchha anticlinorium) with its axial zone passing from Ramche-Mulkharka area. The southern limb in the Betrawati-Kalikastan area is relatively less deformed. However, the northern limb in the Dhunche-Syaphrubensi area is extremely deformed forming tight folds, S-C fabric, stretching lineation etc. probably due to the movement of the Higher Himalayan Thrust sheet over the Lesser Himalayan footwall along the Main Central Thrust (MCT). Stretching lineation are usually oriented NNE to SSW and the S-C fabric show top-to-the south sense of shearing. Although Macfarlane et al. (1992) has shown fault boundaries between different lithostratigraphic units of the Lesser Himalaya in the area, it is difficult to find structural evidence of faulting. However, a brittle shear zone passes through the Syaphrubensi hot spring. This shear zone is about 10-20 cm thick and cross-cuts foliation. Therefore, it must post-date the ductile deformation event in the area. The MCT discordantly covers almost all lithostratigraphic units of the Lesser Himalaya in the area supporting the view that it is a sharp structural boundary. The Gosaikunda Gneiss is overlain by migmatites in the Rasuwagadhi area whereas the same unit is overlain by sillimanite bearing quartzite and gneiss. Therefore, a tectonic boundary (Langtang Thrust) has been inferred between the Gosaikunda Gneiss and the Sillimanite quartzite as suggested by Kohn et al. (2005).

The area south of Betrawati lies in the chlorite zone. Biotite starts from Betrawati and garnet is observed from Mugu. The Lesser Himalaya in the Syabrubensi area lies in the garnet zone. Kyanite is observed at Timure, Khangjim, Bhanjyang Gau and Thulo Syabru. Sillimanite is observed around Langtang Village.

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Effusive activity at the Nevado de Toluca volcano area, central Mexico

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Nevado de Toluca (NT; 19°06'30''N, 99°45'30''W; 4680 m asl) located in central Mexico, is a subduction related stratovolcano that has recorded volcanic activity since 2.6 Ma. The last 50 ka of activity has involved dacitic explosive eruptions, nevertheless the older history of the volcano, specially the effusive activity (lava flows and domes), is poorly understood.

Fifty five lava structures were identified by photogeological observations and field mapping in the area (1290 km^2); lava domes are the most common volcanic features (0.25 domes/km^2) and can be observed inside and outside of the crater, like "Cerro Chalotepec" (7 km SW from crater, 3800 m asl and 1.32 km^3). $^{40}Ar/^{39}Ar$ ages obtained for these volcanic structures combined with field, geochemical and petrological data indicate the presence of twelve stratigraphically ordered lava groups: 1) old olivine andesites (60 wt. % SiO_2); 2) amphibole dacites (63-65 wt. % SiO_2) of 2.6 Ma; 3) clinopyroxene andesites (60 wt. % SiO_2) of 1.4 Ma; 4) amphibole-clinopyroxene dacites (64-65 wt. % SiO_2) of 1.4 Ma; 5) biotite dacites (63-64 wt. % SiO_2) of 1.1 Ma; 6) biotite-clinopyroxene-quartz dacites (65 wt. % SiO_2) of 1 Ma; 7) amphibole dacites (63 wt. % SiO_2); 8) clinopyroxene dacites (64-66 wt. % SiO_2); 9) biotite dacites of ~970 ka; 10) andesites of ~250 ka; 11) orthopyroxene basaltic andesites (54-56 wt. % SiO_2) of ~140 ka; and 12) dacites (64-66 wt. % SiO_2) of <50 ka from the crater.

Whole-rock major elements composition patterns and isotopic compositions ($^{87}Sr/^{86}Sr$: 0.703760-0.704330, ε_{Nd}: +2.82 ±5.36, $^{206}Pb/^{204}Pb$: 18.56-18.67, $^{207}Pb/^{204}Pb$: 15.55-15.59, $^{208}Pb/^{204}Pb$: 38.21-28.42) suggest that there's a crystal fractionation mechanism mainly acting but also crustal assimilation of an intrusive body ($^{87}Sr/^{86}Sr$: 0.707802, ε_{Nd}: -2.13, $^{206}Pb/^{204}Pb$: 18.85, $^{207}Pb/^{204}Pb$: 15.64, $^{208}Pb/^{204}Pb$: 38.7) in the Nevado de Toluca magmatic system.

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Facies analysis and depositional setting of the Jurassic Samana Suk Limestone, Kala Chitta Range, Lesser Himalayas, Pakistan

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The Kala Chitta Range forms the northern border of the hydrocarbon bearing Potwar Basin of the Lesser Himalayas in Pakistan. Detailed sedimentological studies of the Jurassic Samana Suk Limeston from Surg and Chapra in the Kala Chitta Range have been carried out. The Samana Suk Limestone is characterized in the field as well-bedded oyster bearing, micritic, shelly limestone with gastropods and pelecypods, sandy as well as oolitic. The study has documented the details of facies pattern and their implication for platform architecture and evolution through time. The most diagnostic lithofacies including carbonate mudstone, skeletal wackestone, packstone and grainstone were identified. Bioclasts primarily belong to gastropods and bivalves (pelecypods). Non-skeletal oolitic and peloida grainstones were also identified. Lithofacies are arranged in meter-scale upward shoaling cycles that tend to be laterally discontinuous and are interpreted as mainly autogenic. Each cycle is culminated by a hard ground surface at the top which is represented by burrowed, phosphatized and iron stained. Evidences of both marine and meteoric phreatic diagenesis have been observed. The rocks are dolomitized and dedolomitized. Microscopic and ultra-microscopic examination of dolomite crystals has shown compositional zoning, representing changes in pore-water chemistry. Detailed field observations, microfacies and diagenetic analyses of the Samana Suk Limestone are indicative of carbonate platform deposition.

Lithostratigraphy and facies analysis of the Siwalik Group, Karnali River section, far-western Nepal Himalaya

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The Siwalik Group lying in the southern flank of the Himalaya has been considered to be the ancient Gangetic plain deposits. This study analyses the fluvial succession of a large river system at the time of deposition of the Siwalik Group, which is expected to be one of good recorders of the regional changes in climate and tectonics. The 6-km thick Karnali River section, where the Paleo-Karnali River is expected to have been flowing, is the target of the present study regarding stratigraphy and facies of the succession to disclose new findings.

The stratigraphy of the Karnali River section is proposed as follows: Chisapani Formation (equivalent to the Lower Siwaliks, 2045 m), Baka Formation (equivalent to the Middle Siwaliks, 2740 m), Kuine and Panikhola Gaun Formations (equivalent to Upper Siwaliks, 1500 m) in an ascending order. The Chisapani Formation is composed of interbedded red mudstones and fine- to medium-grained sandstones. The Baka Formation is composed of medium- to coarse grained-pebbly sandstones interbedded with greenish grey mudstones. The Kuine Formation consists of clast supported, imbricated, pebbles to cobbles conglomerates and Panikhola Gaun Formation consists of thick matrix supported, pebble, cobble to boulder conglomerates. Facies analysis resulted that the Karnali River section recorded the change of fluvial channel style from fine-grained meandering rivers to sandy braided rivers following gravelly braided rivers. Debris flow deposits predominate at the top of the succession.

The order of the appearance in fluvial facies is similar to that of other Siwalik successions. The timing of the changes in fluvial style at the Karnali River and at the Tinau Khola sections, where the Paleo-Kaligandaki River is expected to have been present, nearer with each other, implying that the regional changes in climate or tectonics might have affected simultaneously on the large fluvial systems along the southern flank of the Nepal Himalaya.

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Flow stratigraphy of a part of Mandu region, Dhar District, Madhya Pradesh, India

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The main aim of the present study is to establish the flow stratigraphy of Mandu region, Dhar district, Madhya Pradesh, India. The area of investigation lies towards the western edge of the Malwa Plateau forming about 470 m. thick horizontal sequence of lava flows covering an area of about 200 sq. km. between Mogarba (Lat. $22^o20'$-$22^o25'$, Long. $75^o 18'$-$75^o23'$) and Lunera (Lat. $22^o 25'$-$22^o30'$; Long.$75^o 22'$-$75^o 30'$) areas.

Four well defined formations exposing 21 lava flows have been identified, which includes "B" (oldest), "C", "D" and "E" (youngest) formations. These stratigraphic divisions are mainly based on distinct field characters, phenocrystic assemblages, major physiographic breaks and significant shift or break in elemental abundance and ratios of various elements.

Early Neogene origin of the Himalayas: some proxies from northern Indian Ocean studies

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Collision tectonics, Trans-Himalaya's geological formations and convergence of Indian and Eurasian plates through time have been investigated to understand the temporal evolution of the Himalaya and Tibetan Plateau. Recent studies of the Central Indian Ocean Basin (CIOB) crust/lithosphere periodic deformations are related to the Himalayan tectonics. Seafloor spreading and turbidites sedimentation of the northern Indian Ocean have revealed noteworthy and interesting variations which appear to be related to the Himalayas Orogeny. Several proxy evidences are also noted from the Tibetan Plateau, Himalayan mountain ranges (young granitoids) and Indian Ocean studies. They shall help to constrain temporal evolution of the mountain ranges and are presented. The crustal processes: pause in Seafloor spreading of the north-eastern Indian Ocean during 42 Ma and 30 Ma, seismic sequence stratigraphy and late Oligocene/mid-Miocene turbidite sediments of the eastern Arabian Sea and Bay of Bengal and early Oligocene- Miocene quiescence in subsidence of sedimentary basins of western continental margin of India are the anomalous and intrinsic observations in this regard. They most likely occurred during the pause in subduction as result of the Island Arcs getting locked in the subduction process and resultant up-rise of the Himalayas. We propose the imprints reflects the plate end tectonics events - the Paleo-Tethyes Oceanic system consisting of continental margin, oceanic crust, mid-plate volcanic island arc and back-arc basin closure occurred on the plate's collision. Based on the observations and several other published results from the Tibtan Plateau and Himalayan ranges it is possible to infer early (~ 30 Ma) formations of the mountain ranges. Therefore, demise of the Tethys Oceanic system and the north Indian Ocean crustal processes are intimately related and contemporaneous and lead to suggest early Neogene formation of the mountain ranges. The noteworthy proxy indicators shall help to constrain temporal evolution of the mountain ranges which have broader implications in understanding the geodynamics of the region and related aspects.

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Re-assessment of the stratigraphic subdivision of the Nawakot Complex by Stöcklin (1980) in the Gorkha-Narayangarh section, central Nepal

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There are many conflicting views, irreconcilable disagreements and endless controversies regarding the stratigrpahy of the Lesser Himalaya in Nepal. Stratigraphic classification of the Nawakot Complex in the Kathmandu area by Stöcklin (1980) is one of the best and widely accepted classifications till the date. The area mapped by Stöcklin (1980) in the Gorkha-Narayangarh section was re-assessed in the present study. The study shows several discrepancies in the stratigraphic classification of Stöcklin (1980). They are:

(i) Banspani Quartzite is not the oldest unit of the Kunchha Formation. This is the westward extension of the Purebensi Quartzite.

(ii) Labdi Phyllite Member of the Kunchha Formation is actually the Dandagaon Phyllite.

(iii) Anpu Quartzite is the westward extension of the Fagfog Quartzite,

(iv) Kunchha Formation is not "entirely non-calcareous" as noted by Stöcklin (1980).

(v) The Nourpul Formation is clearly divisible into three members (possibly three separate formations): Lower quartzite member (Purebensi Quartzite), middle phyllite member (Amdanda Phyllite) and upper carbonate member (Bhut Khola Dolomite).

(vi) The Benighat Slate is actually dominated by quartzite and phyllite. Slate is in subsidiary amount. Therefore, the name Benighat Slate is not appropriate for this formation.

(vii) Basic rocks (amphibolites) are not confined to only a certain formation but they are distributed throughout the Nawakot Complex.

(viii) Benighat Slate and Malekhu Limestone are missing in the southern belt indicating a prominent unconformity between the Lower and the Upper Nawakot Complexes.

(ix) A monotonous and thick black carbonaceous phyllite unit lies above the Robang Formation. It indicates that the Robang Formation is not the youngest unit of the Nawakot Complex.

These discripensies clearly point to the need of re-interpretation of the stratigraphy of the Nawakot Complex in central Nepal.

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Lower Carboniferous biostratigraphy, paleoecology and paleogeography of Balast Section, north Damghan, east Alborz-Iran

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A Balast stratigraphical section was studied at the north Damghan. The section is composed by limestone alternated with shale of Tournaisian and Visean in age. Up to 20 species of corals belong to 11 genera, have been distinguished. The following species are: *Sychnoelasma* sp., *Caninia cornocopiae*, *Caninia lonsdaleiforme*, *Caninia* sp., *Pseudozaphrentoides* sp. ?, *Siphonophyllia iranica*, *Siphonophyllia* cf. *dorlodoti*, *Siphonophyllia cylindrica cylindrical*, *Siphonophyllia* cf. *samsonensis*, *Heterocaninia sp.*, *Dibunophyllum bipartitum*, *Arachnolasma* sp. A, *Kueichouphyllum alborzense minor*, *Kueichouphyllum crassiseptum*, *Kueichouphyllum lalunense*, *Tehranophyllum* sp. A, *Tehranophyllum* sp. B, *Tehranophyllum* sp. C, *Michelinia megastoma, Syringopora* sp.

Stratigraphical section of north Damghan shows regressive sequence from Tournaisian to Lower Visean. Three main environments containing rugosa and tabulate corals were identified: open shelf to oolitic shoals. According to morphology of corals, 3 ecological assemblages were distinguished. First assemblage is composed of solitary, undissepimented rugosa corals. It consists of Cyathaxonia fauna corresponding to Lower Tournaisian. Second assemblage of Upper Tournaisian is composed of solitary dissepimented rugosa corals of median to large sizes. This assemblage occurs at shallow areas of the open shelf. Third assemblage is composed of solitary and dissepimented rugosa corals of big size and occurs at massive oolitic limestones of upper part of section corresponding to shoal areas of Lower Visean in age. Lower Carboniferous corals of Balast stratigraphical section have been compared with Lower Carboniferous corals of another part of Iran. Iranian Lower Carboniferous corals belong to shallow areas of open shelf of unique oceans.

Middle to Late Miocene vegetation and climate from the Siwalik succession, Karnali River section of the Nepal Himalaya

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The Middle Miocene–Early Pleistocene sediments of the Siwalik Group along the southern margin of the Himalayan mountain belt host an excellent archive to study the palaeoclimate developed after Indian-Tibetan continent collision. Altogether 234 mudstone/siltstone samples collected from the Miocene part (~ 16 to 5.2 Ma) of the molasse sequence belonging to Siwalik Group of the Karnali River section (thickness 3560 m) west Nepal were studied for palynological assemblages. The palynological assemblage from Siwalik deposit contain more than 60 taxa which comprises Gymnosperms (*Abies, Pinus, Picea, Podocarpus, Tsuga* and Cupressaceae), Angiosperms (*Quercus, Castanopsis, Carpinus, Myrica, Betula, Juglans, Alnus, Ulmus* , *Artemisia* , Ericaceae , Palmae, Chenopodiaceae , Compositae and Poaceae), Pteridophytes (Polypodiaceae, Pteridaceae, Lycopodiaceae, Sellaginella, *Ceratopteris*), algal cysts (Zygospores of Zygnema, Inapertisporites), fungal remains and abundant charcoal particles. The pollen diagram of this section shows three distinct pollen zones. The pollen zone-I at the lower part (~16 to 12.5 Ma) is mainly dominated by Pteridophyte sporomorphs such as Polypodiaceae, Pteridaceae and *Ceratopteris*. The Gymnosperms in this zone is represented by *Pinus* and *Podocarpus*. In the basal part of this zone Palmae pollen attain their significant presence indicating warm, humid and tropical to subtropical climatic condition. This climate condition at this geological time is also evidenced by high percentages of *Ceratopteris* sporomorphs. The pollen zone-II (12.5-8.5 Ma) is represented by immergence of some other Gymnosperms *Tsuga, Podocarpus, Picea* and *Abies*. Angiosperms such as *Quercus, Betula, Myrica*, Compositae and Poaceae start to appear indicating subtropical to temperate climatic condition. The Pteridophytes especially Polypodiaceae and *Ceratopteris* are still dominant in this zone. The pollen zone-III (8.5-5.2 Ma) shows significant change of vegetation to warm temperate type with increase of Gymnosperms such as *Abies, Picea, Tsuga* and Cupressaceae. There is also increase in percentage of *Quercus, Castanopsis, Betula, Myrica, Juglans, Carpinus*, Ericaceae, Poaceae and Compositae. The subtropical elements such as *Podocarpus* and *Ceratospteris* disappeared. The increase in quantity as well as diversification of vegetation in this zone indicates increase in precipitation. In the time span of approximately 11 Ma (~16- 5.2 Ma) the southern slope of the Himalaya had experienced tropical-subtropical to warm temperate climate system with an increase rate of precipitation at about 12 Ma.

Stratigraphy, depositional environment and provenance of Xaltipa Formation in the Huayacocotla Anticlinorium, east central Mexico

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The Xaltipa Formation is exposed in the central part of the Sierra Madre Oriental fold-thrust belt in Mexico. This unit covers unconformably Jurassic sedimentary rocks of Huayacocotla Formation and the Proterozoic basement named Huiznopala Gneiss; and changes transitionally up section to Tithonian calcareous rocks of the San Andres Formation. The Xaltipa Formation comprises mostly: medium to coarse-grained, low-angle cross-bedded sandstones, interbedded with lens-shaped conglomerate strata, conglomerates with inverse grading, laminated siltstone, fine grained sandstones and breccias form the upper part of the column. Thickness is highly variable (100-1,500 m) in different localities. We measured two detailed stratigraphic columns and recorded sedimentary structures, composition and textures in order to propose a facies classification. Based on field information, we recognized nine sedimentary facies: matrix-supported massive gravel (Gmm), clast-supported gravel (Gci), clast-supported massive gravel (Gcm), clast-supported crudely bedded gravel (Gh), stratified gravel (Gp), massive sand (Sm), cross-bedded sand (Sp), laminated sand (Sh), laminated silt (Fl) (Miall 2006). Those were grouped in five facies associations: channels, gravel bars, laminated sandstones, gravel strata and sediment gravity flows and are interpreted as alluvial fan deposits, dominated by a fluvial braided system and debris flows. The textures and structures suggest deposition in a transitional zone, from medium to proximal alluvial deposits. Clast composition of the conglomerates, descriptions and their modal analysis indicate at least four different sources for the rocks: 1) Quartz-rich sandstones from Huayacocotla Formation; 2) local metamorphic basement (Huiznopala Gneiss); 3) Andesites from the Paleozoic Tuzancoa Formation and 4) a non-identified source of granite. According to the modal analysis of sandstones plotted in Dickinson ternary diagrams, the sandstones fall mostly in the recycled orogen field. Thus, the Xaltipa Formation recorded extensional tectonics in the Late Jurassic time for the eastern part of Mexico, probably related to the opening of the Gulf of Mexico.

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Sedimentology and sequence stratigraphy of the Miocene succession in the Surma Basin, Northeastern Bangladesh

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The Surma Basin in northeastern Bangladesh, a tectonically active province located in the northeastern part of Indian subcontinent, comprises Miocene siliciclastic sedimentary succession that crops out along the Hari River section. Based on detailed field study, three facies associations (FA1, FA2 and FA3) were distinguished in the upper part of the Bhuban, the Boka Bil, the Tipam and the Girujan formations. These facies associations representing distinct depositional environments are tide dominated (FA1), shelf (FA2) and submarine slope-channel environments (FA3). The facies association FA1 is divided into three facies: Facies A, B and C representing to have accumulated in tidal, overbank and distal part of the overbank deposits, respectively. The facies association FA2 is composed of facies SL1 and SL2 which are interpreted as the deposits of inner and outer shelves environments. The Bhuban and the Boka Bil formations comprise an overall deepening upward facies succession suggestive of highstand of relative sea level. The facies association FA3 is subdivided into three facies: Facies F1, F2 and F3 representing the channel fill, marginal channel and abundant channel deposits, respectively. Facies F1 characteristically depicts sand-dominated interval interpreted to have accumulated by gravity flow while alternation of sandstone and mudstone (F2) developed due to depletion of gravity flow in the marginal part of the channel. The mudstone dominate interval (F3) tends to develop by cessation of sediment gravity and is experienced by slope instabilities. Comparatively coarse grained sediments of the Tipam and the Girujan formations unconformably overlie the fining upward successions of the Boka Bil Formation; therefore, comprise mainly lowstand of relative sea level. However, the study area shows retrogradational stacking pattern produced during falling of sea level.

Early Jurassic position of the Lhasa Block indicated by palaeo-biogeographical distribution of Lithiotis bivalves

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Paleogeographical position of the Lhasa Block during Mesozoic times is still matter of discussion. Its Late Paleozoic (Carboniferous-Permian) and Triassic south Pangean (peri-Gondwanan) affinities on the southern margin of the Paleotethys are indicated both by paleomagnetic and facies studies. Separation of the Cimmerian Continent [Iran (Alborz)-Qiangtang-Malaysia-Sibumasu] from this part of Pangea during latest Carboniferous–earliest Permian times by rifting and drifting event originated Neothethyan Ocean and therefore, the Lhasa Block belonged to the southern margin of this new ocean. Northwards migration of the Cimmerian Continent took place during Permian-Triassic times causing wide opening of the Neotethys and closing of the Paleotethys Ocean. The Late Triassic Indosinian Orogeny has been one of the most spectacular geotectonic event reflect collision of this continent (mainly Sibumasu part) with Indochina block. The new break-up of southern Pangea and especially separation of the Lhasa Block from Gondwana is enigmatic but most probably took place during earliest Jurassic times and that's why this terrane started quick shift northward. The world-wide distribution of Pliensbachian-Early Toarcian large bivalves of the so-called *Lithiotis*-facies (dominated by *Lithiotis*, *Cochlearites*, *Litioperna* genus) indicates very rapid expansion of such type of bivalves. Himalayan (Garzanti and Frette 1991) and Tibetan (Nyalam area–Yin and Wan 1998, Jadoul et al. 1998) occurrences of *Lithiotis* and/or *Cochlearites* bivalves could help to reconstruct of Early Jurassic position of the Lhasa Block. Occurrence of *Lithiotis*-type bivalves from westernmost Asia/Arabia (eastern Turkey, Iran, Iraq, Kuwait, Oman) to central Asia in this time suggested migration path from western Tethys trough Panthalassa Ocean up to western margin of North and South America (USA, Peru). These bivalves during larval-stage episodes could use the numerous terranes within Panthalassa Ocean as '*stepping-stones*' allowing free migration eastward from the Alpine Tethyan Ocean to Himalayan/Tibetan one.

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The significance of Cretaceous gastropods abundance in San Juan Raya, Southern Mexico

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The San Juan Raya region is a Lower Cretaceous fossiliferous locality in the southeast of Puebla State, Mexico. It is an important zone for the abundance and variety of fossil fauna, mainly gastropods, pelecypods and corals. Gastropods are the dominant group and the most representative species are the genus *Cerithium*, *Pyrazus* and *Craginia.*

The fossils are found in the San Juan Raya Formation of Aptian age. This unit consists of gray and greenish-gray shale, erratic purple-gray shale and calcareous shale, gray and greenish-gray sandstone and calcareous sandstone of fine to medium grain size. The alternation of shales and calcareous sandstones suggests that the deposition occurred in coastal environmental conditions, near the shoreline covered by shallow and calm water in a lagoon environment. The presence of rudist and coral suggest that the water had a tempered temperature.

Modern marine carbonate sediments accumulate where carbonate producing organisms are abundant and siliciclastic input is low. Such accumulations occur today in two main environments: 1) warm, low-nutrient carbonates (WLN), and 2) cool, hight-nutrient carbonates (CHN). There are few carbonates from warm, high-nutrient carbonates (WHN) environment because these conditions are very rare (Allmon 2007). The WHN depositional environments might have been widespread during the Cretaceous and Paleogene because in these times, the nutrient-rich waters were warmer than they are today; the Cretaceous nutrients fluxes could have been produced by the combination of volcanism, terrestrial runoff and upwelling. Today the accumulations of marine gastropods occur mainly in CHN conditions, they were common in both carbonate and siliciclastic facies in the Cretaceous and Paleogene but occur in the Neogene only in siliciclastic sediments.

Gastropod abundances in the San Juan Raya Formation were founded in siliciclastic rocks from the Early Cretaceous, due to a greenhouse effect the abundant nutrient attributed to the region is the near rift zone.

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Significance of trace fossils from Barail Group of sediments, Manipur, India

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Trace fossils of the Barail Group of sediments (Late Eocene-Early Oligocene, transitional flysch sediments) along the western foothills of Manipur are described and their palaeoenvironmental and sequence stratigraphic interpretations are discussed. The ichnofauna shows a moderately high diversity numbering twenty three ichnospecies namely *Acanthorhaphe* sp., *Arenicolites* sp., *Aulichnites* sp., *Chondrites* sp., *Diplichnites* sp., *Diplocraterion* sp., *Furculosus* sp., *Gordia marina*, *Helminthoidea* sp., *Helminthopsis teneus*, *Lockeae* sp. *Podichnus* sp., *Palaeodictyon strozzi*, *Phycodes palmatus*, *Planolites beverleyensis*, *Ophiomorpha nodusa*, *Rhizocorallium jenense*, *Skolithos linearis*, *Skolithos verticalis*, *Taenidium serpentinum*, *Taphrhelminthopsis* sp., *Thalassinoides paradoxicus*, and *Urohelminthoidea* sp. Following Seilacher's (1967) archetypic classification the trace fossils belong to the *Skolithos*, *Cruziana* and *Nereites* ichnofacies. Based on the ichnological and sedimentological data it is observed that the depositional basin of the Late Eocene-Early Oligocene flysch transition sediments is upper foreshore to distal lower shoreface in a moderate to high storm dominated setting with corresponding high and low oxygenation conditions. Studied succession are found to have been deposited during the development of a trangressive system tract (TST) consisting of retrogradational stacking patterns of parasequences. Non-uniformity in the periodicity of parasequences comprising of relatively thick and thin parasequence sets reveals fluctuation in relative sea level changes.

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Stratigraphic analysis of the Jurassic sequence of the region Tecocoyunca, Tecomatlán Puebla

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Mexico is one of the most complex countries in terms of its geological origin due to particular characters created by the activity of Coco's plate. Tecocoyunca-Tecomatlán is located in the southwestern part of the state of Puebla, Mexico The project is focused mainly on the study of Jurassic sedimentary sequence outcropping in the southwest of Mexico, which is key to explore geology, stratigraphy, structure, paleogeography, geological evolution and thus builds a geological model that allows us to understand the geological history of the area.

The geological setting of the region is represented by sedimentary, igneous and metamorphic rocks, varing in age and percentage of occurrence. The sedimentary sequence belongs to the Jurassic period with a range of ages from Bajocian to Oxfordian, it is represented by conglomerates, sandstones, iron nodules, siltstones, horizons of coal, shales, limestones and breccias, the surfaced sequence in the area of study is an alternation of sandstones and conglomerates.

In the region of Tecocoyunca-Tecomatlán, there are some sedimentary sequences exposed with the presence of fossils containing of a variety of ammonites and pelecypods that were used to determine the age of the formations in the area. The structure geology is represented by normal faults, northwest-southeast left-lateral, segregations of quartz and fracture provoking some tilting. A fluvial sedimentary environment has been deduced with the lithology, paleogeography and geological structures observed in the area, probably generated by marine transgressive process from Pacific Ocean towards to northeast of Mexico.

Microfacies analysis and palaeoenvironmental interpretation of the Early Eocene Chor Gali Formation, central Salt Range, Pakistan

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The Early Eocene succession well exposed in the central Salt Range consists of the Nammal Formation, the Sakesar Limestone and the Chor Gali Formation. The present work is focussed on detailed microfacies analysis and biostratigrapy of the Chor Gali Formation in the central Salt Range. The Chor Gali Formation forms an important hydrocarbon producing horizon in the northern part of the Potwar Basin. The thickness of the formation varies from 20 to 30 meters. The Chor Gali Formation is dominantly composed of thin to well bedded limestone, shale and marl. The limestone units are argillaceous, marly and rich in larger foraminifers while the shale is highly fossiliferous and variegated in color. Four stratigraphically important sections Khajula, Tatral, Badshah-Pur and Karuli were measured. Seven dominant litho-units have been established based on the field observations. Eighty samples were collected and analyzed from these sections to illustrate the vertical as well as lateral variations in facies. The investigation of the microfacies allowed to identify and describe diagnostic microfacies including Bioclastic Mudstone, Bioclastic Wackestone, Bioclastic Packstone and Bioclastic Grainstone. The study of benthic larger Foraminifera revealed nine age diagnostic species; *Nummulites mamillatus* (Fichtel and Moll), *Nummulites atacicus* (Leymerie), *Assilina spinosa* Davies and Pinfold, *Assilina subspinosa* Davies and Pinfold, *Assilina laminose* Gill, *Assilina granulosa* (d'Archiac), *Assilina daviesi* de Cizancourt, *Lockhartia tipperi* (Davies) and *Lockhatia conditi* (Nuttall). Diagenetic characteristics like dissolution of aragonitic shells indicate active zone of meteoric phreatic environment while the presence of stylolites, fractures and calcite filled veins suggest diagenesis in the burrial environment. Present study reveals that major sedimentary control on the reservoir characteristics of the Chor Gali Formation are the development of secondary porosity in the form of stylolites and fractures in the limestone units of the formation. Field observations and microfacies analysis suggest that the deposition of the Chor Gali Formation took place in inner shelf conditions with restricted circulation. Presence of shallow water benthic larger Foraminifera also support inner shelf environment for the Early Eocene Chor Gali Formation.

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Sedimentology of an Early Permian, meandering fluvial succession: the Warchha Sandstone, central Salt Range, Pakistan

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The Early Permian Warchha Sandstone of the central Salt Range, Pakistan comprises 90 to 100 m thick succession of conglomerate, sandstone and claystone (shale) within which seven lithofacies types are recognized to occur in a predictable, repeating order that forms 5 to 8 fining-upward cycles. Common sedimentary structures in the conglomerates and sandstones include planar and trough cross-bedding, planar lamination, soft sediment deformed bedding, compound cosets of strata with low angle-inclined bounding surfaces and lags of imbricated pebbles. Structures in the finer-grained facies include desiccation cracks, raindrop imprints, caliche nodules and bioturbation. Associated facies are arranged into nine distinct architectural elements (channels, gravel bars, sandy bedforms, downstream and laterally accreting barforms, sand sheets, crevasse splays, levee and floodplain units and shallow lakes), which is consistent with a fluvial origin for the succession. Palaeocurrent analysis indicates an overall northerly flow pattern but with a high spread of flow directions within each cycle and with significant changes in mean flow direction between successive depositional cycles. This, together with a dominance of fine-grained (floodplain) facies over gravel-grade (channel base) facies supports the interpretation of a high-sinuosity, meandering fluvial system, in which channel bodies accumulated via the lateral accretion of point bars but in which the active channels covered only a small part of a broad floodplain at any time instant. Coarser-grained facies are arkoses and sub-arkoses with a significant detrital mineral component that was principally derived from igneous sources, though with additional minor metamorphic and sedimentary sources. Given the northerly palaeotransport direction, clast petrography indicates the likely provenance of the Warchha Sandstone to have been Aravalli Range in the southeast and the Malani Range in the south. Drainage of the fluvial system was therefore, from the interior of the stable Indian Craton towards a Tethyan coastline, which lay to the north.

Sedimentology, microfacies analysis and diagenesis of the Lower Eocene Sakesar Limestone, central Salt Range, Pakistan

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The sedimentology and the Foraminiferal biostrtigraphic studies of the Early Eocene Sakesar Limestone have been undertaken from of Khajula, Tatral, Badshah Pur and Karuli areas, central Salt Range, Pakistan. A total of 65 thin sections have been studied for detailed microfacies and micropalaeontological analysis. The Sakesar Limestone is extremely rich in benthic larger Foraminifera, the important genera are *Nummulites*, *Assilina*, *Alveolina* and *Lockhartia*. The red and green algae are also present in it. Based on the field observations, five types of the lithologic variations recorded in the Sakesar Limestone from bottom to top; limestone interbedded with very thin shale, limestone interbedded with marl, nodular limestone, massive bedded nodular limestone and massive bedded cherty limestone. The prominent microfacies observed in the Sakesar Limestone are mudstone, wackestone, wackestone to packstone and packstone. The diagenetic features represents freshwater (meteoric), marine and burial environments setting of the Sakesar Limestone. The prominent diagenetic features are stylolisation, calcitisation, nodularity, dissolution and fracturing. The present study also explains diagenetic process which creates the secondary porosity in the formation. Overall the on the basis of larger benthic foraminifera and detailed microfacies analysis the depositional environment of the Sakesar Limestone is inner neritic

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Comparison between the tectonic movements of Mt. Everest and the Nanga Parbat-Haramosh massif

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INTRODUCTION

If the Himalayas are a land of extremes from the topographical, geophysical and geological point of view (Windley 1984, 1988), the Karakorum is a land of superlative, having the highest concentration of mountains beyond 8000 m, having the longest glaciers beyond the poles, being the source of one of the longest rivers. From the geophysical point of view it contains the largest gravity anomalies (Poretti et al. 1983) and thickness of the earth crust (75 km) (Finetti et al. 1978, 1983) and the highest values of deflection of the vertical.

It contains also the highest relief (4000 m from the Indus plains to the summit of Nanga Parbat). It seems also that this area is subjected to the highest uplift. This has been mentioned by many authors deriving it through indirect methods, but not yet confirmed by accurate direct observations. Owen (1981) reports 0.7 mm/year using fission-track methods. Higher values (2 mm/year) are inferred by several researchers (Zeitler 1985; Gorniz and Seeber 1981; Lyon-Caen and Molnar 1983; Ferguson 1985; Owen 1989). Finally an average value of 6-10 mm/yr is in the hypothesis of Zeitler et al. (1985) including uplift and erosion.

The present study presents the preliminary results of a first survey consequent to the recent installation (2009) of GNSS network including three permanent GNSS stations between Islamabad and the northern areas of Pakistan and four points located on the Nanga Parbat-Haramosh massif. since a permanent GPS station was located near the Pyramid Laboratory at Lobuche in the Khumbu region in 1994 providing long records of data during the last 15 years; the goal of the project is to compare data obtained from Everest with the ones from Nanga Parbat in order to evaluate, not only the total uplift (if quantifiable) of the two massifs, but also the direction of the crustal movements.

REGIONAL GEOLOGY AND PLATE TECTONIC SETTING

Northern Pakistan comprises three former distinct and previously apart plates named Karakoram, Kohistan and Indian. These plates collided with each other during Cretaceous-Tertiary ages and formed the present day configuration of this region (Tahirkheli et al. 1982; Coward et al. 1987). This collisional tectonics and mountain-building activity is termed Himalayan being the result of continent-arc-continent collision. The Kohistan Island Arc is sutured to the Karakoram Block (Shyok Suture) in the north along MKT (Main Karakoram Thrust) and to the Indian Plate (Indus-Tsangpo Suture) in the south. The tectonics of Kohistan is related to collisional tectonics of Hindu Kush, Karakoram and Himalayan Ranges which involve Indian plate with Nanga Parbat-Haramosh massif, Karakoram Block and in between sandwiched Kohistan Arc.

GEOLOGY OF THE NANGA PARBAT AREA

Nanga Parbat-Haramosh massif is delimited by two thrust-displacement shear zones that have a spatial and temporal link with granite plutonism from ca. 10 to 1 Ma. The shear zones define a crustal-scale antiformal pop-up structure, with dominant west-northwest-vergent and subordinate east-southeast-vergent thrusting. This is substantially different than the surrounding area where the main exposed Himalayan structures are oriented parallel to the orogenic trend and are early to middle Miocene or older (Schneider et al. 1999). The western Himalaya syntaxis includes the Nanga Parbat-Haramosh massif, a new exposed section of largely Proterozoic Indian plate crust, initially overthrusted by Cretaceous island arc rocks along the Main Mantle Thrust. Nanga Parbat is an area of extreme relief that has undergone rapid exhumation since 10 Ma (e.g. Zeitler 1985), exposing migmatite and granulite grade rocks at the core of the massif (Smith et al. 1992). Nanga Parbat syntaxis comprises three major rock units: a) Iskhere-Mushkin-Rupal Gneiss; b) Shengus-Harchu Gneiss; and Haramosh-Tarshing Schists. A wide range of rocks intruding these major lithological units has been noticed in nearly all of Naga Parbat synaxial region, which included basic dykes and a wide variety of granites. The younger phases of granite up to 0.75 Ma are intruding the Nanga Parbat Gneisses.

THE SURVEY OF THE MT. EVEREST MOUNTAIN RANGE

Fifteen years (unfortunately not continuous) of observations with a permanent GPS station at the Ev-K2-CNR Pyramid Laboratory allow to determine the precise direction of the tectonic movement of Mt. Everest that seems to be of 4.5 cm/year with an azimuth of approximately 25°.

CONCLUSIONS

The aim of the project is to evaluate the amount in high and direction of the Nanga Parbat massif and to compare these results with the ones obtained from Everest in order to understand if the massive movements concord in amount and direction. After only one year it seems that the movement of Nanga Parbat area is more bended to the east, but it is still too early to draw conclusions that are not within the margin of error of the instruments employed. More reliable results will be obtained from the repeated observations during the next 2-3 years.

A new model to resolve the Lesser Himalayan Crystalline Nappe problem: Implications for Himalayan tectonics

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The work of B. N. Upreti, M. R. W. Johnson, P. Le Fort, S. M. Rai, and many others has focused attention on the Lesser Himalayan Crystalline Nappe problem. The problem is that the geology of the northern Main Central Thrust hanging wall does not match the southern Main Central thrust hanging wall, i.e., the Lesser Himalayan Crystalline Nappes (LHCN). The northern Main Central Thrust hanging wall famously contains the inverted metamorphic sequence of the Greater Himalayan Crystalline Complex (GHC), which underlies the Tethyan Himalayan Sequence along the South Tibet detachment. However, the Lesser Himalayan Crystalline Nappes are dominated by a right-way-up metamorphic sequence in sedimentary contact with overlying Phanerozoic Tethyan Himalayan Sequence sedimentary rocks.

We address this problem by integrating structural, metamorphic, and geochronological investigations to identify the South Tibet detachment in the Lesser Himalayan Crystalline Nappes. Our search focuses on the right-way-up kyanite isograd, because it coincides with the South Tibet detachment of the northern Main Central thrust hanging wall. New mapping along this isograd in the northern margin of the Kathmandu Nappe reveals a ~300 m thick shear zone with dominantly top-north sense of shear. To the south, this shear zone merges with the Main Central thrust, marking the southern limit of paragneiss and leucogranite. The fault intersection is not exposed, but the merging fault zones outcrop less than 300 m apart immediately north of the merger. 36 U-Th-Pb ion microprobe spot analyses were acquired from 24 zircon grains from a leucogranitic lense deformed by top-north shear bands within the top-north shear zone. Grains have complex cores with some d” 30 ìm prismatic rims. Grain cores yield variable, pre-Oligocene ages and low U/Th ratios (~50 to 250). Rim analyses (from 8 zircons) have latest Oligocene – earliest Miocene ^{238}U/^{206}Pb ages and variable U/Th ratios (~50 to 1700). Core data are interpreted as inherited/mixed ages; rim data reveal zircon that grew during crystallization of the leucogranite. These results, together with published ^{40}Ar/^{39}Ar thermochronology across and below the Kathmandu Nappe, indicate that the top-north upper shear zone was active here in the Early Miocene.

We interpret the newly discovered shear zone as the southern extension of the South Tibet detachment on the bases of matching lithologic and metamorphic juxtapositions as well as consistent sense and timing of shear. Its southwards merger with the Main Central thrust along the northern margin of the Kathmandu Nappe suggests a resolution of the LHCN problem: this fault merger bounds the southward tapering leading edge of the GHC (locally, the Sheopuri gneiss). Therefore the right-way-up metamorphic sequence of the LHCN (locally, the Bhimphedi Group and associated granites) is continuous across the South Tibet detachment and Main Central thrust hanging walls, and is assigned to the Tethyan Himalayan Sequence. These results match recent discoveries in the NW Indian Himalaya. Therefore, the frontal tip of the GHC can be inferred along the strike of the orogen for over 1000 km. Preservation of this leading edge of the Himalayan crystalline core requires that the southern segments of the upper bounding fault did not breach the surface during motion (this is particularly clear in light of the many kilometers of exhumation since the Miocene).

These results have first-order implications for Himalayan tectonic models. Wedge extrusion and channel flow models show exhumation of the GHC to the surface between its bounding faults during the Early and Middle Miocene. Recently proposed tectonic wedging models show emplacement of the GHC at depth during the Early and Middle Miocene, with the upper South Tibet detachment acting as a back-thrust off of the Main Central thrust which transfers top-north displacement northwards to the Great Counter thrust. The southern merger of the Main Central thrust and South Tibet detachment and corresponding preservation of the leading edge of the GHC observed in the central and western Himalaya is only consistent with the tectonic wedging hypothesis.

The concept of the South Tibet detachment as a back-thrust challenges the long-standing interpretation of normal-sense slip along this structure. The normal fault interpretation is reinforced by a basic metamorphic consideration: the shear zone places colder rocks atop hotter rocks. A schematic model demonstrates that this juxtaposition may also be accomplished in a back-thrust model. A thermal field dominated by Main Central thrust motion features isotherms that dip south in the Main Central thrust hanging wall and locally overturn across the fault. In this field, a sub-horizontal back-thrust off the Main Central thrust may displace the southward dipping isotherms/isograds to juxtapose colder rocks atop hotter rocks.

Remnants of southern Tibetan Plateau in north-western Himalayas: morphological and thermochronological evidences

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The northwest Himalaya is characterized by strongly contrasting relief. Deeply incised mountain ranges, including some of the highest peaks in the belt, such as Nanga Parbat (8126 m) and K2 (8611 m), are in contrast with high-elevation (around 4000 m), smooth-relief, low-slopes areas such as the Kohistan range and the Deosai plateau in northern Pakistan, or the Ladakh-Tso Morari ranges in northern India. Using morphological data, the low relief areas appear to be the actual prolongation of the southern tibet Plateau.

Very fast Mio-Pliocene exhumation has been evidenced in Nanga Parbat and Karakorum belts. In contrast, recent low temperature thermochronology data from the Deosai Plateau (Van der Beck and al. 2009), from the Ladakh range (Kirstein et al. 2009) and from the Tso Morari area (Schlup 2003) show that most of the exhumation in the low relief areas was completed before 30-35 Ma. Thermal history modelling shows that those areas have undergone continuous slow denudation at rates below 250 m/Ma for the past 35 Ma at least. Scarce data in western Tibet indicates that the same exhumation path could have been followed here too.

Those data show that similarly stable surfaces exist throughout the entire northwest Himalaya and share common morphologic characteristics and denudation histories, which are comparable to those of the western Tibetan Plateau. It suggests that these surfaces are preserved remnants of the Eocene south-western Tibetan plateau, which was extending farther west than admitted.

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Geology and tectonic setting of the volcanoclastic succession of the Upper Cretaceous, western Sulaiman Foldbelt, Pakistan

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The volcaniclastic rocks of the Upper Cretaceous are exposed through out the Ziarat district within the western part of the Sulaiman Thrust-Fold Belt, east of the Quetta Syntaxes, Pakistan. These volcanic rocks generally comprise basic volcanic rocks, volcanic conglomerate and breccias, sandstone, mudstone and ash beds, deposited by various processes of sediment gravity flows on the western margin of the Indian Plate. Limestone, interbedded with volcaniclastic facies in lower part, is very finely crystalline (bio-micritic) possessing foraminifera of the Globotruncana family suggest deposition during calm periods when gravity flows had been suspended intermittently.

Paleo-current pattern indicates a south-southwest paleo-flow direction and a source area to the north-northeast of the studied area based on characters of various rocks associations, their vertical and lateral organization, paleo-current pattern and composition of detritus.

Seamounts developed on sea floor of the northwestern margin of the Indo-Pakistan Plate. Detailed petrography and geochemical analyses of clasts of the volcanic conglomerate and sandstone were carried out to determine the origin and provenance of volcanoclastic sediments. Volcanic conglomerate contains clasts of alkali basalt, picrite, trachy basalt, tepherite/phonolite, trachy andesite, dolerite, diorite and granodiorite, which are varieties of the alkaline magma suite. Sandstones are also dominantly composed of the basaltic rock fragments and pyroxene. XRF data of both major and trace elements of the volcanic and associated intrusive rocks indicate the analyzed samples, fall in the field of within-plate alkali basalt. Trace elements suggest that the parent magma was enriched in mantle source and confirm that the fragments of the volcanic conglomerate were derived from a hotspot related (within-plate setting) volcanic terrene.

Role of active tectonics in geothermal exploration: a case study in Büyükmenderes graben, SW Turkey

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Turkey is located on the geologically very complicated Alpine-Himalayan orogenic system. One of the tectonic members of this system is the Anatolian platelet. It is moving in west-southwestwards along its boundary fault systems, the North Anatolian and East Anatolian strike-slip fault systems, onto the oceanic crust of the African plate along the South Aegean-Cyprus subduction zone. The study area is Pamukören, which is located along the northern margin of a very active intracontinental extensional structure. This is an about 3-18 km wide, 170 km long and E-W trending Büyükmenderes graben. It is included in southwestern Anatolian graben-horst system, which comprises the southwestern frontal part of the Anatolian platelet, and is located on the back-arc side of the northerly dipping south Aegean-Cyprus subduction zone.

The Büyükmenderes graben has two morphotectonic configurations: (1) a wider, uplifted, dissected and deformed initial configuration of Miocene-Middle Pliocene age, and (2) the narrower, linear, undeformed and continuous recent configuration of Plio-Quaternary age. These two configurations are here termed as the Büyükmenderes paleotectonic graben and the Büyükmenderes modern (neotectonic) graben, respectively. These two grabens are represented by two sedimentary packages separated by an intervening angular unconformity. The older sedimentary package is deformed (steeply tilted to folded) and consists of, from bottom to top, unsorted boulder-block basal clastics and coal-bearing flood plain-shallow water deposits of Miocene-Middle Pliocene age. The younger sedimentary package is undeformed and consists of very thick (up to 1.2 km) debris flow and fluvial deposits of Plio-Quaternary age.

The paleotectonic configuration of the Büyükmenderes graben is bounded by detachment type of normal faults and they are still seismically active. However, the modern configuration of the Büyükmenderes graben is bounded by a series of steeply dipping normal faults with step-like landscape. Geophysical studies indicate that the steeply dipping normal faults are meeting with the low-angle detachment faults at the depth. Hot water springs are concentrated along the trace of the detachment faults. But they are not seen along the modern graben-boundary faults. However, the hot fluids are being obtained by the help of boreholes drilled on the down-thrown hanging wall block of the modern graben. This means that the hot fluids are circulating by using the major detachment fault and rising at shallower depths, where hot fluids are being shared by both categories of the normal faults. Consequently, major detachment faults are more suitable ways for circulation of hot fluids, therefore, they have to be more taken into account in geothermal explorations.

Neotectonic signatures in the southern Peninsular India and Gulf of Mannar

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The seismic hazard of Peninsular India has been a focal point of discussion today due to the occurrence of many moderate earthquakes on unexpected locations. The stress in accumulation within the Peninsular India is identified as due to back thrust from the collision zone of Himalaya and the push from the midoceanic ridges. Later studies identified a number of E-W trending flexures within the land mass of Peninsular India resulting from this compressional tectonic regime. The accumulation stress generally concentrates on pre-existing weaker planes. Even though the accumulation of stress is very slow in Peninsular India, in comparison with Himalayas, moderate earthquakes are occurring along some of those weak zones, which could be identified only after the earthquakes.

The present paper enumerates some of the tectonic and morphologic signatures which can be used to classify the faults in southern Peninsular India as active. The NW-SE trending Achankovil fault system is a major ductile shear zone within southern Peninsular India of Precambrian age. A number of similar lineaments can be identified, on either side of Achankovil fault, in the region south of E-W trending Palghat Cauvery shear zone. Geological studies close to the Palghat shear zone identified a NW-SE trending fault (Desamangalam fault), which disturbed the west flowing river system of the area. Later studies identified four episodes of movement on this fault in the present stress regime and characterised it as active. The NW-SE trending Periyar lineament falls south of the Desamangalam fault and is identified based on the exceptionally straight river course. This lineament is reported said to be the source for 1988 Idukki earthquake (M=4.5). Further south another NW-SE trending lineament demarcate gneissic and charnockite rocks. At the coastal area archaeological studies identified an ancient port much inside the present coast suggesting uplift within the human observation. Further inland repeated seismicity identified, where the latest sequence occurred during 2000-2001, along this lineament.

In the east coast recent evidences of uplift of the northern part near Dhanushkodi between east coast and Sri Lanka along another NW trending lineament. This lineament, termed as Vaikai River fault, demarcated from the straight course of river Vaiga. Further south one of such lineament (south Achankovil fault) running from west coast to Gulf of Mannar. The trace of the fault in the Gulf of Mannar shows perturbation of south western side of land mass into the sea, where beach rocks are exposed only in the south western side. Karamaniyar River, one of the major east flowing rivers in this zone, flows through some part of this lineament. A surface indication of this fault is also traced out in laterised Miocene rocks. The continuation of earthquake locations along the NW trending systems in the region into the Gulf Mannar may indicate the continuation of the features into the gulf.

The above discussed morphotectonic and related seismicity suggest that the NW-SE lineament/fault system, south of Palghat-Cauvey shear zone is reacting to the present stress regime.

Problems with respect to the channel flow model in the Himalaya and Tibet

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There are number of problems about the channel flow model in the Himalaya and Tibet area (Jamieson et al. 2002). Those problems are separated into two kinds; one is from the viewpoint of numerical method (1, 2 and 3) and the other is from the geological side (4 and 5). (1) The boundary conditions are almost agreeable except for the elastic beam treatment for crustal flexure. The authors treat the crust as plastic or viscous materials in horizontal convergence, while they assume it as an elastic beam flexuring with vertical deflection. This is clear when comparing the more natural treatment. (2) Also for the boundary condition, the constraining velocity along the inclined subduction plane is too artificial comparing to the nature that should not be constrained directly by the external velocity condition but be controlled through the other internal factors. (3) When we consider the model HT-6 (Jamieson et al. 2002), for example, we wonder whether the erosion condition which has connected to re-sedimentation has enough geological data supported from observation. The erosional mechanism is considered not to be unique and still unclear. (4) Jamieson and others wrote their worry as “for a given set of thermal and mechanical model parameters, individual P-T-t paths are not particularly diagnostic of tectonic style”. Still now we have not adequate metamorphic data for two neighboring points along the MCT zone. Two adjacent points taking out arbitrarily around the MCT show usually quite different P-T-t paths that mean their instable channel flow deformation. (5) The channel flow model is not an inevitable model to understand the development of STDS, since normal faults including STDS can be produced by assuming the ramp structure along MHT. It is obvious from the Anderson’s theory using stress distribution within elastic or plastic material; for example, refer to a series of elastic stress and fault analyses (Chamlagain and Hayashi 2007; Joshi and Hayashi 2008)

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Three-dimensional strain variation across the Kathmandu Nappe: implication to internal deformation

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Among the crustal-scale thrusts, the Main Central Thrust (MCT) in central Nepal Himalaya is one of the most controversial issues regarding its nature, location and position. Further, the MCT zone is significant to understand the nappe tectonics in central Nepal because it is considered that the MCT acted as a glide plane for the thrust sheets, which travelled more than 100 km towards south over the Lesser Himalaya forming a large folded thrust sheet called Kathmandu Nappe. To the date much of the research has been focused on the structural and kinematic analysis of the MCT zone, a root zone of the Kathmandu Nappe. These studies have confirmed a top-to-the south directed sense of shear in the MCT zone associated with the nappe emplacement. Although large-scale geometry of the Himalayan thrust sheets are relatively understood, features of the internal deformation are not well understood in terms of strain geometry and emplacement mechanism. Several studies have shown that the pattern of the internal deformation varies between thrust sheets because it depends on pressure, temperature, and complex tectonic boundary condition. Although strain analysis bears important role to understand internal deformation, there is still lack of studies across the MCT zone at the periphery of Kathmandu Nappe. In the present work, efforts have been made to address several problems like (1) three-dimensional strain geometry, (2) validity of the plane strain condition for the Himalayan thrust sheets, (3) relation between temperature, inverted metamorphism and strain pattern, (4) thrust related strain heterogeneity, and (5) precise kinematic model to gain better understanding on internal deformation and tectonics of the Kathmandu Nappe. Structural data support a single nappe model considering Mahabharat Thrust as a southern continuation of the MCT, which acted as a glide plane for the Kathmandu Nappe. Kinematic indicators suggest that a top-to-the southeast-directed shear sense consistent with a nappe emplacement direction. Three-dimensional strain data show heterogeneous strain field both in footwall Lesser Himalayan sequence and hanging wall Kathmandu Nappe. In the footwall Nadai amount of strain intensity varies from 0.396 at the base to 0.575 adjacent to the MCT whereas in the Kathmandu Nappe, it varies from 0.345 to 0.946. In general, the footwall block shows increasing trend of strain intensity towards MCT whereas in the Kathmandu Nappe strain intensity increases away from the MCT. Lower value of strain intensity at the base of the Kathmandu Nappe is probably due to thermal relaxation that led to a low temperature dynamic metamorphism and plastic deformation after the emplacement of hot Kathmandu Nappe. The complex patterns of orientation of the strain ellipsoids are due to superposition of strain partitioning mechanisms on different scales, which have also created a complex regional strain variation in terms of magnitude. The shape, orientation of strain ellipsoids, and mesoscale structural data indicate transpressional strain field in the MCT zone. The dominancy of prolate type strain ellipsoids suggest simple shear model for the footwall. In the hanging wall, however, strain field is dominantly oblate type with few prolate types suggesting pure shear with a thrust parallel shortening model. For the both walls computed k-values have revealed non-plane strain deformation for the MCT, which is apparently consistent with several fold-and-thrust belts on the earth.

The Main Central Thrust Zone in eastern Nepal explained by petrology

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Identifying the location and nature of the Main Central Thrust Zone (MCTZ) is a major challenge in most of the Himalayan chain. In order to clarifying this conundrum, a number of metapelite samples were selected for a petrologic study along the Milke Danda ridge, on the eastern flank of the Arun Tectonic Window in eastern Nepal. Both to the west and east of the study area, the Makalu and Kangchenjunga transects show metamorphic units characterized by a well-documented inverted metamorphism (Le Fort 1975; Meier and Hiltner 1993; Goscombe et al. 2006), with metamorphic grade increasing northward from lower (Lesser Himalaya) to higher (Higher Himalayan Crystallines) structural levels across the MCTZ.

Metamorphic assemblages in the studied metapelites range from the low–grade chlorite zone, to the medium–grade garnet-biotite, staurolite and kyanite zones, up to the sillimanite zone and a further zone of partial melting with breakdown of white mica and formation of K-feldspar. The detailed petrologic study of the selected samples allowed us to recognise three superposed tectonometamorphic units which are separated by cryptic metamorphic discontinuities. These units are characterized by different P-T evolutions, peculiar zoning styles of garnets and contrasting T/depth ratios. Specifically:

i. The structurally lowest unit shows a prograde P-T path characterized by an increase in both P and T, up to peak metamorphic conditions of 550°C and 0.65 GPa;

ii. The structurally intermediate unit preserves relics of a prograde P-T history characterized by heating and decompression up to peak metamorphic conditions of 600-650°C and 0.85-0.95 GPa;

iii. The structurally highest unit shows chemically equilibrated assemblages that do not preserve relics of their prograde metamorphic history. Peak metamorphic conditions of 655°C, 0.75 GPa (still inside the white mica stability field), and minimum T of 790°C at 1.05 GPa (beyond the stability limit of white mica) have been determined for these samples.

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Deformation-based criteria for identifying the MCT in the southern part of the Kathmandu Nappe, central Nepal

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Located in the central Himalayan collisional wedge, the Kathmandu Nappe is a >100 km broad re-entrant in the regional tectonostratigraphy. The tectonostratigraphic package includes the orogen-wide renowned Main Central Thrust (MCT), which juxtaposes the Lesser Himalaya (footwall) with the Higher Himalaya (hanging wall). The entire re-entrant feature has syn-formal architecture (the Mahabharat Synclinorium) thereby the regional tectonostratigraphic foliation is S-dipping on the northern flank. Differing interpretations question (1) whether the rocks of the Kathmandu Nappe are equivalent with the rocks of the Higher Himalaya, (2) whether the thrust lying in the southern flank (also called as Mahabharat Thrust, MT) is southward extension of the MCT or an out of sequence thrust.

To address these questions, two profiles in the southern part of the nappe have been chosen to identify the timing and amount of strain associated with major lithospheric thrusting around the Kathmandu Nappe by using field mapping, structural surveying and detailed microstructural kinematic and strain analyses in addition to geochemistry. These profiles were made around the Manahari and the Hetaunda area both lying in the southern portion of the re-entrant where foliation is N-dipping. These belts comprise two local tectono-stratigraphic elements, the Kathmandu and Nawakot Complexes, representing the hanging wall and footwall, respectively. The zone of contact between the Nawakot Complex and the Kathmandu Complex is observed to about 100 m thick zone of thrust deformation. Visible intensity of strain gradually decreases away from the core of this main thrust zone.

The upper greenschist facies Kathmandu Complex contains grt-calc-schist, marble, quartzite and mica schist±grt. In addition to asymmetry of monoclinic geometry mica micro-domains, quartz micro-ribbon features, garnets (restricted to <500m of lowest hanging wall) preserve dramatic rotation history. All demonstrate consistent thrust kinematics. The thrust belt footwall (the Nawakot Complex) comprises greenschist facies phyllite, slate, limestone and quartzite. Although the intensity of strain is less spectacular than in the hanging wall, kinematic indicators again consistently demonstrate thrust sense.

The Sm-Nd whole rock analysis carried out in the Nawakot Complex phyllite and highly deformed phyllite of the MCT zone shows a linear trend of $^{143}Nd/^{144}Nd$ vs $^{147}Sm/^{144}Nd$ plot. ε(0) Nd values (>-20 for the Nawakot Complex phyllite -16 for thrust zone rock) are equivalent with the Lesser Himalayan rock and the rock of the MCT zone.

Although the garnet-biotite thermometry shows a low metamorphic temperature (422ºC), the nature of deformation, petrography and the nature of strain history of both the hanging wall and footwall rocks is strikingly consistent with descriptions of the MCT from elsewhere. We therefore conclude that our thrust belt is the local MCT. Consequently, the Katmandu Nappe is required to be an MCT trace re-entrant.

Elasto-plastic finite element modeling along the project INDEPTH profile: implication for the role of crustal strength variations in Himalaya and Tibet

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INDEPTH geophysical and geological observations imply that a partially molten mid crustal layer exists beneath southern Tibet. This partially molten layer has been produced by crustal thickening and behaves as a fluid on the time scale of Himalayan deformation. It is confined on the south by the structurally imbricated Indian crust underlying the Tethyan and High Himalaya and is underlain, apparently, by a stiff Indian mantle lid (Nelson et al. 1996). Considering this partially molten middle crust and existing fault zones as plastic bodies and remaining crust as elastic body, a 2-D finite element elasto-plastic model is developed for the analysis of the stress field and displacement vectors. Young's modulus, density, Poisson's ratio, yield strength and strain hardening are used to constrain the physical properties of the layers (Table 1). Convergent displacement from the southern boundary is applied. Lower boundary is fixed vertically. The northern boundary is fixed horizontally but can move vertically. The upper boundary is free to move both horizontally and vertically (Fig.1). Series of calculations were done with the variation of the physical properties of different layers and displacement boundary conditions. 0.1 m, 1 m, and 10 m were chosen for the incremental displacement. If 20 mm/yr is considered as the present convergent rate of the Indian plate, 0.1 m increment can be considered for 5 yrs. The total output is cumulative for example 10 m total output can be considered as for 500 yrs at 0.1 m increment and so on. All the calculations were performed under 3% volume change. Stress field does not vary so much on the increment rate, but the velocity vector varies. Finer increment produced more reasonable velocity vectors. Model results indicate that crustal strength variations have remarkable effect on the stress field and fault types. Reasonable and comparable stress fields (Fig. 2), velocity vector (Fig.3) and shear stress (Fig. 4) were obtained when pre-existing variations in crustal strength were considered. A stronger homogenous crust or a weaker heterogeneous crust did not produce comparable results. In general, model results show compressive state of stress in Himalaya and Tibet in the lower realm but the upper part in the Tibet shows tension. Magnitude of principal stresses increases with increase in displacement. The frontal part of the Himalaya also showed some tension and tensional stress was found near STDS and major fault also (Fig 2). The north Himalayan domes and normal faults in the Tibet are well simulated in our model (Fig.2). Shear stress is concentrated just north of the MCT ramp and on the MCT duplex (Fig.4). Material flow is toward the weak zone as shown by the velocity vectors (Fig. 3). Preliminary results of the simulation show that rock layer properties and boundary condition has strong effect on the stress and velocity vector. More detail calculations are needed to explore their effects in detail.

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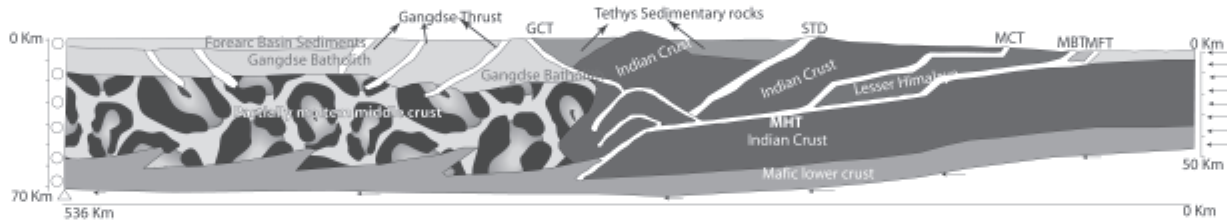

Fig. 1 Geological Cross Section along Project INDEPTH, Geometry and Boundary Condition

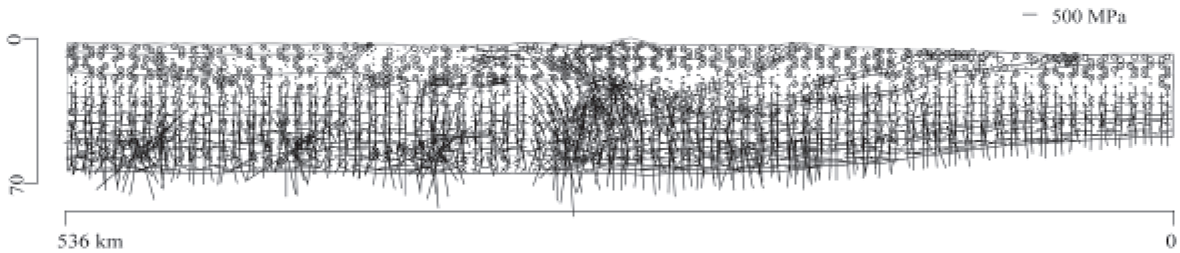

Fig. 2 Stress distribution at 100 m displacement with 1 m increment, each pair of perpendicular lines represent σ_1 (Long lines) and σ_3 (Short lines), tensional stress are represented by small black circle

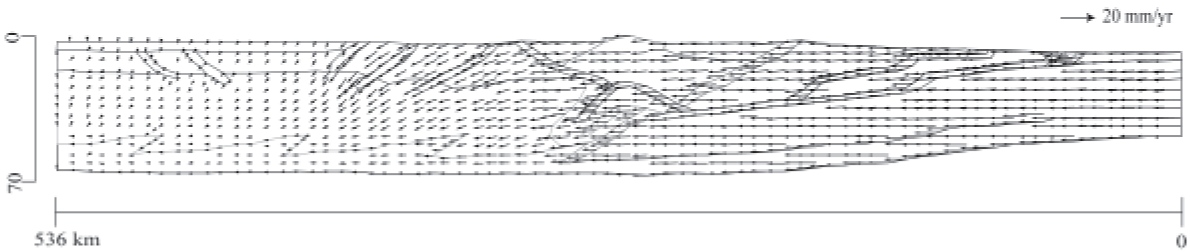

Fig. 3 Velocity vector at 100 m displacement with 1 m increment

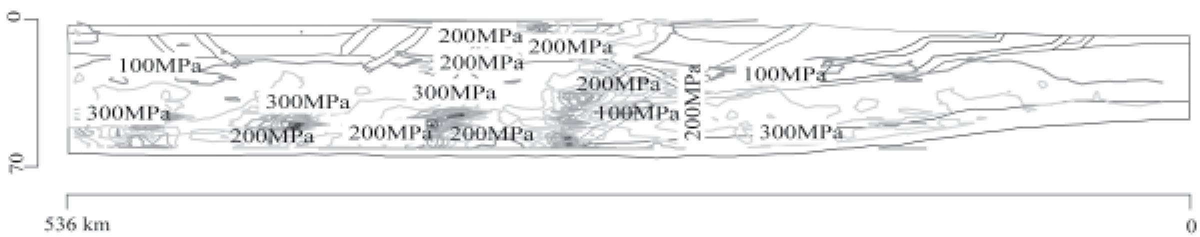

Fig. 4 Shear stress distribution at 100 m displacement with1 m increment

Layer	Layer name	Young's Modulus (MPa)	Density (kg/m3)	Poisson's Ratio	Yield Strength (MPa)	Strain Hardening °
1	Mafic Lower Crust	111.7E+9	2900	0.25	300	10
2	Indian Crust	81.2E+9	2800	0.25	100	10
3	Partially Molten Middle Crust	5.0E+9	2800	0.38	10	0
4	Indo Gangetic Sediments	15.0E+9	2000	0.25	5	0
5	Main Frontal Thrust	15.0E+9	2000	0.25	5	0
6	Sub Himalaya	32.0E+9	2400	0.25	5	0
7	Main Boundary Thrust	15.0E+9	2000	0.25	5	0
8	Lesser Himalaya	54.2E+9	2600	0.25	10	0
9	Main Central Thrust	15.0E+9	2000	0.25	5	0
10	Main Himalayan Thrust	15.0E+9	2000	0.25	5	0
11	South Tibetan Detachment	15.0E+9	2000	0.25	5	0
12	Tethyan Sedimentary Rocks	54.2E+9	2600	0.25	10	0
13	MCT Duplex	15.0E+9	2000	0.25	5	0
14	Great Counter Thrust	15.0E+9	2000	0.25	5	0
15	Gangdse Batholith	54.2E+9	2600	0.25	50	0
16	Gangdse Thrust	15.0E+9	2000	0.25	5	0
17	Fore Arc Basin Sediments	15.0E+9	2000	0.25	5	0
18	Thrust Below Fore arc	15.0E+9	2000	0.25	5	0

Table 1 Physical properties applied for rock layers

Indian plate motion constrained by GPS measurements

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We have used data from 29 continuous GPS sites and 41 campaign-mode GPS stations over the past 15 years, to constrain Indian plate motion and examine intra-plate strain accumulation. We have combined more than 1800 GPS-measured velocities from India and surrounding regions to study interactions between Indian and surrounding tectonic plates. GPS data available so far supports the concept of a stable Indian plate. Even though a north-south shortening of 2 ±1 mm/yr could lead to a possibility of a localized convergence along the Narmada-Son Lineament; conjecture of a two-plate model could not be established statistically in a robust way. Most parts of the Himalayan Frontal Thrusts accommodate ~50% of the India-Eurasia convergence with as much as 18 mm/yr of slip accumulation along some segments. In the eastern 200 km long segment, Shillong plateau moves towards south by 4-7 mm/yr indicating high earthquake hazard associated with north-eastern part of India and Bangladesh.

Timing of the end of motion along the South Tibet Detachment shear zone: an important constraint on collision models

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The South Tibet Detachment System (STDS) is a major normal fault system that runs parallel to the Himalayan range for more than 1500 km, and that is fundamental to the major models proposed to the belt for tectonic evolution. The STDS is a fossil structure, as it has no clear morphological expression, is crosscut by perpendicular (N-S) active normal faults (Gurla Mandata, Thakkhola, Ama Drime, Yadong), and no crustal earthquake indicative of ~N-S extension has ever been documented in the South Tibetan crust. It has long been proposed that the STDS and the MCT slips where coeval during the Miocene, however, the timing of the STDS all along its length has rarely been investigated.

Near Dinggye (~ 28°10'N, 87°40'E), the South Tibet Detachment (STD), main branch of the STDS, dips ~10 ± 5° to the North and separates Paleozoic Tethyan series from Upper Himalayan Crystalline Series (UHCS). Immediately below the STD, the UHCS is highly deformed in the STD shear zone, stretching lineations trend NNE and the shear senses are top to the NE. In micaschist, P-T path constrained by pseudosection and garnet chemistry, shows successive metamorphic conditions of ~0.6 GPa and ~550 °C and 0.5 GPa and 625 °C. U/Pb dating of monazite and zircons in deformed and undeformed leucogranites suggest that ductile deformation lasted until at least ~16 Ma but ended prior to ~15 Ma in the STD shear zone ~100 meters below the detachment. Ar/Ar micas ages in the footwall span between ~14.6 Ma and 13.6 Ma, indicating rapid cooling down to ~320 °C, and suggesting persistence of normal faulting, at that time. The STDS is cut and offset by the N-S trending Dinggye active normal fault, which initiated prior to 11 Ma thus providing a minimum bound for the end of STDS motion. These data are interpreted as reflecting 0.3 GPa (11 km) to 0.6 GPa (22 km) of exhumation along the STDS starting prior to ~16 Ma and ending between 13.6 Ma and 11 Ma.

On both sides of the Ama Drime, analysis of structural and geochronological constraints available from the literature allows us to propose a time interval for the end shearing on the STDS in 11 Ma, similar to other sections along the Himalayan arc. It appears that the STDS stopped first in the west, at ~17 Ma in Zanskar but only after 13 Ma, east of the Gurla Mandata. This timing difference could be related to interactions with the Karakorum fault zone that shows a strong bent at the level of the Gurla Mandata. The 1000 km long stretch of the STDS, east of the Gurla Mandata probably stopped almost synchronously between 13 Ma and 11 Ma ago. This generalized stop appears coeval to a sudden switch from NNE-SSW to E-W extension at the top of the accretionary prism, with jump of the major thrust from the lower Main Central Thrust (MCT I) to the Main Boundary Thrust (MBT), and with change in India and Asia convergence direction. This synchronism is probably better explaination in the frame of a thrust wedge or thrust system model than a lower channel flow model.

Cretaceous deformation and new structural model of the Petlalcingo Monocline, Oaxaca México

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In the zone of Huajuapan de Leon Oaxaca (SW Mexico), Jurassic calcareous shales cropped out show a chevron fold verging towards NE, while in the same area an outcrop of Cretaceous calcareous rocks with open folds is verging towards SW. Limestone unit folded into open folds includes fault propagation folds, ramps, collapse breccias, thickening hinges and slided tectonic breccias. The folds have general verging direction towards SW. The average shortening quantified is 20%.

Chevron folds in the calcareous unit have a general direction of the axis towards NNW, however, verging towards NE and shortening average of 50%.

The differences in deformation and shortening amount between the two different lithologies are because of the differences in mechanical competence of these two units and also due to the presence of an older sandy limestone at the base of the Cretaceous unit.

The direction of deformed structures is similar to the regional faulting of Huajuapan Petlalcingo Fault (NNW), which suggests a direct relationship between shortening of the units and regional faulting.

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Collision tectonics of the north-western Caucasus, Russia

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Many geologists suggest a determinative role of folding in the formation of the northwestern Caucasus structure. Mapped or drilled thrusts are considered minor structures complicating steep fold limbs. In accordance with the generally accepted concept of overthrusts as subordinate structures relative to faulting, they are shown as short unlinked segments, which do not extend beyond anticlinal folds. However, this concept is erroneous and inconsistent with factual data. Actually, the genesis, morphology, and position of folds in plan view are completely controlled by overthrusts, which define the general tectonic style of the north-western Caucasus.Thrust faults have a distinct listric form; i.e., they have steep near-vertical fault surfaces in the frontal part, which rapidly become gentler to the south-south-east grading into near-horizontal decollement fractures. Correspondingly, the archs of semi-anticlines are also displaced in accordance with the dip of thrust surfaces. Occasionally, they are transformed into monoclinal blocks jammed between adjacent thrusts. Thus, horizontal tectonic movements are transformed into vertical ones in the frontal parts of slices under the influence of lateral stresses to form characteristic fold–thrust structures. Such areas are marked by the formation of high-amplitude linear anticlines with steep asymmetrical (occasionally overturned) limbs, the maximum amplitude of vertical displacement along ruptures, and the highest stratigraphic range of their penetration. From the front to both sides of the imbricate thrust, the amplitude of vertical displacement along the rupture significantly decreases with the appearance of strike-slip component. The obtained data indicate that the northwestern Caucasus has a distinctly expressed asymmetrical bilateral tectonic zoning. The structure of the region and the formation of fold-thrust dislocations can be explained only by NNE-trending tangential stress caused by underthrusting of the Transcaucasian-eastern Black Sea plate beneath the Caucasus fold system.

Partitioning of convergence and slip rates between the Himalayan Frontal Thrust and the Main Boundary Thrust in Kangra re-entrant, NW Himalaya

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Of the 45-50 mm/yr convergence between the Indian and Asian plates, 18-20 mm/yr is consumed in the Himalaya and the remaining is taken up farther north in Asia including Tibet. Estimation made earlier in the Sub Himalayan frontal zone in Nepal and Garhwal indicates 18 mm/yr and 15 mm/yr± convergence respectively on Himalayan Frontal Thrust (Wesnousky et al. 1999). In the Kangra re-entrant, the regional strike takes a bend from southeast to southwest forming a concave geometry of the Sub Himalaya zone. The Kangra reentrant region is made of fold-thrust packages of Sub Himalaya Tertiary strata, ~ 80 km wide, between the Himalayan Frontal Thrust (HFT) and the Main Boundary Thrust (MBT). The strath terraces of the Banganga River in Kangra area and on the hanging wall of the Soan Thrust in Una area and an abandoned alluvial fan on the hinge zone of the Janauri anticline were used to calculate the bedrock uplift rates. Based on the bedrock uplift rates, convergence and slip rates on the Jawalamukhi Thrust (JT), the Soan Thrust (ST) and the Himalayan Frontal Thrust (HFT) were estimated on the observation that the strath terraces lie on the hanging walls of the JT and the ST, and the Janauri anticline is developed as a fault propagation fold over the HFT. The seismic profiles and exploratory hydrocarbon wells provide a good constraint on the subsurface dip of the JT, the ST and the HFT (Fig. 1). The strath surface elevations were determined precisely using total station, and the sands in the gravel cover on the terrace strath surfaces and the post-Siwalik alluvial fan sediment on the culmination (hinge zone) of the Janauri anticline were dated through luminescence (OSL) method. The Kangra strath terrace on the hanging wall of the Jawalamukhi Thrust gives an uplift rate of 2.02 ± 0.22 mm/yr. The shortening and slip rates calculated on NE 30º Jawalamukhi Thrust are 3.48± 0.38 mm/yr and 4.04 ± 0.40 mm/yr respectively during 32 ka.. The uplifted strath terrace on the hanging wall of NE 30º dipping Soan Thrust gives uplift rate of 1.72 ± 0.18 mm/yr. The convergence and slip rates on the Soan Thrust is estimated as 2.98±o.31 mm/yr and 3.44±0.36 mm/yr respectively during 29 ka. The abandoned alluvial fan on the hinge zone of Janauri anticline, a fault propagation fold, yields a bedrock uplift-rate of 3.49±0.2 mm/yr. The shortening and slip rates on the HFT are estimated as 6.04 ± 0.4 mm/yr and 6.98±0.5 mm/yr respectively during 42 ka. The GPS measurements and a balanced cross-section indicate 14 ± 1-2mm/yr shortening/ slip rate across the reentrant between the HFT and the MBT (Powers et al. 1998; Banerjee and Burgman 2002). Our estimations indicate the convergence and the slip rates between the HFT and the MBT are partitioned and consumed along the HFT, the ST and the JT.

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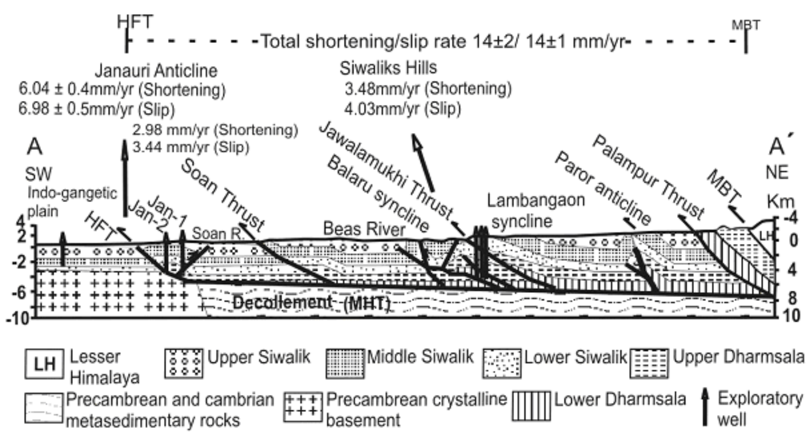

Fig. 1: Cross-section across the Kangra re-entrant, Adampur in Panjab plain to Dharamsala (after Powers et al. 1998), showing convergence and slip rates estimated on the Himalayan Frontal Thrust, Soan Thrust and Jawalamukhi Thrust.

Stone of Heaven: Jade

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Jade is a gemological material that has been used since the dawn of civilization because of its attractive colors- green; the most common in Mesoamerica and hardness that makes it useful and resistant. The word Jade comes from the term "loin stone" that in Spanish refers to the cavity between the false ribs and the hips. From the gemological view the term Jade is used to name for two minerals: Jadeite and Nephrite.

Jadeite is named after the Spanish word "ijada"; it is a mineral from the pyroxene group. Jadeite is one of the boundaries of the chemical composition of Jade and its formula is $NaAlSi_2O_6$. Jadeite is a characteristic mineral of metamorphic terrains of high pressure tectonic environments corresponding to eclogite facies.

Nephrite is named after the Greek word "nefros" that means kidney because of its shape as it is found in the placer deposits where it is mined. Nephrite is a mineral from the amphibole group, and it is a variety of actinolite $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$. This is a fibrous and compact mineral. It is a characteristic mineral of green schist facies.

It is normal to think that Jade appears in different geological environments because it represents two different minerals, however, the most common geological model used to explain its appearance is with a high pressure regional metamorphism of an ophiolitic sequence in blue schist, green schist and eclogite facies.

There are a few ore deposits being extracted through the world. These ore deposits are located in China, Canada, Guatemala and New Zeland.

Jade is a wonderful stone because of its meaning for ancient cultures and its beauty. For too long it will be still considered as the "Stone of Heaven".

The amazing miniature world of the Montezuma mine, Sonora, Mexico

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The Moctezuma's mineralized zone is located in the central-eastern state of Sonora, Mexico, which belongs to the province of the Sierra Madre Occidental and the subprovince of Parallel Mountains and Valleys. The formation Arenillas of Paleogene-Neogene age is a package of volcanoclastic rocks containing one or more layers of limestone, which are hosting rocks of the mineralization. In the area plutonic rocks and dykes of felsic composition are prevailed. The ore deposit of the Moctezuma mine corresponds to vein structures, the majority corresponding to quartz veins of epithermal type having gold and silver values with a thickness up to 2 m.

The primary minerals found in the Moctezuma mine, also called the Bambolla, are pyrite, native gold, bambollaite and benleonardite. There are also polymetallic minerals such as native tellurium and minerals as silver, copper, iron, bismuth, mercury and uranium. A characteristic feature of the mineralization of this mine is the gold-tellurium association. The associated minerals having very flashy colors work as mineralogical tracking guide for gold deposit. In this case, nature took time to build a great diversity of endemic tellurium minerals. The above mentioned characteristics make this mine a wonder because they have made as many mineral discoveries of great beauty and capricious habits. The work puts special attention on Mexican type minerals found in Moctezuma mine. The names of this minerals have booth Mexican roots or takes their names from characters with great contribution to the Mexican and world mineralogy.

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Distribution of trace metals in sediment cores of Sunderban mangrove wetland, India and their possible toxicological effects on biota

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The study documents the comprehensive account on distribution and possible sources of heavy metals in core sediments (<63 µ particle size) from intertidal zone of the Sunderban mangrove wetland, India to evaluate geochemical processes influencing their distribution and possible environmental consequences. Sundarban is a typical and unique ecosystem of the Indian subcontinent formed at the mouth of the Ganges (Hugli) estuary. A significant ecological change is pronounced in this estuarine environment due to indiscriminate discharge of industrial and domestic wastes. An erratic behavior of the heavy metal distribution in sediment core was pronounced which might be ascribed to the metal deposition in coastal sediments through natural processes (erosion and atmospheric deposition) and anthropogenic activities (fishing, boating and tourist activities). The most interesting feature of the study is the downward increase of concentrations of majority of the heavy metals reaching overall maximum values at a depth of 24-28 cm of the sediment core. The intermetal relationship revealed the identical behavior of metal during its transport in the estuarine environment. Arsenic provides overall high values at those sites infested with mangrove vegetation which can be attributed to arsenic solubilization, especially through diagenetic processes in organic-rich mangrove sediments. Mercury concentration showed lack of any spatial variability with an almost uniform decreasing trend from surface to deep cores. The resulting compositional data set was tested by principal component analyses and cluster analyses. Pollution load index (PLI) and index of geoaccumulation (I_{geo}) revealed overall low values but the enrichment factors (EFs) for Pb were typically high for all the stations. The mean concentrations of As, Zn and to some extent Cu exceeded the Effects-Range Low (ER-L) values indicating that there may be some ecotoxicological risk to biota living in the sediments and thus deserve immediate attention.

Measurement of ammonium in silicates by reflection spectroscopy

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Ammonium minerals occur in a large number of environments, from sedimentary basins rich in organic matter to hydrothermally altered volcanic rocks in geothermal fields and epithermal deposit environments. Even though these minerals are interesting for geothermal and mineral exploration, they have not been properly characterized. This paper proposes the use of Short Wave Infrared Reflection (SWIR) spectroscopy for identification and characterization of two ammonium silicates found in the geothermal alteration in Acoculco, Estate of Puebla, Mexico. The studied samples were taken from drill-hole EAC-1 that belong to the *Comisión Federal de Electricidad* (CFE), and were analyzed by petrographic microscopy by a SWIR ASD spectrometer. These two mineral phases are Tobellite (ammonium illite) and Buddingtonite (ammonium feldspar). The intervals mostly rich in ammonium silicates correspond to the shallowest interval of the drill-hole EAC-1. Tobelite occurs in the first 260 m and, after, there is an enrichment in Buddingtonite. The two ammonium silicates could be the product of alteration of the caldera sequence rocks by vapor-dominated, ammonium-rich geothermal fluids. The origin of ammonium could be the organic matter-rich sedimentary basement of the caldera. Ammonium alteration could be one of the latest alteration stages in the geothermal system, taking into account the fluid low density and relative position in the sequence.

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Mineral deposits location and regularities of depth structure of the Earth's crust

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The present period of the Earth sciences development shows particular attention to investigate of the planet deep structures, which is caused by necessity to solve theoretical problems of geodynamics, forecast deeply lying mineral deposits sites more effectively, study issues of seismic danger, predict and lessen natural disasters damage, especially caused by earthquakes and volcanic eruptions, and also to research environment protection problems. Continuous and complex geological evolution of the Asiatic continent has been under way for practically all the Earth history. Different regions of the continent have common patterns both in forming tectonic structures and mineral deposits location.

Maps of deep-layer structures of the Earth's crust for the territory of folded system have been created on the basis of a 5-layer model to give an idea of general arrangment and distribution of masses above the basaltic layer of the crust. Some geological aspects of the problem of metallogenic relations, the distribution of polymetallic deposits and the deep structure of masses above the basaltic layer of the crust are discussed. Such investigations give the prognostic possibility for searching deposits on the basis of deep structure investigations. The obtained regional regularities of the deep tectonic structure and mineral deposits location are characteristics also for the areas of Asiatic continent, which can be used for searching prognosis.

An account on the prospects of cement grade limestone in the Markhu Formation, Lesser Himalaya, central Nepal

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The use of cement in the country noticeably began only since 1950's after the establishment of democracy. The requirement of cement for development works was met through import until country's first mini cement plant, Himal Cement Company Ltd. was established in 1974.

Due to increasing construction activities, the consumption of cement is continuously in the rising trend. At present, the annual demand of cement in Nepal is estimated (for 2009/10) to be around 2 million tons. It is likely to increase more than 3 million tons within next 5 years, with a conservative growth rate of 10%. The data shows that the production of government and private sector cement industries including clinker based units can only fulfill nearly 60% of its demand. In this context, more cement industries should be established by utilizing the raw materials available in the country. Laxmi Cement Industries Pvt. Ltd started to look for cement grade limestone in the nearest localities from Kathmandu to establish a cement plant.

In this regard, geological exploration was conducted to explore carbonate band around Trikhandi area of Malta Village Development Committee in Lalitpur district. The rock distributed in that area is medium to coarse grained, medium to thick bedded crystalline limestone. Intercalation of thin schist and quartzite are noted in the limestone occasionally. The limestone band is developed at stratigraphic upper level of the formation. The formation is of Precambrian age and belongs to the Markhu Formation of the Bhimphedi Group rocks (Stocklin and Bhattarai 1980).

Limestone of the Jhiku carbonate beds of the Benighat Slates and the crystalline limestone or marble beds of the Bhainsedovan Marble are now being used in cement industries in central Nepal. Occurrence of the cement grade limestone in the Markhu Formation provides opportunity to search for new areas of limestone prospect. The present site is located at a distance of 38 km south of Kathmandu along the Kanti Lokmarg. This paper discusses on quality and quantity of the limestone and the methods used to assess the economic viability of the deposit for establishment of a cement factory.

Detailed topographical and geological mapping over an area of 20 ha in the scale of 1:1000 was completed. A number of chip and channel samples were taken representing 80 m and 124 m at different locations respectively. In addition, three exploratory drilling of 178 m thickness were carried out over an exploration area of 20 ha at regular intervals of 100 m. The limestone beds extend further below the drilled depths and beyond the limits of 20 ha in east-west direction. Samples were analyzed and the results computed. The geological reserve in the detailed investigated area is estimated to be 3.40 million tons of proved categories and 12.83 million tons of probable categories. The weighted average of the chemical content of the limestone deposit is as given below:

	Category	LOI	Insoluble	R2O3	Fe2O3	Al2O3	CaO	MgO
Wt. Av.	Proved	38.3	10.97	1.57	1.04	0.53	47.6	1.64
Wt. Av.	Probable	36.1	8.54	2	0.83	1.1	47.4	2.05

The net mineable reserve in the studied area has been calculated to be 12.5 million tons of the cement grade limestone. All the parameters have been found to be well within the acceptable range for the production of ordinary portland cement. The present available reserve is sufficient to support an 800 - 1000 ton per day cement plant for a period of 26-33 years.

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A comparative study of geological controls on gas hydrate occurrences along the Indian continental margins

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Gas hydrates are ice-like crystalline solids composed of water molecules surrounding a gas molecule which is generally methane. Gas hydrates form under low temperature and high pressure conditions along the continental margins where water depths exceed 600-800 m and in permafrost regions. Biogenic methane can be formed if the sedimentation rate is greater than 30 m/Myr (3 cm/Kyr) and Total Organic Carbon (TOC) content exceeds 0.5%. Bottom Simulating Reflector (BSR) in the multi-channel seismic data provides the inference about the presence of gas hydrates in a region. Gas Hydrates have been reported in the offshore regions of the Indian subcontinent. They have been found in Eastern continental margin, Western continental margin and Andaman sea areas. The Western continental margin evolved during late Cretaceous period as a complex ridge-graben regime by the presence of several basement ridges as well as offshore sedimentary basins. The width of shelf of the Western continental margin is more than 350 km in northern region and 60 km in the southern region. Several graben and half-graben structures and fault-controlled subsidence have facilitated sedimentation along the western margin. The total sediment thickness in the deep basins varies between 1 and 10 km. Sedimentation rates vary between 0.44 and 0.88 mm/yr. The individual stratigraphic units consist of shales, limestones, sandy shale, siltstones and clay-siltstone units. Total organic carbon content exceeds 4% for the Western continental margin. All these conditions would be favorable for formation of gas hydrates in western margin. Eastern continental margin and Bay of Bengal evolved during early Cretaceous period. The margin on the west side (off the east coast of India) is characterised by narrow shelf and steep continental slope up to 1500 m water depth in the northern part and increases to 3000 m in the southern coast. The margin is associated with slope failures, slumps and shale tectonics.

The sediment thickness varies from 2 to16 km. High sedimentation rates 20–40 cm/Kyr have been reported for the Bay of Bengal. The sediment flow is manifested in the form of deltas and delta fronts. Lithological sections obtained from drilled wells in Krishna-Godavari offshore basin comprise predominantly clay stone, sandstone and shale units. TOC content exceeds 1.6% for the Bay of Bengal. All these conditions would be favorable for formation of gas hydrates in the eastern margin. The heat flow in the Eastern continental margin is somewhat higher than in the Western continental margin. The indicated geothermal gradient in the Bay of Bengal of the order of 2° per 100 m is highly favorable for formation of thick and massive gas hydrates. The Andaman sedimentary basin has formed under a convergent plate tectonic regime. Lithological section in the Andaman basin consists of sandstone, shale and clay stone units. The TOC varies from 2.4 to 5.2%. Well defined BSRs have been found in the Andaman Sea indicating the presence of gas hydrates. An attempt is made to study the geological controls on gas hydrate formations in the varying tectonic settings. The role of various geological features such as tectonic setting, nature of sediments, sedimentation rate, organic carbon content, general morphology, salinity, thermal regime and tectonic features will be discussed with examples of gas hydrate/BSR occurrences in the western offshore, eastern offshore and Andaman offshore regions.

Characterization and modelling of gas discharge in Lower Dolpo, Western Nepal

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Carbon dioxide (CO_2) discharge zones, presumably from metamorphic decarbonation, have been found near hot springs at the Main Central Thrust (MCT) in Ccntral Nepal. These discharge zones, associated with high radon-222 flux, are being monitored as a function of time to study a possible relationship with the seismic cycle. For this purpose, however, western Nepal, where no megaquake has occurred since 1505, offers an important alternative. Following the strategy implemented in central Nepal, gas discharges have been searched around hot springs located at the MCTzZone. Three sites have been studied in Lower Dolpo: One hot spring located near Rupa Ghad River, 4 km south-east from Juphal airport, one located near Suli Ghad River, 2.5 km north-east from Sulighad village, and another one located near Ghatta River, 2.5 km south from Sahartara village. While CO_2 fluxes, initially sampled randomly, were found to be rather small, significant gas discharges were found to anomalous radon fluxes. Systematic investigations later confirmed this initial indication. While radon fluxes, at some places, were found comparable to Central Nepal, CO_2 fluxes remained lower. A preliminary model of radon transport indicates that this observation requires that, in addition to CO_2, another carrier gas must be present in Lower Dolpo. This model is based on the measurement of the radon source term (effective radium concentration) obtained with more than 40 rock samples from Lower Dolpo. Implications and perspectives of these first results will be presented.

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Platinum Group Element (PGEs) occurrences and exploration studies in India – current status

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The platinum group elements (PGEs: Ru, Rh, Pd, Os, Ir, Pt) abundances in crustal rocks formed from silicate melts and magmatic volatile phases, are widely studied to identify the fundamental geochemical controls of their distribution in Earth's crust and to understand the primary mantle derived magmatic processes as well as the secondary enrichment processes responsible for the formation of PGE mineralized zones in different geological and tectonic settings all over the world. PGE and Au generally occur at exceedingly low concentration levels (ng/g) in crustal rocks. PGEs are currently receiving world-wide attention as attractive exploration-targets because of their extensive utility in high technology applications and commercial value. Hence, the discovery of new PGE deposits/mineralized zones is of great economic importance for any country.

PGE mineralization occurs in layered igneous complexes, komatities in greenstones and ophiolite belts. In India their occurrences have been reported in the last three decades mostly from the plutonic to hypabyssal magmatic intrusions of Archaean - Early Proterozoic age, mostly emplaced into the cratonic areas to the south of the ENE-WSW trending Son-Narmada Lineament. Some of the layered ultramafic complexes + chromite have indicated moderate to high anomalous PGE values. Such prominent occurrences are reported from Sukinda and Baula – Nausahi areas of Orissa in Singhbhum Craton, Sittampundi area of Tamil Nadu in Southern Granulite Belt, Madawara igneous complex, Bundelkhand massif, Central India and Hanumalapura area of Karnataka in Dharwar Craton.

For identifying economically viable deposits and their mining, detailed geophysical, geological, petrological and geochemical studies are essential on massive scale in potential areas. Recent studies show that there is a tremendous potential for PGE-mineralisation in mafic-ultramafic and ophiolite complexes, and the fine grained sediments such as sulfide bearing black shales, occurring in different parts of India. It is essential to intensify our research efforts in this direction by establishing analytical centers with capabilities for the precise estimation of PGE and for the required mineralogical studies in different parts of the country. Only consorted and integrated efforts towards a conceptual understanding of the nature of the inter-relationship between the magmatic sulfides and their host rocks will facilitate the discovery of hidden Ni and PGE resources that surely occur within India.

Exploration of hydrocarbon in Proterozoic basins using geochemical tracers

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Near-surface geochemical prospecting technique is used to detect the surface anomalies of hydrocarbons, which give the direct evidence of their occurrence in the subsurface. The light gaseous hydrocarbon concentration data in shallow soils can be used for i) preliminary assessment of hydrocarbon generation potential of a basin, ii) distinguishing productive and non-productive basins and iii) predicting possibility of oil and gas reservoirs in the area. The surface geochemical exploration data when prudently integrated with geological and geophysical analysis can form a better exploration tool to reduce exploration risk.

In the present study, one of the oldest Proterozoic Vindhyan Basin was selected for hydrocarbon exploration. The Vindhyan Basin is the largest Proterozoic basin in India with an area of >105 km^2. It is intra-cratonic basin comprising of shale, limestone and sandstone horizons with a thickness of ~4300 m. Most of the Vindhyan are un-metamorphosed. Ray et al (2002) has reported the age of this basin is ~1600 Ma. The occurrence of organo sedimentary structures and fossils indicate that the basin may have potential source rocks for the generation of hydrocarbon. The basin is constrained by Great Boundary Fault and Narmada-Son lineaments. The combined gravity, magnetic and seismic studies reveal deepening of the basin towards southern margin.

Soil samples were collected in the depth range of 1.2 to 3.5 m at intervals using metal hollow metal pipe by manual hammering to a required depth. The cores retrieved were wrapped in aluminum foils and sealed in poly metal packs. The sample number, core depth and GPS location (Latitude & Longitude) were marked on each sample in the field.

The light gaseous hydrocarbons were desorbed from soil core samples by treating 1gm of sample with orthophosphoric acid in vacuum. The CO_2 evolved from soil carbonates is absorbed in KOH solution and the desorbed light gaseous hydrocarbons are collected by water displacement in a graduated tube fitted with rubber septa. The volume of desorbed gases is recorded and 0.5 ml of the gas sample is injected into Varian CP 3380 Gas Chromatograph fitted with Porapak-Q column, equipped with Flame Ionization Detector. The gas chromatograph was calibrated using an external standard with known concentrations of methane, ethane, propane, i-butane and n-butane. The quantitative estimation of light gaseous hydrocarbon constituents in each sample was made using peak area measurement. The moisture content was determined and the gas concentrations are reported in ppb on dry weight basis. The accuracy of measurement of C1 to C4 components is < 1 ng/g.

The concentration of CH4, C2H6, C3H8, iC4H10 and nC4H10 desorbed from the soils vary from 1-2500 ppb, 1-550 ppb, 1-180 ppb, 1-40 ppb and 1-30 ppb, respectively. The cross plots between C1-C2, C1-C3, C2-C3, C1-?C4 and C1-?C3 shows linear correlation (r ~0.9) between methane and higher hydrocarbons. This indicates that the light hydrocarbon components are generated from thermogenic source and the effect of secondary alteration during their seepage towards surface is insignificant. Concentration of methane falls in three groups i.e. >200 ppb, 100- 200 ppb and <100 ppb. The cumulative frequency distribution curves for C1 and ?C2+ are bimodal and polymodal in nature.

Pixler (1969) proposed a variation diagram using the ratios of C1/C2 and C1/C3 to distinguish the non productive zone from the oil/gas producing zone. Ratios below 2 and above 60 are from non productive zone. These ratios clearly define the transition between biogenic and thermogenic gases. In the Pixler plot 70% of these samples fall in the oil window and rest in the gas window. Concentration of light hydrocarbon data plotted in Geological map shows the anomalous zone in the southern part of the basin. The geochemical study on the soil samples indicates that this part of the basin is a warm area for hydrocarbons and suggests further exploration using geophysical techniques.

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Reconnaissance survey of kaolin deposit at Meetiyagoda in Sri Lanka

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Kaolin is one of the clay minerals and is used as one of the main raw materials in ceramic industry. Clay is used as a raw material in many industries. However, high quality kaolin needed for ceramic industry. Therefore, demand for kaolin has increased with the expansion of the ceramic industry in Sri Lanka within last two decades. According to the literature, there are two known kaolin deposits in Sri Lanka. They are located at Borellasgamuwa in Western province and Meetiyagoda in Southern province. To estimate the variation of the thickness of the kaolin deposit at Meetiyagoda deposit and to quantify the volume of the deposit, reconnaissance survey had carried out. Initially ten bore-holes were made at a distance of 500 m using hand augur. After identifying the possibility of extraction of high quality kaolin in the study area, samples were collected at 50 m X 50 m grid intervals using hand auguring method. At each sample location, continuous samples were observed from top to bottom. Auguring depths were varied from location to location. However, average auguring depth is about fifteen to twenty meters. Observations at all locations were recorded in continues log sheets. Also samples were collected at about every 25 cm depths at each sample location. A chemical analysis has carried out for these samples to clarify their whiteness and brightnesses. According to this reconnaissance survey it was noted that the kaolin deposit at Meetiyagoda was formed due to weathering of feldspars in pegmatites and granites. Also it was observed that the kaolin occurs as isolated in-situ deposits. Thickness of the good quality kaolin varies from one meter up to about six meters.

Exploration results of Iron ore deposit at Thosey, Ramechhap, Nepal

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Thosey Iron ore (Hematite) deposit is located at about 200 km east of Kathmandu at Thosey VDC of Ramechhap District, central Nepal. Small scale mines were in operation by the local people from 1865 onwards till 1952 or so. Existence of over 1000 of old working pits in the deposit site, few smelting places around and existence of remnants of a gun factory at Thosey Megchan are the evidences of small scale mine operations at Thosey. Local minors used to smelt the metamorphosed hematite locally and the blacksmiths make agricultural tools, utensils, knives, iron chains etc. The government had also established a gun factory based on the refined iron from Thosey.

For the first time Geological study of Thosey iron prospect and preliminary evaluation of the deposit was carried out by Kaphle and Khan (1995, 1996), Kaphle et al. (2006) from Department of Mines and Geology (DMG). Thosey prospect area is represented by Dorje Khola Formation (?) of Nawakot Complex. This Formation is divided into Arubote Schist Member and Dorjekhola Phyllite Member. Arubote Schist member is further divided into (i) Calc Mica Schist unit which is represented by medium to coarse grained light gray to gray calc mica schist locally with few siliceous crystalline dolomite/marble bands and (ii) Chloritic Mica Schist unit which is represented by fine to medium grained, greenish gray chloritic mica schist occasionally with few minor basic rock bodies and quartz chlorite veins. The Hematite mineralized ore body lies at the upper part of this unit just below the calcareous mica schist. Each 1-3 m thick two mineralized bands were traced in 4 km strike length by compass tape traverse and shallow trenching and pitting.

N and C Minerals Pvt. Ltd. got the prospecting license from DMG to explore Thosey iron deposit in September 2007 and started follow up and detail exploration activities in four phases. It has prepared the Regional Geological map covering the whole lease area, semi detail geological map of the prospect area (at 1: 10,000 scale) and traced the mineralized body by additional trenching and pitting works. Later on during Second and Third phase Topographic maps and detail Geological maps (scale 1:2000 scale) of two separate blocks (Arubote-Sanodadakharka sector and Singati-Barappu sector) covering 100 hectare in total and geological cross sections were prepared. The area was extended further south from Jhoreni to Singati and further west from Singati to Barappu old working sites. At the same time few more trenches and pits were excavated and chip, channel and bulk samples from the ore body were collected and analyzed. On the basis of geology, nature of mineralization, size and shape of the ore body, it has recalculated the possible Geological reserve as 15.91 million metric tons with an average grade of 45.3%Fe including all the three blocks (Block-I. Arubote-Sanodadakharka Sector, Block-2. Dadakharka-Bhosbhose Sector and Block-3. Singati-Barappu Sector). During 4th phase of exploration a Mining plan, EIA study and Feasibility study of the deposit is in progress. N & C Minerals Pvt. Ltd. has plan to obtain Mining License from DMG and start mine development works by later part of 2010.

The Dadakharka-Bhosbhose Sector (central part) is under very thick overburden of rock mass and earth materials. Therefore, it is wiseful to starts first with opencast mining in Singati-Barappu and Arubote-Sanodadakharka sectors and later start underground mining in Dadakharka-Bhosbhose sector.

Preliminary beneficiation by simple washing of selected ore samples and removing some unwanted gangue minerals like chlorite, mica, quartz etc. helped to upgrade the low to medium grade ore (32-45% Fe) up to 62% Fe content. It is recommended for metallurgical and industrial testing of the ore just to confirm that the ore is suitable for making sponge iron which is demanded by local iron and steel industries.

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Future of water in Pakistan

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Water shortage is one of the greatest threats to the human beings on the Earth. Within the next 25 years more water conflicts can emerge between the countries. This warning may be overstated but Pakistan's water situation is deeply troubling. In recent years, Pakistan has suffered from severe water shortages, flooding and declining water quality. The worsening water crisis must be resolved if the country is ever to achieve stability and develop. Using water more efficiently is a necessary but insufficient strategy. Far deeper changes are required that includes understanding the dynamics of changing weather patterns, pressure on resources due to unchecked population growth and institutional capacity constraints in this sector.

The paper describes the issues affecting the water availability in Pakistan including the effect of Indus Water Treaty on water resource.

Potential of failures of small scale hydropower projects in Nepal due to adverse geology

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Annually some 35 to 45 hydropower electricity projects including micro, small and large are built in Nepal. In recent days, the trends of building hydropower projects are interestingly increasing and so does the investment. At a time when Nepal is reeling under an acute power shortage problem and load shedding is going throughout the year, this is a good gesture for countrymen. Unfortunately most of those are built without considering the potential threat from geo-hazards. In consequence, most hydropower projects suffer serious damage from geo hazards and some of them are at a great risk of failure. If prevention and correct remedial measures are not taken, for sure, a huge investment on hydropower sector will be worthless.

Many hydropower structures have been built on poor geological areas that are prone to geo-hazards (landslides and flood). Sadly these geologically poor areas are either almost neglected for protection from the possible geo-hazard failure or poorly treated with insufficient measures (Fig. 1). Mitigation of geo-hazards is highly important for the sustainability of hydropower projects. This paper is intended to present some case examples about the failed and potential hydro power project prone to failure in Nepal where the author has done the site investigation. Together, more emphasis is given about the poor practice of mitigation measures, which are not only improperly built but are also inadequate to prevent the effect of geo-hazards.

Fig. 1: Slope failure just down the forebay of the Mardi Khola small hydropower project (3 MW) (July 2010)

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Geological challenges in the development of hydropower in Nepal

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The major geological challenge for development of underground structures is to predict and confirm reliable rock mass condition due to jointed, faulted, sheared, and folded nature of rocks. Constructing tunnels, dam and powerhouses through such rock mass is risky, and are susceptible to caving, rock squeezing, water ingress, slope instability, structural failure and related other process. These geological uncertainties create great difficulties and can delay the construction schedule which in turn can offset the estimated cost of the project negatively. A thorough and convincing geological investigation is therefore, very essential to identify and predict reliable rock mass condition prior to the actual construction that can minimise project cost significantly. Proper geological investigation is the key to planning, predicting rock and soil behaviour, economical design, and cost estimation of any hydropower project. The degree of accuracy in predicting geological conditions, evaluation, and interpreting the quality of rock mass during planning phase is a key measure for the successful completion of any hydropower project. In this paper case studies of such geological challenges faced in different hydropower projects in Nepal are highlighted.

Influence of thrust planes in the planning of hydropower projects in Nepal Himalaya

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By virtue of their origin, the presence of thrusts and faults implies weak zones represented by crushed rocks and sends alarm bells ringing for the planners of hydropower projects. The Tamakoshi, Likhu and Dudhkoshi basins on the left bank of the Sunkosi River in Central Nepal are dissected by a major thrust where the Precambrian Ulleri Formation has been thrust over the younger Ranimatta, Seti and Naudanda formations. This northward extending thrust merges with the Main Central Thrust (MCT) where the Precambrian Himal Group of rocks overrides the younger formations.

In Tamakoshi sub-basin (Ramechhap District), the thrust cuts across the Tamakoshi river at its confluence with the Khimti Nala near Devitar/ Khirni on Manthali road (powerhouse of the 60MW Khimti HEP), and in Likhu sub-basin, the thrust cuts across the Likhu River, about 500 m upstream of its confluence with the Leti Khola in Jili area (near Sirise, Okhaldhunga District). Both these occurrences are highlighted by the well exposed thrust planes that have been documented in details as a part of the geological investigations for hydropower projects in these areas. Contrary to the general belief, the thrust plane has been found to be a sharp lithological contact between the overlying augen gneisses of the Ulleri Formation and the underlying phyllites belonging to the Naudanda Formation. There is no trace of any weakness like crushing along the well exposed contacts.

The sharpness of the lithological contact along the thrust plane provides further evidence of the benign geotechnical character of the Main Central Thrust that has been found to be equally sharp at hydropower project sites like Tala HEP in Bhutan and Nyamjang Chhu HEP in Arunachal Himalaya of India.

The thrust cuts across the proposed structures like head race tunnel and pressure shafts and, by virtue of its lithological sharpness, is not expected to pose any special problem of excavation and support.

The paper provides geological details of the thrust under reference and discusses its implications in the light of several other hydropower projects in the Himalayan terrain.

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Himalayan mountain building and fragile ecosystem

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The Himalayan arc extends about 2,500 km from northwest to southeast incorporating from west to east the loftiest peaks,viz., Nanga Parbat (8,125 m), Everest (8,848 m), and Namcha Barwa (7,755 m). The width of the belt varies from 250 to 350 km. The mighty Himalayas and the Karakoram, embodying the largest concentration of lithospheric mass, grew south of the Pamir. The Himalayas consist a fascinating geological record of Precambrian to present and terminate both east and west with spectacular syntaxial bends.

The collision of India with Asia is the most facinating event to have occurred in the past 100 Ma. It is responsible for uplift of the Himalayas and Tibet and rejuvenating tectonic architecture of Karakoram and Kun Lun, thus resulting changes in the Earth's orography and consequent climate change are directly tied to this ongoing collisional event. This collisional event has been argued for long to have responsible for geological, geochemical and climatological consequenses of global extent. The uplifting process is still going on with the approximate rate of one cm. per year with continued erosion and denudation. The eroded material from its rugged topography is repeatedly and regularly being shed into different depositional settings within the Himalayas to Bay of Bengal, Arabian Sea by youthful rivers drainage network.

Global warming responsible for recession of Himalayan glaciers at alarming rate is a serious matter of concern for the survival of humal civilization in the Indo-Gangetic plain.

The stress and strain caused due to plate motion is responsible for frequent earthquakes in this region making enormous loss of human life.

Geoelectric resistivity sounding for deciphering hydrogeology and locating deep tubewell installation sites in Pouroushava area of Bagerhat, Bangladesh

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The study area includes Bagerhat Pourashava area and its surroundings under Bagerhat Sadar Upazila covering an area of 7.53 sq. km with a population of about 50,000. Bagerhat is a coastal district and the subsurface geology is complex. As in other areas of the coastal belt the quality of ground water in the area is also variable. For ground water development in the study area the shallow aquifer is not suitable as the water is mostly saline to brackish except some isolated fresh water pockets of limited yielding capacity. The deep aquifer is also not very homogeneous in water quality. In the northwestern part it bears fresh water but water quality deteriorates south-southeast with higher depth of occurrence. A comprehensive study is carried out to demarcate the aquifers and to judge the water quality to find the suitable location of the deep tubewells in Bagerhat Pourashava area.

15 geoelectric soundings have been executed in the study area using Schlumbereger configuration with maximum spreading 1200 m. Based on the vertical electrical sounding interpretation results the subsurface sequence is divided into following geoelectric units: The top unit has resistivity less than 5.0 Ωm with a thickness of 1.5 to 20m and represents the top clay-silty/sandy clay layer. The second geoelectric unit represents a very fine to medium sand with thin clay lenses and resistivity varying from 5.0 Ωm to more than 100.0 Ωm with a thickness of 16 to 135m. The resistivity of the following unit range from 1.40 Ωm to 4.8 Ωm and thickness varies from 100 m to more than 300m, respectively. The deepest geoelectric unit shows resistivity from 8.0 Ωm to 18.0 Ωm and represents the deep aquifer. The depth to the aquifer varies from 235 m to 355 m. The most suitable site for groundwater development from the deep aquifer is in the vicinity of East Saira of Shatgambuj union.

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Interference and inefficiency of water wells: a constrain of water conservation in Naogaon Upazilla, Bangladesh

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Systematic hydrogeological studies relating to aquifer properties, well properties and actual location of water wells of two Unions of Naogaon Upazilla, northwestern part of Bangladesh has been evaluated. The surfacial deposits of the study area are classified as Recent Floodplain and Older Alluvial deposits (Barind Unit). The main aquifer zone comprises of medium to coarse sand with gravel having a variable depth of 18 to 30 m. This zone is considered as most productive zone and corroborated present days activities of groundwater extraction. The transmissivity value varies from 848 m^2/day to 3868 m^2/day both in the Barind area and the floodplain respectively.

Present study found that most of the wells are interfered with each others, ultimately reduce the optimum discharge. For avoiding such economic loss wells should be installed at least 2.7 km and 1.4 km distance apart in the floodplain and Barind area respectively.

The overall efficiency values revealed that the well efficiency value is high (98-80%) in Barind and low (60-46%) in floodplain area. Lower efficiency values signifies that the design as well as well construction procedures are improper and need to be further development to obtained desired discharge.

Comparison of surface water and groundwater arsenic in the floodplains of the Ganges and Niger Rivers

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The widespread contamination of groundwater by Arsenic (As) in the floodplain of the Ganges River (Bangladesh, West Bengal, Terai region of Nepal) has been well-documented. The dominant paradigm for elevated groundwater arsenic in south Asia is the reductive-dissolution model, according to which, in the strongly reducing conditions of the thick sedimentary package of the Indo-Gangetic Plain, As is released from adsorption sites on Fe oxyhydroxides after dissolution of the Fe oxyhydroxides by micro-organisms. By this logic, elevated groundwater As should occur in any major river floodplain. A competing paradigm that has never been adequately tested is that elevated groundwater As results from excessive use of phosphate fertilizers that displace As from sediment adsorption sites. The objective of this study is to test the reductive-dissolution and phosphate-displacement models in the floodplain of the Niger River in Mali. Water samples have been collected from 36 dug wells, seven tube wells, seven public faucets and two cisterns fed by tube wells, three stream sites, and one lake in the city of Bamako and the rural commune of Ouelessebougou. Electrical conductivity, pH and water temperature were measured on site. Concentrations of Fe, Cu, Mn, K, nitrate, phosphate, sulfate, hardness and fluoride have been measured with a spectrophotometer and samples have been returned to UVU for measurement of As and chloride. Preliminary measurements show elevated concentrations of As (As = 0.012 mg/L) in the Niger River upstream from sources of anthropogenic contamination similar to what is found in the tributaries of the Ganges River in Nepal upstream of the Indo-Gangetic Plain. Phosphate concentrations in wells are both elevated and highly variable (up to 155 mg/L), probably due to the widespread contamination of groundwater by human waste. This unfortunate occurrence could make Mali a natural laboratory for testing the phosphate-displacement model. Further results will be reported at the meeting.

Potential of shallow ground water recharge through rainwater harvesting in the Kathmandu Valley, Nepal

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Infiltration and recharge test were carried out in fifty locations in urban and sub-urban area at the Kathmandu Valley and to study the variation, the tests were carried out in three seasons: pre-monsoon, monsoon and post-monsoon. The test was carried out by three different methods: recharge test in wells, infiltration test in pits and by using infiltrometer.

Sites located in Chapagaon Formation and Gokarna Formation consisting of relatively coarse grained sediments, show high infiltration and recharge rate while those in Kalimati Formation consisting of fine grained sediments show low infiltration and recharge rates. Core area of Patan Sub metropolis and Kathmandu Metropolis as well as some terraces of higher areas in Kathmandu indicate high to moderate potential for rainwater recharge. Some exceptions are the terraces of Khumaltar and Minbhawan which show low potential for rainwater recharge probably due to geological reasons. Flood plains and other low lying areas have low infiltration rates primarily due to fine sediments and higher water table. Infiltration tests carried out in Thimi, Bhaktapur and Kirtipur Sub metropolis show mostly moderate to low infiltration rates.

Economically as well as availability of open spaces for constructing recharge structures and small pits are more effective for rainwater recharge at household level while dug wells are better option in large community of *bahals* and *chowks* (mean surrounding courtyard and crossroad areas in Nepali). For a pit with depth of 0.80 cm, pit size of a = 0.21A; a =0.24A; a =0.26A (Where, a =required area of pit; A = area of the roof or catchments) are sufficient to hold rainwater from roof for recharge in areas of low, moderate and high infiltration rates.

Arsenic and other heavy metals in the Sun Koshi and Sapta Koshi Rivers, eastern Nepal

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Elevated fluvial arsenic has been found in many tributaries of the Ganges River system in Nepal, although fluvial arsenic is very low downstream in West Bengal and Bangladesh. The objective of this study was to determine where in the Ganges River system arsenic precipitates or becomes adsorbed onto sediments. The objective was accomplished by rafting the Sun Koshi River to the Sapta Koshi River across eastern Nepal from Dolalghat to the Sapta Koshi Barrage at the Indian border (219 km), and collecting water samples twice daily or whenever a major tributary was crossed, and collecting sediment samples daily for a total of 27 water and 11 sediment samples. A spectrophotometer was used to measure As, Fe, Cu, Mn, Zn, Ni, Co, and Cr. Of water samples collected upstream of the confluence of the Sun Koshi with the Sapta Koshi (upstream of the Indo-Gangetic Plain or Terai region), 45% showed dissolved As levels exceeding the WHO drinking water standard (As = 0.01 mg/L). No detectable dissolved As was found in the Sapta Koshi River within the Terai region. There were no significant differences in any other parameters between samples collected within and upstream of the Terai region. Deposition of the coarser sediment at the edge of the Terai region increases the distribution coefficient of the water-sediment mixture, resulting in the adsorption of nearly all dissolved As onto the finer sediment still in suspension. The distribution coefficient of the other metallic cations does not change since they are much smaller than the arsenic oxyanion and can still diffuse between the deposited and suspended sediment. We are suggesting that arsenic contamination of groundwater upstream of the Terai region results from recharge by losing streams with elevated As, while arsenic contamination in the Indo-Gangetic Plain results from transfer of As from sediment to groundwater.

Rainwater recharge of shallow aquifers–a viable solution to address water shortage in the Kathmandu Valley, Nepal

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Coping with water shortage has become a daily routine for most residents of the Kathmandu Valley even in the monsoon season. Sale of water (in bottles or through tankers), something unheard of in recent past, has become a thriving business nowadays. Increase in population and sealing of the ground surface due to urbanization have drastically reduced infiltration from the surface. It is estimated that at the current state of growth, not a single drop of water is expected to infiltrate from the surface of Kathmandu Municipality in 36 years time.

Alluvial sediments of variable thickness (Max. 35 m) in the central and southern part of the valley and comprising much of the residential area make up the shallow aquifer system. In the north the shallow aquifer is much thicker. A thick impermeable clay bed locally known as 'Kalimati' separates the shallow aquifer system from the deep aquifer. A pilot project initiated to recharge shallow aquifer in Lalitpur Sub metropolis, Nepal, has produced encouraging results so far. 25 recharge wells and 25 recharge pits helped recharge 7621.2 m^3 of rainwater to shallow groundwater. This is only 0.51 % of the total rainfall falling in the area. Installation of recharge facilities in the remaining wells in the area is expected to deliver additional 16,525 m^3 of water. The result has been encouraging as the recharge locations were strategically located with reference to subsurface geology, topographic gradient, water table, need assessment and local cooperation.

Addition of rainwater into the groundwater has also diluted the salt concentration in groundwater there by improving the quality of water. However lack of proper selection of monitoring wells, reliable monitoring data and presence of multiple aquifers have so far produced little visible impact in the monitoring wells. The awareness the project has created is impressive and is likely to help emulate similar recharge projects in other parts of the valley including Kathmandu and Bhaktpur.

Developing effective groundwater monitoring mechanism for Kathmandu Valley, Nepal

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Groundwater has now become a major natural resource contributing the water supply system in Kathmandu Valley and people have been using groundwater since ages through dug wells and stone spouts. Usually groundwater gets recharged during rainfall period. Rise in urbanization has increased the surface sealing which has reduced the infiltration from the surface. Similarly exploitation of the shallow groundwater aquifer has been thoughtlessly amplified with exceed in its replenishment capacity. The result has been decrease in ground water level over the years. However, very little data is available to support the depletion in groundwater level. Monitoring works have been erratic and unplanned. Also many question the reliability of the available data and the selection of the monitoring wells as most of them are extraction wells or near extraction wells. Hence, the need for developing sound and effective groundwater monitoring mechanism has been felt over the years.

The major objective of the study is to propose for the development of sound and effective monitoring mechanism network for groundwater in Kathmandu Valley. The study shows that most of the deep wells are located in northern groundwater district. According to the sediment distribution, this is the potential area for the groundwater exploitation for drinking water in Kathmandu Valley. Central and southern groundwater district have mainly confined aquifer below thick impermeable clay layer which yields less than the northern aquifer. Effective groundwater monitoring mechanism can give a detailed picture of the aquifer characteristics of various strata and an indication of the water quality. This permits to identify the potential aquifer and to place the well screen in the most desirable position.

From the litho logs of the deep wells, it is found that the Kathmandu Valley has more than 10 aquifer horizons of variable hydrogeologic characteristics. It is also observed that the aquifer bodies are not continuous and are not of the same thickness all over the valley. Litho log data also shows that the Kathmandu Valley consists of one large continuous basin at places locally divided into sub basins by the outcropping of basement rocks.

The NWSC is the largest user abstracting about 78.3% of groundwater in the Kathmandu Valley. Hotels are the next largest user followed by industries and government institutions using about 8.4% ,7.9% and 5.3% respectively. Deep aquifers have a natural water quality problem. Concentrations of iron, manganese, dissolved gases (e.g. ammonia, methane etc.) and BOD are high. This is due to the interaction between water and rock- soil matrix. EC values and other parameters in deep aquifers are found to be increasing towards the western part of the Kathmandu Valley. Similarly, soft, very low salinity water is found in northern part of Kathmandu Valley which implies recent recharge into shallow aquifers and also into deep aquifers in the northern part of the valley. Systematic monitoring of selected wells representing different aquifer horizons should provide not only changes in groundwater quality but also the recharge system and recharge potential of the aquifer.

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Two-dimensional numerical modeling of surge shaft at upper Tamakoshi Project, Nepal

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Stability analysis and design of optimum rock support for underground structures in the Himalaya are challenging issues due to the complex nature of the rock mass in the region. Numerical modeling of complex underground structures such as the proposed surge shaft for Upper Tamakoshi Hydroelectric project may help to understand the characteristic behavior of the rock mass. Hence, the main purpose of this paper is to carry out two-dimensional numerical modeling of the proposed surge shaft with main emphasis on the stability analysis and optimization of rock support. The study includes estimation of representative input variables needed for the modeling based on the data from pre-construction phase engineering geological investigations and literature review, analysis of the in-situ stress condition, assessment on the redistribution of rock stresses caused by shaft excavation, evaluation on the extent of yielding in the shaft. Finally, rock support optimization is carried out to stabilize the instability (plastic deformation) caused by the change in stress condition. The results are compared with rock support estimation using empirical approach.

Landslide susceptibility mapping using frequency ratio and logistic regression: a case study from Phidim, eastern Nepal

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The aim of present study is to produce landslide susceptibility map at Panchthar, Nepal, using Geographic Information System (GIS) by means of frequency ratio and logistic regression. The ArcView was used as primary software for the management of spatial data. Landslide locations were identified from the field survey. The aerial photograph was used to determine the lineaments in the study area. Ten different factors such as slope, aspect curvature, distance from drainage and so on, and their respective relations with the occurrence of landslides in the study area were analyzed. These factors were used to analyze landslide susceptibility by means of frequency ratio and logistic regression. The landslide susceptibility maps produced by both the methods were quite analogous. The frequency ratio suggests that distance near to drainage and slope angle higher than 30° are main factor contributing landslide occurrences.

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Landslide susceptibility mapping in west Nepal using active fault map

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Though east Nepal was struck by 1934 Bihar earthquake (M84), recently no large earthquake has occurred in west Nepal. Therefore, it is necessary for west Nepal authorities to prepare earthquake disaster including landslides. Mapping susceptibility for earthquake inducing landslide is one of the important preparations against the disaster, and many previous studies have mapped it using Digital Elevation Model (DEM). We choose the study area of 27 km by 27 km in Mahakali zone and in this presentation we propose the method of the mapping it using not only DEM but also active fault map produced by another study.

Foundation characteristics of the soils of different parts of Nepal

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This paper deals with foundation characteristics of the soils of different parts of Nepal. Foundation characteristics of the soil depends upon the soil properties such as soil type, grading, liquid limit, plastic limit, density, cohesion, compactness of the soil in the layer, friction angle etc. This paper deals with the multiple approaches carried out to find out foundation characteristics of the soil. In this study a total of 14 sites were selected. 2 sites were from the hilly region 2 from the inner Terai and 10 from the Terai.

In each of the site two test sites were selected. In each test site Simplified Penetration Apparatus tests were carried out. This is the simple instrument designed for the shallow soil slope investigation. Here this instrument was used to characterize the subsurface soil horizons using the Nc number (the no. of blows required to penetrate the 10 cm.depth). For each of the site two tests were carried out so that direct comparison can be done. Each site is accompanied by the auger test so that direct observation of the soil at depth of penetration can be done. Cross litholog of each site along with the Nc value was used to prepare the detailed subsurface soil horizons. Soil samples from different depths in each site were collected for laboratory test. Undisturbed soil samples were collected for the direct shear test and disturbed samples were collected for the soil classification, LL- PL test, density and other test. Bearing capacity of the soil thus obtained from the laboratory was compared with the soil type of the depth and the Nc value at that depth. From the study it was found that the Nc value depends upon the types of the soil and on the compactness of the soil. Once the standard value is obtained it can be used to determine the bearing capacity of the soil reducing the laboratory test.

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Geological and bioengineering investigation on the Dhungagade–Aarughat section of Gorkha–Aarughat Road, Nepal

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This paper presents typical road stabilization works implemented in Dhungagade–Aarughat Road section, 37.7 km of Gorkha–Aarughat Road under Decentralised Rural Infrastructures and Livelihood (DRIL) Project, Nepal. Upgrading of earthen road to gravel standard and making the road all-weather condition was objective of the project. Investigation revealed of potential threats to road by two major landslides *viz*. Kokhe Ahale at Ch 7+000 and Koyabhanjyang at Ch 21+100 where road sections are damaged obstructing traffics. Temporary access is opened and traffic flows are brought normal. Another site at Ch 17+820–18+240 known as Khanchowk loops is kind of future problem if not carefully engineered at the time of road widening. There are 56 number other medium to minor sites all scattered along the road where standard bio-engineering slope stabilisation techniques are prescribed.

The terrain is represented by metamorphic rocks i.e. phyllite, schist, and quartzite. About 34 km road length passes through colluvium and residual soil with occasional appearances on short section of rock outcrops. About 3.7 km road runs along the lower valley slopes through alluvium and rock cliff exposed by Budhi Gandaki River. Within the 37.7 km of road distance, there are two faults (including local vertical fault near Ahale Bhanjyan landslide) and three thrusts intersect to road alignment and other two faults exist within the vicinity of road corridor. The road runs through rouged terrain of mid-hills with general cross slopes ranging from 15° to 60°. Source of quality construction materials are hard to find along the road corridor. There is one potential quarry site identified at Ch. 19+000 (Gyampesal), which is in the private land. Up on the operation of said quarry, one house will have to be relocated.

Twenty-year data from Gorkha Bazar station reveals, GAR corridor receives 1,776 mm mean annual precipitation with the 10 years record. One standard nursery and two stock nurseries are required for production and multiplication of plants. All planting materials are required to produce/grow in project nurseries. Skilled nursery staffs are required for operation and maintenance. All sites bio-engineering designs are composite in nature and supplementary to conventional civil engineering structures to slope stabilisations. Therefore, they are important elements, which come in an integrated form and should be completed at all sites as prescribed. Timing is another aspect and should strictly be followed as per the bio-engineering calendar. Success of the bio-engineering activities is dependant to success of planting part.

All stabilization works will cost NRs. 59,449,010.89, of which 34% will be spent on wages of skilled and unskilled workers, 49% will be utilised for procuring of civil engineering construction materials. Procurement of vegetative materials will take 5% of share and production of planting materials will cost 7%. Technical supervision part will be taking about 5% of the total estimates. The experience has been highly relevant and has been replicated in stabilization of roadside slides in other parts of Nepal.

Prospects of railway development in Nepal

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Transportation system in Nepal is dominated by road transport since the existence of railway network is very negligible. As of rapidly expanding demands of both passenger and freights transportation, development of alternative effective and efficient transport system that would support the rapid economic growth is an urgent need. Railway system seems to be a viable alternative since it's successful use in many parts of the world provides a strong evidence. With this option we can not only carry huge amount of loads and passenger efficiently to a long distance but also in less time. Moreover, the huge hydropower potential could solve the need of power-prerequisite for the railway system. Compare to the development of highways, railway offers many competitive advantages. For example, its track need less wider space which is a crucial factor for developing long distance transport system in a rugged and difficult topography of Nepal. Railway is environmental friendly compare and can be based on the renewable energy source. In these contexts, this paper aims to shed some light on the potential of railway development in Nepal and suggests a few viable and feasible railway alignments connecting east-west, and north-south areas. The paper reviews the criteria for alignment selection such as availability of river corridors and the minimum required gradient, threshold population, potential economic zones, topography, geology and river morphology. An analysis of the economic, environmental and social dimensions are also made. The paper concludes with a recommendation for further research and strategy formulation.

Soil restoration using rock dust

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In many parts of the world, food security is at risk. One of the causes of the falling on food production per-capita is the decline on soil´s quality and quantity. In order to reverse this trend, and increase soil fertility, soil and plant nutrients have to be replenished.

There are several ways to enhance and maintain the soil´s health. The application of so-called agrogeological practices is only one of the biophysical instruments that are used to tackle long-term soils related problems.

The objective of this study was to assess the effect of applying crushed rocks, locally available in Huatusco, Veracruz, Mexico to soil, and to record the chemical and physical characteristics, and the productivity of an andosol.

The research project consists of three phases:

1. Physicochemical characterization of soil
2. Experiments to determine the availability of nutrients present in the rocks
3. Greenhouse experiment

The application of large quantities of ground basaltic rock (ten tons per ha) increased the pH measurements, it also increased cation exchange capacities, and enhanced cation levels in the soil. Furthermore it showed exponential growth, and increased the total yield of perennial Rye grass *Perenne* Linn *(Lolium perenne)*.

Concept of Metro tunnelling in the Kathmandu Valley, Nepal

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Kathmandu Valley, the capital city of Nepal, is the largest urban center and the nation's main business hub. Due to rapid migration from rural areas Kathmandu Valley is growing and urbanizing. Traffic density in the valley is increasing so rapidly that this city is at the verge of traffic collapse. There is no more open space to widen the existing road and to develop new transport related infrastructures. This increasing urbanization involves great challenges to improve the urban environment and quality of life of the Kathmandu Valley. To improve the life and environment of the Kathmandu Valley, additional infrastructure and open space is required. Therefore, the new infrastructural developments will ultimately taking us to the alternative third dimension, either underground or overhead transport network in the valley. Compared to the overhead network the underground mass transport network will be the best alternatives to create new rooms without disturbing the existing lifeline of the valley and its beauty. The concept is to construct underground mass transport network of metro railway and rediscover old open spaces on ground which will help to improve the environment and quality of life in the Kathmandu Valley. This paper deals with this alternative and is believed that the proposed underground metro system will create new room for easy and fast intercity mass transport system in Kathmandu Valley.

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Geotechnical instrumentation and its implications in dams, slopes, and tunnels: an experience from middle Marsyangdi Hydroelectric Power Project (MMHPP), Nepal

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Geotechnical Engineering in construction projects is becoming a precise design tool through its approach to modern equipments and instrumentation in underground explorations. The inability of surface investigations to detect in advance all potential significant properties and conditions in natural form require designers to make assumptions and generalization that may vary with actual field condition. Visual observations and field tests combined with instrument data can provide realistic basis for design parameters.

The design parameters obtained through the interpretation of field data will also help for back calculation, and ultimately results in economical and perfect size of concrete structures. Analysis of data obtained from geotechnical instrumentation can be utilized to verify design parameters, design assumptions, construction techniques, analyze adverse events and verify apparent satisfactory performance.

Construction of hydropower involves a number of heavy structures to be found on weak soil to hard rock, excavations of large underground caverns and excavation of soil and rock slope. Most of the structures are designed to be in underground caverns while the semi-underground structures require excavation of high slopes in soil and rock. The stability analysis of such slopes and underground caverns require continuous monitoring of the movements throughout the construction period and afterwards too. Such movements and internal pressures obtained through geotechnical instruments are very important for the safety of the existing structures and criteria for future designs.

The geotechnical instruments viz. Inclinometers, Extensometers, Piezometers, Load cells, Strain gages, Tilt meters, Survey monuments, Seismic accelerometers etc. are the mostly used at Hydropower sites. Every instrument at the site is selected and installed to assist with answering a specific question and it is intended to provide data for evaluation. From the observations and monitoring of Geotechnical instruments in MMHPP, very useful quantitative data relating the behavior of dam, slopes and reservoir during construction, reservoir impounding and operation of the project are obtained.

This paper deals with the installation, monitoring and interpretation of data obtained from various instruments from Middle Marsyangdi Hydropower Project, Lamjung. The results obtained from geotechnical instruments are very outstanding in modifying the design criteria and geotechnical parameters.

Engineering and geotechnical evaluation of Panthial landslide along National Highway (NH), Jammu and Kashmir, India

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Strategically very important and the only surface link to the valley of Kashmir with rest of the country, the Jammu-Srinagar National Highway (NH-1A) has been facing major problems due to landslides from last four decades. The fragile lithology and lack of understanding of the failure mechanism have aggravated the situation more in the recent past. Panthial landslide along the National Highway at Km. 169 created initial failure in the late nineties, but during 2006-2007 the highway remained closed for more than a month including a period of 15 days continuous blockade. The road blockade not only caused a lot of discomfort to passengers but the shooting stones from the slide also inflicted loss to the life and property. An inclinometer has been installed to monitor both the subsurface and surface movement of the rocks in the area under a DST funded project. A drilling core of 25 m has been retrieved for studying the subsurface lithology. Various short term measures were suggested to the Border Roads Organization (BRO) and these measures have been successful. This study illustrates the impact of various geotechnical parameters and engineering properties on the possible landslide triggering mechanism.

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Investigation of effective parameters in fracturing of sedimentary rocks

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Every point of the earth always is under different forces such as overlaying strata weights (matrix and water porosities), magnetic forces, and tectonics forces and else where applied on it in varies directions. On the bases of deviatoric stresses exist caused by forces in different directions rock deforms under it's physical and mechanical properties. So, in respect to these properties another distribution of stresses forms and causes different elastic and plastic deformations such as fractures. To find out effective parameters in modelling of fractured formation detailed study has been done. To do this, the frothy variables which are expected to have important roles in fracturing and forming stylolitse taken by drilling cores and thin sections carefully analyzed. For analyzing, discrete statistic methods have been used for different depths. It is found that three most factors such as crystallization, anhydrites and foraminifers are more highlighted and the effectiveness varies in different sedimentary layers.

Flow characteristics of densely packed granular shear flow subjected to slow deformations

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The densely packed assembly of granular materials subjected to slow deformations is studied experimentally in the 2D shear flow apparatus. It is found that the consecutive cycles of solid like (jammed) and fluid like (un-jammed) states characterize the flow. The jammed state is represented by negligible mobilization of particles, whereas the un-jammed state is represented by considerable mobilization of particles. The rotational and translational kinetic energy shares their dominancy in the jammed and un-jammed states respectively. Nevertheless, rotational counterpart also increases quite high in un-jammed state. There exists clearly a gradient of translational and rotational velocity across the shear cell especially in the un-jammed state indicating the phenomenon of strain localization. The un-jammed state originates because of the breaking and buckling of few columns near to the inner moving wall as noticed by previous researchers, and the jammed state regenerates once the broken and buckled columns regrouped into new columns. The dilatation phenomenon is found to be associated with the un-jamming states indicated by the drop in the local particle concentrations.

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Development of HAZUS compatible fragility functions for non-engineered buildings in Nepal and Bangladesh

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The buildings that are not been designed or supervised by an architect/engineer are classified as non-engineered buildings. Such buildings are obviously prevalent in the rural or non-urban areas including the periphery of cities. A large percentage of the buildings even in urban areas of many developing countries are non-engineered.

More than 90% of buildings in Nepal are non-engineered. In case of Bangladesh, recent survey carried out in three cities; Dhaka, Chittagong and Sylhet shows more than 65% as non-engineered even in the city areas. These are the ratio of masonry and tin-shed buildings over total building stock and do not include reinforced concrete buildings. Many reinforced concrete buildings in these cities are still non-engineered if the structural design and supervision is the basis for defining non-engineered buildings. The non-engineered concrete buildings, which are generally lightly reinforced, are termed as lightly reinforced concrete buildings in this study. If these buildings are added to non-engineered ratio, the percentages of the non-engineered buildings will be even more.

Recent earthquakes in developing countries have shown that damage ratio of non-engineered buildings, specially the masonry buildings, are more than engineered causing a large number of casualties. So, the loss estimation result in cities of developing countries is highly dependent to the fragility functions of masonry buildings.

Different fragility functions/curves for masonry buildings are suggested by various authors are either acceleration or intensity based. Some give the function in terms of economic loss and some others give in terms of damage grade.

This study focus on HAZUS compatible fragility functions development for different type of non-engineered buildings in Bangladesh. Fragility functions are developed using qualitative methodology where different available fragility functions are analysed, appropriate one are selected and customized to fit to HAZUS compatible form. Qualitatively developed fragility functions were verified numerically. Detail non-linear analysis of selected brick masonry buildings were conducted using Extreme Loading for Structures (ELS) software developed in Applied Element Method (AEM) to verify the qualitatively developed fragility functions numerically. A good agreement was found on qualitatively developed fragility functions and the numerically obtained one.

Updation of land use information and generation of land use zoning maps: an application of integration of GIS and Remote Sensing through knowledge base

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Land use planning is an issue of public policy that binds multiple disciplines in order to regulate the use of land in an efficient way to avoid land use conflicts and acts as a tool for the safeguard of environment. A task of updating of land use information and then land use zoning was carried out in few plain as well as mountainous areas of Nepal. The objective of the study was to classify land based on the present pattern of use and then ultimately prepare Land use zone map that would support decision makers to formulate policies for the justified use of land in immediate future. The fist task was accomplished by applying the integration of remote sensing and GIS technology that assisted characterizing and analyzing the dynamic environments so that the change in some objects in terms of geometry, class and topology could be identified. Updating co-registered vector data of the study areas by using remotely sensed imagery was performed by simultaneous viewing them using GIS tool. For the discrete field features, knowledge based engineering was applied to extract discrete information that was integrated at the final stage by applying the map algebra techniques in the realm of GIS. The raster based information was then undergone self developed algorithm for generalization to render the product in required scale of measurement i.e. 1:50,000. Land Zoning was performed based on the criteria that help to allocate land within defined classes that fit for the certain use of land. The criteria were mainly related to land capability, land system, socio-economic indicators and most importantly present land use pattern. It was found that the present use of land is erratic in nature and there exists decreasing trend of spatial extent in vegetation cover as well as agriculture over the study areas. As the land having medium grade of suitability to one class can have very high suitability measures in the other classes, the land use zoning criterion should be standard, coherent and consistent which must be backed by authorized decisions. Spatial planning is recommended to be carried out through iterative process based on dialogue amongst all stakeholders aiming at the negotiation and decision for a sustainable use of land.

Engineering geological investigations of Dik Chhu hydropower project, Sikkim Himalaya, India

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The Dik Chhu hydroelectric project is located in the Dik Chhu Valley of Sikkim Himalaya where the Gorubatham Formation rocks are composed mainly of medium-to high-grade metamorphic rocks represented by quartzo-feldspathic gneisses, garnet-mica schists, schistose quartzites, phyllites and biotite gneisses with schist layers. The installed capacity of the project is 20 MW. The proposed dam site across the Dik Chhu River is located 150 m downstream of confluence of the Bakcha Chhu and the Rate Chhu Rivers. The intake for water to be conducted to the tunnel is proposed immediately upstream of dam site, on the right bank. The proposed headrace tunnel alignment passes through a rough and rugged terrain, on the right bank of the Dik Chhu. The tunnel length is about 5.6 km and the diameter will be 3–4 metres. Two possible locations for intermediate adits have been identified from the point of minimal length and suitable geological setup. The surge shaft at higher levels on the right bank of the Dik Chhu, near to Sangam village is proposed. The penstock slopes have reasonably good gradient and exposes quartzitic phyllites. The powerhouse is proposed as an open structure and is of 90 m in length, 23 m in breadth and 40 m height. The tail water after production of power is being conducted through a channel about + 300 m (approx.) long downstream of the Dik Chhu on its right bank. To design the rock support for the underground structures of HRT, surge shaft, and for the foundations of dam, intake of sedimentation tank penstock, power house and TRC, rock mass classifications was attempted following the methods of Bieniawski's Rock Mass Rating (RMR) Classification and Tunnel Quality Index (Q) of Barton et al. The result from the surface mapping indicates that the rock masses of the project area fall under the good, fair and poor rock quality, which is required to be confirmed by drilling and drifting. On the basis of above study recommendations have been made for the proper and safe construction of the project components.

Role of geological structures and clay minerals in triggering landslides on Mugling-Narayangarh Highway, central Nepal

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The Mugling-Narayangarh highway suffers from numerous landslides and debris flow events each year. To understand the causes of landslides, the area was investigated from geological, structural and engineering geological point of views. Major landslides in the area were studied and mapped. Soil samples collected from landslide areas were analyzed to understand clay mineral content in the soils. Illite and chlorite groups of clay minerals were found in all samples. In general, clay plays a significant role on landslide occurrence, but in the Mugling-Narayangarh section, it has little role in comparison to the geological factors. Geology, geological structures, rock weathering and topography are the main factors and precipitation, erosion and land use changes are some of the other factors in triggering landslide and debris flow in the area.

Disappearing glaciers of Himalaya in the context of global warming

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Most mountain glaciers worldwide are retreating but in recent decades they have begun melting at very high rates. They are the Earth's largest freshwater reservoir, and form the lifeline of many of the world's major rivers including the Himalayan Rivers. Projected climate change over the next century will further affect the rate at which glaciers melt. Average global temperatures are expected to rise 1.4-5.8 ^{0}C by the end of the 21st century (IPCC 2001). Simulations project that a 4^{o}C rise in temperature would eliminate nearly all of the world's glaciers.

Himalayan region together with Tibetan Plateau has glacier coverage of 33,000 to 34,000 km^2, the region is aptly called the "Water Tower of Asia" as it provides around 8.6 X 10^6 m^3 of water annually for hundreds millions of people during dry season, feeding seven of Asia's great rivers: the Ganga, Indus, Brahmaputra, Salween, Mekong, Yangtze and Huang Ho in which basins more than 1.3 billion people find their livelihoods. Glaciers in the Himalaya are receding faster than in any other part of the world (IPCC 2001). Himalayan glaciers are retreating at rates ranging from 10 to 60 m per year, and retreat rates of 30 m per year are common. Many small glaciers (<0.2 sq. km) have already disappeared. Studies show that the terminus of most of the high altitude valley glaciers in Bhutan, China, and Nepal are retreating very fast. Warming in the Himalayan region has been much greater than global average. Previous studies estimate that in the Ganga, the loss of glacier meltwater would reduce July-September flows by two-thirds.

Our recent study in Langtang valley shows a consistent trend of increase of temperature since late 1980s that has resulted in the fast melting of glaciers and their retreat both horizontally and vertically. On analyzing and comparing the satellite images of 1979, 1989, 1999 and 2009, it is found that there are distinct changes in the snout positions of the glaciers. The present study shows that in the higher part of the Langtang valley in Kyanjing Gumba area, the yearly temperature data shows a consistent rising trend since 1988, a clear indication of global warming. However, the temperature data from the lower altitude at Dhunche station shows much subdued rising trend indicating that higher altitudes are much more sensitive to temperature increase than at lower altitudes due to global warming. The hydrological study shows that despite the decreasing trend of annual precipitation, the discharge of the Langtang River is showing an increasing trend of discharge. This can be possible only due to the increased rate of melting of the glaciers at higher altitudes.

The interpretation of satellite imageries of the valley very clearly shows horizontal retreat of most of the glacial snouts and in the last 30 years (between 1979 and 2009). some of them have retreated or shrunk for over 900 m with an average retreat of about 30 m/year. Similarly some glaciers have retreated over 100 m vertically in the last 30 years. Comparison of the aerial extent of the glaciers in the Langtang Valley between 1979 and 2009 shows that the Langtang Lirung Glacial coverage area has shrunk by 62% in the last 30 years. If this rate continues, this glacier might just melt away within a short period of time. The total loss of glacial coverage area of the entire Langtang watershed within the last 30 years is 24%.

Climate change has tremendously impacted the glacier ecosystem in the Nepalese Himalayas climate change is a pressing issue and a growing concern to Nepal as all-Nepal temperature (maximum mean) since 1977 has raised 0.9 ^{0}C, at a rate between 0.03 °C yr^{-1} and 0.12 ^{0}C yr^{-1}, with an average of 0.06 ^{0}C yr^{-1} whereas the global average surface temperature rise of the last century was only 0.6±0.2 ^{0}C. Associated with the temperature change, monsoon precipitation has undergone some changes with decreasing rainy days and increasing high-intensity rainfall events, resulting into increase in magnitude and frequency of water-induced disasters - landslides, debris flows and floods. Breaching of some of the lakes have already resulted into seven major Glacier Lake Outburst Flood (GLOF) events in the past 30 years, and the 26 glacial lakes (out of the 2315 lakes in Nepal) are reported to be potentially dangerous for GLOF. Almost 20% of the glaciated areas in Nepal above 5000 m are likely to be snow and glacier free area at an increase of air temperature by 1 ^{0}C. The depletion in the water resources (projected) is likely to be seriously affecting the hydropower potential, irrigation, and even the drinking water supply in the country and the region.

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On the occurrence of fatal landslides in Nepal

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Landslides represent a substantial geological hazard in Nepal, causing high levels of economic and social losses, and numbers of fatalities in the range of tens to hundreds each year. A database has been constructed of the occurrence of landslides that cause loss of life in the period 1968 to the present across all of Nepal. The database allows analysis of the temporal and spatial patterns of landslides in Nepal. In this paper an analysis is presented of the occurrence of landslides in the period up to the end of December 2009. As of that time a total of 648 fatality-inducing landslides had been recorded, with a total of 3376 lives lost. The data show that the overall trend in landslide-induced losses is upwards with time, but that the pattern is rendered more complex than might be initially supposed by a marked cyclicity over a decadal timescale. It is demonstrated that this cyclicity is primarily associated with trends in the southwest monsoon, with the occurrence of fatality-inducing landslides mirroring the occurrence of high annual monsoon rainfall on an annual basis. However, overprinting the cyclicity is an increasing trend in landslide occurrence, which is likely to be associated mainly with changes to the structure of society in Nepal, most notably the growth of the overall population and the development of roads in rural areas. The spatial pattern of landslides closely reflects the distribution of high annual rainfall and the distribution of steeper slopes, with a smaller influence from the proximity of large tectonic structures.

Using this data, the final part of the paper considers likely future trends in landslide occurrence in Nepal in the context of economic development, population growth and climate change.

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Climate change impact scenarios and possible strategic programs for building climate resilient communities in Nepal

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Impact of climate change in Nepal has been cited in technical reports and research publications with different perspectives. Literature review clearly suggests that the increase in temperature has been observed higher in the high mountain than the other ecological zones. Decreasing trend of temperature has also been reported in some districts. In general, comparatively hotter summer and colder winter are reported throughout the country. It has also been reported that the rainfall patterns are being altered resulting delayed monsoon, erratic rainfall and shorter rainfall duration. The season to season increasing and decreasing trends of pre-monsoon, monsoon and post-monsoon precipitation are also reported to be not consistent. In general, frequency of high intensity rainfall (precipitation more than 100 mm within 24 hours) is in increasing trend.

Climate change impact has resulted several outcome risks out of which landslide, flood, drought, glacial lake outburst flood (GLOF), debrish flow, soil erosion, and river bank cutting are at the forefront in geologic perspective. These hazards and their consequences are found to have different extent in different tectonic zones of the Nepal Himalaya. In general, GLOF hazard is critical in Tibetan Tethys Zone and Higher Himalayan zone whereas landslides and drought form major climate induced hazard in the Lesser Himalayan zone. The Siwalik zone seriously suffers with landslides, debris flows and soil erosion while the Terai region is more prone to floods.

The impact of climate change is projected to be severe in water and energy, forest and biodiversity, agriculture and food security, urban settlements and infrastructures, climate induced disaster and public health sectors in the days to come. This paper first takes stock of the climate change impact scenarios sector wise and proposes possible strategic program for most vulnerable villages in Nepal as a means of making the communities climate resilient in short duration.

Application of GIScience for combating food deficiency risk due to climate change: a case from Terai Plain of Nepal

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Land is a vital production unit to produce food to sustain livelihood of the people. Age-old farming activities have been threatened because of variability of rainfall pattern and increasing atmospheric temperature due to climate change. Traditionally adopted subsistence farming practices have problems to maintain enough production due to drought, irregularity in irrigation system, natural disasters and scarcity of extra land. It needs to acquire new knowledge on adopting new technology to maintain the livelihood. The application of GISciences (Geographic Information System, Earth Observation Satellite Imageries and Global Positioning Systems) helps to acquire detail land related information and also provide basic knowledge to reclaim wasteland to produce different crops. However, it is equally essential to mobilise the community with enough information about the seasonal flood and sedimentation behaviour along the river channels.

Southern plain of Nepal is now experiencing scarcity of suitable land due to influx of mass population, facing severe natural hazard i.e. flood during the monsoon which has direct result on decreasing per capita land and reducing both production and productivity of the land under cultivation. In the mean time extensive area along the river/stream course is under the flood zone during monsoon and usually left as wasteland during the long dry months of the year. Because of change in slope gradient major rivers and their tributaries originated in the northern mountains and hills reach to the south and immediately change their course. Many such rivers/streams have several kilometres wide channels. Those channels have riverborne soil constituents with highly productive organic materials. During dry season those channels remained dry and left as wasteland.

This paper has attempted mapping dry river channels of the Tarai Plain of Nepal with the help of Landsat TM image data. The image data are integrated with thematic layers of topographic maps and other social attribute data of Central Bureau of Statistics (CBS). Finally, the identified area of seasonally dry channels is analysed for its possibility of reclamation at least in long dry months of the year for the seasonal farming.

Recent environmental constraints in the valley of Flowers National Park, Uttarakhand Himalaya, India

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The famous "Valley of Flowers" (a World Heritage Site ~ 87.5 km^2), located in the Central Himalayan region between latitude N 30^0 41'51" to 30^0 47'15" and longitude E 79^0 33'11" to 79^0 43'13" in Uttarakhand, is known for its rich biodiversity. Approximately 600 species of temperate, sub-alpine to alpine plants including herbs, shrubs and trees are reported within the 10 km^2 area of the catchment (Kala and Rawat 2001). In the last 2-3 decades there has been remarkable changes observed in the bio-geoenvironment of the valley. This in turn changes the overall eco-tone of the valley. In the present communications, efforts are being made to summarize some of the observations carried out during last few years particularly the impact of microclimatic changes in the glacial, glacio-fluvial and fluvial environment. Evidences of the glacier recession, upward migration of woody plants with variation in structure and composition of the vegetation are also discussed. Recently, there has been increasing evidence of species range shifts due to climatic fluctuations in this valley (Bisht et al. 2010).

Efforts are also being made to understand the various geomorphic processes operative in this region which changes the overall landscape scenario of the terrain. The gradual changes in the landform characteristics along with climatic fluctuation effect the composition and structures of the biota. The initial glaciated valley continuously modified by present fluvial system is gradually modifying not only the shape of valley but also habitat characteristics for the biomes.

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Global climate change and its effects on hydro-geo- environment of Bangladesh coastal belt

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This paper attempts to conceptualize and sketch a possible creation of an alliance of the Global Water and Climate Change with the aim to contribute towards Bangladesh coastal belt and is building a sustainable future plan. The paper may be treated as an indicative working document and is designed mainly for initiating a discussion that might hopefully lead to the creation of an innovative academic network for the promotion of sustainability of climate change in the Bangladesh coastal belt in education and research.

Bangladesh has about 710 km long complex shoreline. It extends along the Bay of Bengal from the mouth of the Naf River in the southeast to the mouth of the Raimongal River in the southwest. The coastal morphology of the country is a very complex and dynamic system undergoing continuous changes as a result of active delta building processes. With the exception of the hilly region in the east, the entire central and western part of Bangladesh is drained by the Ganges, the Brahmaputra and the Meghna Rivers, which together have developed one of the largest deltas of the world. The coastal zone of Bangladesh is unique in the sense that it is located at the land-sea interface, and is thought to be ecologically very sensitive. The zone may be described as the transitional area between the two environmental domains, the continental and the marine. One of the major consequences of increased surface air temperature and intense floods is the rise of sea level. Coastlines in some parts of the world are unstable due to tectonic activities and isostatic adjustment changes in sea level should, therefore, be considered relative to such shifts in coastal topography as a result of continuing geologic activity. The sea level usually rises due to thermal expansion of near-surface ocean water and melting of snowfields, ice-sheets and glaciers. During the last 100 years, the sea level has risen by about 10-15 cm.

The Ganges Delta Region of southwest Bangladesh is a transient zone from the tropical to the subtropical and landing area of the monsoon from the Indian Ocean, where strong gradient and variance in the surface air is observed. Present researches on the different parts of the world have also been revealing many basis features of the climatic changes of the past. This is the main source of basic for the projections of the future climate. The relevant organizations of Bangladesh should investigate the issue of Global Water and Climatic Change immediately in the whole area of Bangladesh.

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The climate change and chemical management in Pakistan–a situation analysis

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The emerging and unprecedented public health threat of accelerating climate change may significantly alter global and local development, use, distribution, and degradation of chemicals in ways that could affect human health.

Environmentally extreme precipitation threaten water quality by increasing urban and agricultural run-off of petrochemicals, industrial chemicals, chemical waste, pesticides and fertilizers into surface waters or potentially dangerous exposure situations. Climatically, increased temperatures will cause volatile chemicals to disperse more quickly in the air and some chemicals will degrade more quickly potentially creating local hot spots of exposure. Evaporation will be enhanced leaving non-volatile chemicals to concentrate in water bodies.

Global movement of persistent chemicals will be modified with changes in global water and air currents, and population exposures will also change. Chemicals have been powerful tools supporting improvements in health and lifestyle in the past and can be critical tools in the global response to climate change. As the world warms, chemical use patterns will likely change in several sectors and affect human exposure levels.

In view of these scenarios, tools–including existing and new chemicals as well as non-chemical alternatives–are required to respond to climate change effectively. The paper will explore how climate change may alter human exposure to chemicals, identify who may be at particular risk of harm, and suggest some actions that can be taken now to reduce adverse health impacts.

Glacial lakes and Glacial Lake Outburst Floods in the Himalayas

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Himalayan glaciers are sources of freshwater reserves providing headwaters for ten major river systems in Asia which support the lifeline for almost one third of humanity. The Himalayan region is also an ecological buffer between Tibetan Plateau and South Asia controlling the monsoonal climate pattern and hydrology of the region. Glaciers in many parts of the Himalayan region are currently thinning and retreating, as a result of the current climate warming. Glacial lakes often form between the frontal moraine and the retreating glacier or on the surface of the lower section of the glacier. These kinds of lakes are held back (dammed) by more or less unstable moraine complexes, and have a potential to breach their moraine dams. In certain instances, such breaching can instantaneously release a huge amount of water and debris. This phenomenon, in the Himalayas and elsewhere, has become known as a glacial lake outburst flood or GLOF. This most likely would cause extensive effects on the downstream areas posing a threat to human lives and infrastructure.

The impact of such an outburst depends upon the physical characters of the dam, the lake size, depth and the rapidity of its drainage, and the nearby surroundings. Glacial hazards, such as ice avalanches, GLOFs, and debris flows have caused severe damage in populated mountain areas in the Himalayan region (and in many mountain areas throughout the world), and there is a concern that their frequency could increase as a result of accelerated glacial thinning and retreat. At least thirty four GLOF events have been recorded in the Himalayas of Bhutan, Tibet Autonomous Region of China and Nepal in the past which resulted in heavy loss of human lives and their property, destruction of infrastructures besides damages to agriculture land and forests. Thus, GLOF risk assessment has become an issue of considerable significance that must be dealt with.

The International Centre for Integrated Mountain Development (ICIMOD) and its partner institutes have been conducting the study of glaciers, glacial lakes and GLOFs in the Himalayas. The studies generated the baseline information which is fundamental for future monitoring of glaciers, glacial lakes and GLOFs of the region and the research related to climate change. The information generated is also essential for the flood risk management including the development of monitoring and early warning systems, for planning and prioritizing disaster mitigation efforts, for estimating the availability of water resources in future and their planning and management.

Study also revealed that there are many potential dangerous glacial lakes in the Himalayas which are in urgent need of further investigation. Some of the past GLOF events have demonstrated transboundary nature with GLOF occurring in the upstream country and damaging effects extending to the lower riparian country. Thus, regional cooperation is required for GLOF risk management which is likely to increase due to continued increase of current climate warming as we progress through the 21st century.

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Geotechnical evaluation in GLOF hazard assessment of potentially dangerous glacial lakes of Nepal Himalayas

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Geotechnical evaluation technique was used for GLOF hazard assessment of selected glacial lakes mainly Imja, Tsho Rolpa and Thulagi from the list of potentially dangerous high priority lakes after inventory and ranking study of all the glacial lakes of the Nepal Himalaya in 2009. The geotechnical parameters taken into consideration are mainly composition and degree of compaction of the moraine material damming the lake, slope stability condition of the moraine and rock/ debris slopes in the surrounding, status of buried ice in the moraine, status of the stability of glacier tongue, presence of hanging glacier in the surrounding, condition of the outlet flow path of the lake, and condition of ablation valleys on either side of the lake. From instability point of view, Tsho Rolpa was found to be the most vulnerable among three, although, some mitigation measures had already been applied in the past in this particular lake. Because, the freeboard height of about 200 m high natural moraine dam of Tsho Rolpa (from outer valley bottom to the crest) is only about 6 m and its minimum crest thickness at old outlet channel is about 50 m. The dead ice in the terminal moraine dam is melting fast. Moreover, loosely packed pile of debris deposited by old glacier was observed that located on the left side slope of the lake near the glacier terminus having a potential to trigger GLOF event in highly susceptible condition.

In case of Imja and Thulagi glacial lakes the heights of freeboard is about 15 m and the dam crest length are at least 500 m for Imja and 300 m for Thulagi, respectively. There is extensive amount of near surface dead ice in the moraine dam of Imja Lake whereas in case of Thulagi the near surface dead ice was not encountered up to the depth of 15 m from the top of the moraine. Although, continuous cascading of the sediments from the inner slopes of lateral moraine of both the lakes were observed but was considered that the amount of material falling into the lake will not be enough to trigger any GLOF event. Further, the outer slopes of the moraine damming both the lakes were observed fairly stable at present condition.

Assessment of potential GLOF from Imja Glacial Lake on the basis of multidisciplinary study

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Glacial Lake Outburst Flood (GLOF) from Dig Cho in 1985 and Nare in 1977 is still in the minds of the people of Khumbu Sagarmatha Region in east Nepal. Imja Glacial Lake identified as one of the potentially dangerous lake in terms of GLOF is located at 5010 m above sea level in the south east of Mt. Everest region of Solukhumbu District. The lake was a group of several supra-glacial ponds appearing on top of Imja Glacier in the late 1960's. It developed to a glacial lake of considerable size in 1975 and is ever increasing in its area and length at the cost of melting of mother glacier. To assess the status of the potential GLOF hazard from this lake a multidisciplinary study was conducted in 2009. This paper presents the findings of the study.

Imja Glacial Lake at present is dammed by more than 500 m wide heavily ice cored moraine dam. The lake is more than 2 km long and about 0.55 km wide. About 20 m high frontal moraine dam holds 35.5 million cubic metres of water. Dam break simulation of possible GLOF event from this lake suggests the maximum flow at the toe of the dam will be about 5800 m^3s^{-1} and the flow at 54 km downstream near Hatema will be about 3000 m^3s^{-1}. The study revealed that, 20 bridges, 1511 houses and a big area of cultivated land along the river valley would be at risk due to potential GLOF from this lake. Khumbu region, which is one of the top tourist destination in Nepal will also be affected from the GLOF widely. A field based hazard assessment revealed that the possibility of immediate outburst threat from Imja Glacial Lake can be ruled out. However, in view of high downstream vulnerability continuous monitoring of the lake is required.

Landslide hazard assessment in Mansehra district, Pakistan

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A bilateral governmental cooperation project between the Federal Institute for Geosciences and Natural Resources Germany (BGR) and Geological Survey of Pakistan (GSP) is engaged in developing a methodology for landslide hazard assessment and hazard zonation mapping in northern Pakistan as a geoscientific input to the national disaster management authority structures in Pakistan.

The Kashmir earthquake of 8th October, 2005 with a magnitude was 7.6 in Richter scale was the deadliest earthquake in the recent history of Indo-Pak sub-continent. Besides the direct impact, it also triggered thousands of landslides and destabilized most of the slopes in the area which were later on activated during monsoon/heavy rainfall. The same phenomenon is still prevalent in the whole affected area. A network of cracks has developed all around on the slopes. A very high concentration of large and small landslides was observed in the mid-slope area along the surface projection of the Bagh-Balakot fault. Deep seated landslides are far less numerous than shalow slides.

Landslides have been a major threat for population and infrastructure before and after 2005 earthquake in the areas of Balakot (Mansehra) and surroundings, particularly along the road from Balakot to Paras. Along with the other factors responsible for the occurrence of landslides, road cutting was one of the major factors that initiated most of the slope failures before the 2005 earthquake and authorities had to allocate a substancial amount of money for the maintenance of the roads. The landslide zone from Kawai Nakka to Paras, Jammu da Nakka, Bagha, Bhegra, Bun, Hassa, Dhamdhar, Kalas, Shangrian, Kanshian and Ghareeb Abad were among some of the important mass movements zones before and after the earthquake.

The Geological Survey of Pakistan is in the process of determining the extent of the geo-hazards in the earthquake affected areas especially focusing on the landslides as a potential threat for life and property within the framework of this technical cooperation. In the process of geo-hazard assessment Geological Survey of Pakistan and German Federal Institute of Geosciences and Natural Resouces, signed a two years joint cooperation project ‘Geohazard Assessment in Northern Pakistan’ and Mansehra District has been selected as pilot area. The mapping in the selected area will be carried out with GIS and Remote sensing as desk work and a special focus on detailed field verifications.

The implementation of geo-hazard investigations within regional and local planning processes as well as proposals for law making (planning for settlements and infrastructure) will be enhanced by means of GSP participating actively in these planning processes. With regard to the high potential of danger of landslides to settlements and infrastructure in the earthquake affected areas mitigation measures to prevent severe damages will be taken into account as well. Desired Output:

- Landslide inventory maps and database
- Landslide susceptibility maps
- Hazard zonation maps
- Guidebook and/or atlas for planning authorities
- Guidelines for awareness rising within the population affected
- School materials concerning disaster awareness and mitigation measures

Use of earth observation data for disaster mitigation in river basin: an example of Riu River Basin, Chitwan District

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The mountains of Nepal Himalayas, that constitute majority of the total area, are geologically young and tectonically active with steep and unstable landscape. Intense and prolonged rainfall causes erosion, slope failure, river bank erosion and flooding during the monsoon period. The result is the loss of agricultural lands damage of properties, infrastructures and loss of lives each year. A proper management of river basin is the only solution for appropriate infrastructural development activities maintaining the natural waterways of river and proposing the required mitigation measures at required site.

In order to identify the critical area to the flood hazards and vulnerable areas and proposing appropriate preventive and mitigation measures the use of earth observation data has been used in the study of Riu River Basin. The Riu River flows through the Madi valley in Chitawan district. Chitawan National Park lies at the right bank of the river and at the four VDCs, namely Gardi, Baghauda, Kalyanpur and Ayodhyapuri VDCs lies at the left bank. The east-west flowing Riu River originates at Someswor hill in Siwalik range and discharges to the Rapti River. The Riu River Basin covers an area of 302.24 km^2 at Confluence with Rapti River in the west. The Width of the river varies from 1300 m at upstream to 200 m in the downstream part (near the confluence with Rapti River).

The river is having cobble to gravel stage at the upper reaches (eastern part) of the survey area and the sediment size on the river channel decreases westward. Fan deposit can be observed at the confluence of major tributaries at the left bank. The sediments are basically derived from the tributaries in the southern catchment as the relief is high in comparison to the northern part. River is shifting towards north as a result of the geological structure and hence wider terrace is present in the left bank. The river morphology as studied in satellite image indicates that it is braided on the eastern half and meandered at the western half. The paleochannels of Riu River as well as Rapti River is clearly observed on the satellite image. Likewise, the recent satellite image provides the information on the present distribution of settlements. These information, when blended with the output of flood modelling, provide an excellent scenario of the water induced hazardous sites in the river basin. Based on the scenario, the locations of specific mitigation measures have been proposed. The present study suggests that the use of earth observation data is helpful to effectively carry out the river basin study thereby enhancing the disaster mitigation activities.

Sustainable development and natural accidents

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For development of strategy of behaviour of society in expectation of natural accidents it is important to mean that along with such almost instant accidents as earthquakes, tsunami or flooding, exist the latent accidents the natural phenomena developing slowly and leading to catastrophic events through tens and hundreds of years. Freezing concerns number of the latent accidents, liftings (transgressions) and falling (regressions) of sea level and the big lakes, desertification, bogging, erosion and abrasion, smooth tectonic movements. Certain critical episodes-imposing of more frequent fluctuations of the natural phenomena (for example, imposing of droughty season on is long drought) that the latent accident became obvious are required. Still the big intervals of time are necessary for investigating to establish periodicity of earthquakes in active zones (seismotectonic cycles), i.e. average repeatability of events or epoch of frequent strong earthquakes. Presence of the latent accidents and importance of estimation of laws of repeatability of the catastrophic phenomena oblige to consider geoenvironmental problems in historical retrospective show. Necessity of the historical approach is defined also by that variation of geodynamic parametres of environment rendered on life of people not only negative, but also positive influences. To realise their value it is possible besides only in historical context.

Consideration of climatic changes among the geodynamic phenomena demands the explanatory. The geodynamic phenomena partly cause cold snap of last millions years. So, the high area of continents, abundance of land and mountains increases òåïëîîòäà÷ó planets and strengthens contrast of climatic ash value. However, during Holocene (last 12 000 years) direct influences of geodynamics on climate weren't defining. For last 100 years average temperatures of climatic system of the Earth have increased on 0.6 degrees. On the scale of planet as a whole it much also serves as the main argument of apologists of global warming. The important certificate of such warming reduction of the areas of polar ices admits. But for last three years their volumes were restored. With end of current cycle of activity of the sun warming can appear time anomaly–the predecessor of global cold snap.

Dangers and risks of glacial debris flows in the northern Caucasus, Russia

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In the nearest decades ahead the global trend of the increasing negative impact of debris flow processes is expected to continue as a result of the forecast degradation of mountain glaciation, connected with the changes in climate. In the Caucasus region of Russia, where debris flows stand out for the frequency of occurrence in space, time and power of their energetic manifestation, and are mostly of glacial origin, this follows from the analysis of the developing situation, which relies on the real events of the last 20 years of the 20th century and the first years of the 21st century. As glacier tongues retreat to the higher true altitudes, massifs of friable single-grained, primarily moraine, formations become exposed; peri-glacial water-bodies rapidly (comparatively speaking) appear, grow and disappear; gradients of tributaries, in which water torrents may become saturated with friable detritus, increase. Threats and risks of initiation of regimes of debris flows on river channels grow. Most considerable debris flows, with regard to their destructive effect, are connected with outbursts of lake neoformations, lying close to glaciers. Discharge of intraglacial hollows more and more frequently acts as a triggering mechanism for the start and further development of the debris flow process.

The length of the period of high temperatures in July-August, causing heightened ablation of ice masses against the background of a lowered filtering stability of natural dams, which retain lake neoformations, is the most significant factor for the initiation of conditions for the start a debris flow process. Not every near-glacier or glacial hollow at the realization of the outburst scenario thereupon is able to initiate a debris flow process - for this to happen outer slopes of the dam massif (usually of friable recent moraine) should have $30\text{-}35^{0}$ steepness; $\sim 20^{0}$ steepness is insufficient, and within the $20\text{-}30^{0}$ range the possibility of an avalanche-like increase of conditions for transformation of a water flood into a debris flow may be realized only with certain water mass volumes (~ ε 80-100 thousand cubic metres) and relative heights of eroding natural dams (~ε80-100 m). At that, every significant debris flow changes geomorphological preconditions for the next one. The set forth statements are illustrated with factual material.

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Landslide susceptibility mapping of Aandhi Khola River Basin and vulnerability assessments

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This paper deals about with the landslide susceptibility and assessing the vulnerability of the most hazardous locations in the Aandhi Khola River Basin. The main data used for the present study is aerial photograph, recent satellite image (ALOS-PRISM) and primary data collected from the field. All important information was integrated in the GIS database. The stereo-pair satellite image (spatial resolution 2.5 m) has been used to generate DEM and orthophoto, and also used to update land cover map, drainage, geological, geomorphic maps, and landslide distribution maps.

In this study, a statistical method is applied to prepare the landslide susceptibility map of the river basin. The model was calibrated comparing the predicted susceptible areas to the real field condition. The low, moderate and high susceptible class occupies 47.5%, 30.25% and 22.19% areas of the river basin. It is observed that maximum number (77.9%) of landslides have occurred in high class followed by moderate and low class. The relationship between landslide and that of different classes in each thematic layer was assessed. It is observed that landslides are common in dolomitic and quartzite rocks. Likewise, landslides are most common in the areas having topographic slope more than 35 degree. The eastward (NE, E, SE) slope is having more landslides in comparison to other. The north and north-west facing slopes are having least landslides. Most of the landslides are occurring in the rocky areas while the areas covered by slopes are having very few numbers of landslides. The analysis of temporal data (last one decade) indicate that there is increased trend of the landslides area (by 0.372 Km^2) in the river basin.

The vulnerability assessment within the Aandhi River Basin has been carried out based on the landslide susceptibility map, population density, settlements, infrastructures and economical importance of different lands and the output is categorized as low, moderate and high. The areas occupied by low, moderate and high vulnerability are respectively, 75%, 20%, and 5%. The approach of present study with the integration of information extraction from satellite image, field data collection, interpretation, analysis in GIS has yielded good result. Similar technique can be used in other river basin to assess the landslide susceptibility and vulnerability analysis.

Landslide distribution as a potential GLOF risk in Mangde-chu River Basin, Bhutan

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There are many glacial lakes in the upper basin of Mangde-chu river in Bhutan. Detection of landslide slopes is essential for hazard assessment of Glacial Lake Outburst Flood (GLOF) along the river, because the occurrence of GLOF may reactivate potential landslides by river bank erosion. The authors made a landslide distribution map in the Mangde-chu basin by the interpretation of satellite images and field survey, as the activity of "Study on GLOFs in the Bhutan Himalayas" supported by JST-JICA, SATREPS to clear the characteristic of landslide phenomena.

In this presentation, we introduce the results of landslide distribution mapping in 1:50,000 scale as follows:

1) Detected landslides are topographically classified into deep-seated, shallow and rock-creep types.

2) The mountain slopes are widely occupied by many old deep-seated landslides along the Mangde-chu.

3) Many large-scale landslide bodies consist of deep-seated and rock-creep types have over several km in width are recognized.

4) Some deep-seated landslide slopes located at the undercut slope of the river may reactivate by GLOF and also may continue as unstable slopes.

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Pokhara Valley: a place under permanent threat

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The loveliness of the place of Pokhara is the result of a disaster that happened 750 ± 50 BP according to detailed ^{14}C datings. Not only the decent flat landscape so favourable for human settlements and agricultural activities but also the unique beauty of Lake Phewa with the impressive Annapurna Range on the background are the results of a series of really giant debris flows. These mass movements in historic times filled the valley with about 5 km^3 of sediments (Pokhara Formation). The material originated from the huge col-like Sabche Depression northeast of Machapuchre. A similar event has taken place 11,000 ± 1000 BP signifying around the end of the last glaciation; these sediments are called Ghachok Formation.

Both huge debris flows have transported mainly glacial material composed of predominantly calcareous Mesozoic sedimentary rocks from the huge col-like Sabche Depression northeast of Machapuchre. The landscape about 800 BP had a similar shape as the present one. All tributary valleys were blocked and lakes formed most of which were totally filled by sediments except for Phewa, Begnas, and Rupa Lakes.

The Ram Ghat, a strange depression east of Pokhara, is also a result of these filling/erosion processes: astonishingly, the waters of Seti River did not cut into the lose Pokhara sediments but after a certain period of meandering on top of the Ghachok Formation decided to cut down into these well-cemented deposits and to create the famous gorge of Pokhara. That means the gorge is younger than 750 ± 50 BP.

Both giant debris-flow events occurred during periods of climatic warming; the first at the end of the last glaciation and the second one during the Mediocre climate optimum. As we are undoubtedly in a global warming phase as well, the conclusion is that the probability of a recurrence of a similar event now with unimaginable consequences can not be excluded. As long as the nature of the trigger of the former events is not known (GLOF, burst of landslide lake, sturzstrom from rock/ice avalanches), any estimate of the recurrence probability remains in the dark, however.

Large landslides related to earthquakes: a direct and indirect threat to Asian mountain communities

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Large landslides in Asian mountains are often conditioned or triggered by earthquakes. Whilst the direct impact of earthquake-triggered landslides on mountain communities is obvious (casualties, severe damage), the indirect consequences of related processes are sometimes at least as significant. Such can be the earthquake-induced destabilization of slopes, resulting in an increased landslide susceptibility for many years (e.g. the Chi-Chi Earthquake in Taiwan 1999 or the Sichuan Earthquake in the PR China in 2008).

The work presented, however, is focussed on another phenomenon: landslide deposits often block valleys and dam lakes. Such landslide dams may fail suddenly due to internal destruction or by retrogressive erosion, resulting in flood waves downstream. The lakes may also drain stepwise or continuously or persist for a long time. Geomorphic evidence of former landslide-dammed lakes exists in several places. For example, the Pasor Landslide in the Bartang Valley (Pamir, Tajikistan) dammed an 8 km long lake. The patterns of the eroded lake sediments and the deposit downstream indicate sudden drainage of the lake.

Recent examples of lake-damming landslides are Hattian Bala (Pakistan Earthquake, 2005), Tangjiashan (Sichuan Earthquake, 2008), and Attabad (conditioned by at least two earthquakes, 2010). Spillways were constructed in order to reduce the maximum lake level and to control drainage. In the case of Hattian Bala, this mitigation strategy first worked, but the spillway was eroded five years later due to a landslide-induced spillover. The Tangjiashan spillway was eroded immediately. In both cases, destructive flood waves causing major damage were the consequence. The Attabad Lake has not spilled over by May 2010, but a major flood wave far down the valley was expected.

Whilst there are usually no means to prevent the landslides themselves, appropriate mitigation measures include monitoring of suspicious slopes and landslide dams as well as related emergency evacuation plans and activites.

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Mountain lakes of Kyrgyzstan with regard to the risk of their rupture

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Nearly 20 % of about 2000 of Kyrgyz Alpine lakes are supposed to be potentially dangerous because of instability of moraine or landlside dams, overflowing, rapid development of lake basin and melting of buried ice inside the moraine.

According to the last inventarization in total 328 lakes have been considered as potentially dangerous. Since 1952 more than 70 disastrous cases of lake outburst have been registered. The hazardous Alpine lakes are studied in Kyrgyzstan systematically since 1966. Last seven years the monitoring work is carried out within the programme of Czech-Kyrgyz cooperation.

The largest potentially hazardous glacial lake is the Petrov lake. According to the recent knowledge the lake has an area of 390 hectars, the water volume of more than 60 million m^3 and the maximum depth 69 m. during the last 50 years, the area of the lake has expanded 4 times. The annual retreat of frontal part of glacier tongue is 50–65 m. during the last decade. The lake lies inside the area of Kumtor gold mine just two kilometers upstream of the lake containing poisonous tailings after ore processing. The tailings can be washed down in case of extremely powerful outburst.

The danger of GLOF is increasing significantly due to the influence of recent climate changes and rapid glacier retreat. The evidence for this fact was the outburst of Zyndan lake in 2008. Three people died besides the damage of some houses and infrastructures. Glacial lakes and landslide dammed lakes on the northern slope of Kyrgyz range are monitored on the long-term basis. The lakes threated densely populated Chu Valley including Kyrgyz capital Bishkek as well as popular tourist areas nearby.

The climatological and glaciological programmes have been implemented in addition to the lake monitoring of Adygine pilot locality.

Multidisciplinary natural hazard analysis along the eastern segments of the north Anatolian fault zone, Turkey

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The North Anatolian Fault Zone (NAFZ) is one of the largest currently active strike-slip fault zone in the world, situated along the Alpine-Himalayan Mountain Belt. It extends from the town of Karlýova in eastern Turkey for 1200 km to the Gulf of Saros in the northern Aegean Sea, where it is thought to branch into several roughly parallel faults through the Sea of Marmara region and points westward. Multidisciplinary studies along active fault zones have notably increased in recent years especially immediately after the 17th August 1999 Kocaeli Earthquake in the western part of the NAFZ, and have mainly focussed in the Sea of Marmara.

Whilst settlements along the North Anatolian Fault Zone are prone to earthquakes, landslides are a common local consequence. The eastern part of NAFZ includes a number of large cities and the area has suffered several large earthquakes and landslides in historical and recent times. Between 1939 and 1999 the fault zone experienced remarkable episodic activity during which a progression of seven westward migrating large earthquakes created a 1000 km long surface rupture from Erzincan to the Sea of Marmara. Considering damage to man-made structures caused by natural hazards in Turkey, earthquakes and landslides are the most important hazards. Planning of protective and mitigation measures requires the acquisition of reliable data and with this objective in mind, a large-scale study entitled KABIS Project has been carried out between 2006 and 2010 along the eastern part of the North Anatolian Fault Zone with the participation of nearly 30 researchers from different institutions of Turkey. In this paper, the summary of results from this multidisciplinary study including active fault mapping, paleoseismology, geodesy, remote sensing, soil microzonation, borehole and landslide data will be presented. All data obtained from the study have then been combined in a Natural Hazard Information System (KABIS) based on GIS.

Monitoring tectonic movements in this region is also a most challenging activity and a dedicated geodetic network for geodynamic purposes was constructed in the region. Kelkit GPS network has settled with 36 points at the eastern part of the North Anatolian Fault Zone between Tokat and Erzincan. Soil radon monitoring and continous monitoring of geothermal fluids in 12 installed stations along the eastern segments of the NAFZ have also provided important data for earthquake mitigation in the region and will be discussed in this talk.

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Glacial Lake Outburst Flood risk assessment of Tsho Rolpa glacial lake, Rolwaling Valley, Nepal

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The Tsho Rolpa glacial lake, located at 4550 m above sea level in the Rolwaling Valley of Dolakha District, is the largest glacial lake in contact with glacier in Nepal. It has evolved from a series of small supra-glacial ponds in the late 1950's, as the Trakarding glacier has retreated. It is now more than 3 km long and about 0.5 km wide. About 200 m high frontal moraine dam is now holding back around 85 million cubic metres of water in the lake. Because it was feared that there was imminent danger of the lake bursting its moraine dam, a project to reduce this risk was implemented in the late 1990s. Thus the lake level was lowered by 3 m by constructing an artificial outlet channel through the end moraine.

During 2009 ICIMOD in collaboration with partners, carried out multi-disciplinary field investigation of Tsho Rolpa glacial lake and its surroundings. Five major themes were emphasized during the field study.

1. Assessment of the stability of the natural moraine dam
2. Estimation of the lake storage volume
3. Potential external GLOF (Glacial Lake Outburst Flood) triggering factors
4. Hydro-meteorological data analysis
5. Dam-Break Modelling and Downstream Vulnerability assessment

The above study revealed that, in case of a GLOF event, the maximum flow across the lake dam will be about 7000 m^3/s, while the flow at 60 km downstream near Busti will be about 3000 m^3/s. During the middle of the monsoon season, the discharge is about 400 m^3/s. The study also showed that, 15 bridges, 1166 houses or their contents, settlements, agricultural land, and components of hydropower project, would be at risk due to possible GLOF. As several hydropower projects are being planned downstream from the lake, there is an urgency to restore the early warning system that was put in place in 1998 which is not functional at present. The recent GLOF risk assessment reveals that the lake is still regarded as potential dangerous which needs continued and close monitoring including further field investigations for mitigation measures.

Comparative assessment of potential GLOF hazard and vulnerability of Tsho Rolpa, Thulagi and Imja Glacier Lake, Nepal

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The three high priority lakes of Nepal Himalaya; Tsho Rolpa Glacial Lake (27º 52' N, 86º 28' E, and 5460 m asl), Thulagi Glacial Lake (28° 29' N, 84° 29' E, and 4044.0 m asl) and Imja Glacial Lake (27° 54' N, 86° 56' E, and 5,010 m asl) which are located in central, western and eastern part of Nepal Himalayas respectively are well investigated by multidisciplinary teams in 2009. The results of the investigation of these three lakes are compared for GLOF hazard and vulnerability assessment in the downstream valley.

These lakes started to develop in the middle of 20 century as small supra pond but has expanded at alarming rates of 0.0241 km^2 , 0.0145 km^2 and 0.0115 km^2 per year for Imja, Thulagi and Tsho Rolpa respectively. The increases in storage volume are 0.54x$10^6 m^3$, 0.43x10^6 m^3 and 0.53x10^6 m^3 per year posing GLOF hazard and vulnerability at different scale for Imja, Thulagi and Tsho Rolpa respectively.

The expansion of lake is at the cost of ice calving and melting of mother glacier in contact with lake water at a rate of 40-43 m, 40-47 m and 6-14 m per year for Imja, Thulagi and Tsho Rolpa respectively. But the moraine dam height is more than 200 m, 60 m and 20 m and free board of 5 m, 15 m and 10m for Tsho Rolpa, Thulagi and Imja respectively. The narrowest parts of dam width are 16 m (Tsho Rolpa), 340 m (Thulag) and 567 m (Imja) respectively. Tsho Rolpa has largest storage volume of 86x10^6 m^3 and highest dam height and lowest free board and narrowest width of dam, making this lake with highest GLOF hazard despite lowering of lake level by 3 m as part of mitigation. Imja and Thulagi even though have same storage volume of 35x10^6 m^3, Imja has least potential GLOF hazard than Thulagi, due to lower dam height and wider thickness of moraine dam.

The peak discharge of Tsho Rolpa, Thulagi and Imja, in case of breaching of moraine dam of height 20 m are 7242 m^3/s, 4750 m^3/s and 5817 m^3/s respectively as simulated by dam break model. But because of wide valley immediately downstream of outlet, the peak flood is reduced substantially for Imja GLOF simulation. The monetary value of exposed elements are 11.89 (Imja), 406.73(Thulagi) and 1.84 (Tsho Rolpa) million US$ respectively. Thus, due to series of hydropower projects in the Maysyangdi River basin, Thulagi has highest GLOF vulnerability in the downstream valley.

Potential GLOF hazard and vulnerability assessment of Thulagi Glacial Lake, Nepal

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The Thulagi Glacial Lake (28^0 29' N, 84^0 29' E at an elevation of 4044 m asl) is one of the high priority potential dangerous lakes of Nepal. This lake started developing in the middle of the 20^{th} century as small supra glacial pond of 0.223 km^2 but rapidly expanded to an area of 0.94 km^2 storing $35.3x10^6$ m^3 of water in 2009. The growth rate of 40-47 m/year in length, 0.0145 km^2 per year in area and $0.43x10^6$ m^3 per year in storage volume between 1995 and 2009 is of great concern for existing hydropower projects in the downstream. An outburst from this lake could cause severe damage to the hydropower projects and other infrastructures. Thus, multi-disciplinary investigation was conducted to assess the GLOF hazard and socio-economic vulnerability.

End moraine damming Thulagi Glacial Lake has a freeboard of about 15 m, an outlet channel of about 340 m long and a dam height of about 60 m. Dam Break simulation analysis suggests that worst case scenario of breaching of the moraine dam by 1/3 would lead to peak discharge of 4750 m^3/s (with a peaking time of 0.92 hours) that would be propagated in the downstream valley.

Study has revealed that water level of outlet channel of the lake has lowered by 3 m over a decade. This in combination with large dam width and high freeboard makes Thulagi more or less stable lake in absence of other triggering factors such as hanging glaciers and rock falls, except for earthquakes. Although, the mother glacier in contact with lake water is highly dissected and fractured but considered not to be capable to generate displacement waves overtopping the dam causing failure. No seepage flow is found during field investigation but needs regular monitoring.

Based on the data collected during field investigations potential GLOF hazard from Thulagi Glacial Lake cannot be ruled out absolutely, but the likelihood of occurrence of GLOF is low, hence, periodic monitoring of the lake is required.

Geological significance of the Tam Pokhari Glacial Lake Outburst Flood, eastern Nepal

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The moraine dam of the Tam Pokhari (Sabai Tsho) glacial lake was breached on 3 September 1998 causing catastrophic Glacial Lake Outburst Flood (GLOF) along the Inkhu River channel (outlet of the lake). A two-week-long engineering geological field investigation was conducted in late summer of 2008 to make an evaluation of the possible mechanism of the moraine dam failure and the geomorphic changes brought about by the GLOF in the river channel. Geologically, the area belongs to the Higher Himalayan Zone consisting of metamorphic rocks like gneiss, schist and marble. The Inkhu River takes an almost straight course clearly showing a lineament which could be of a fault origin. Field investigation revealed a fact that a huge landslide occurred in the northeast facing inner slope of the dam prior to the failure. The U-shaped valley observed in the breached part of the dam suggests that the breaching was not by slow erosion of moving water but by an impact of surges or seiches which can swift the materials at once. It seems that the returning surges or seiches produced in the lake water by the huge landslide promoted the failure of the dam whose stability was already in critical state due to increase in pore water pressure resulted by continuous rainfall. The resulting GLOF eroded river's bed and banks at several locations and also deposited a huge amount of sediment at some places. It was observed that the erosion and deposition activities of GLOF have substantially changed the original river geometry and bed profile. This is a new discovery that the glacial lake was breached in the Himalayan region not by the increase in volume of water in the lake but by the occurrence of a landslide on the inner side of the glacial lake itself.

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Earthquake resilience capacity of the KathmanduValley: a case study of Gairi Gaun, Kathmandu, Nepal

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Researchers argue that soft lacustrine sediments of the floor, shallow groundwater table, unplanned urbanization and rapidly increasing population make the Kathmandu Valley more vulnerable to seismic hazard. However, there is a perceived lack of empirical studies leading to rational opinion building in this area. This paper evaluates the strategic measures, policy options and the tools relevant in the context of seismic risk management of the valley taking Gairigaun of Ichangu-Narayan VDC as a case. This study assessed the knowledge of community people regarding seismic hazard by conducting questionnaire survey and key informants' interview. Field survey was conducted to identify safe places and nearby health centers and the routes to follow after an earthquake within the community.

Awareness level of the community people regarding seismic hazard was found generic. Knowledge of seismic hazard and the activities to be carried out before, during and after the earthquake, was found limited to none. Only few people heard about GO BAG, an emergency kit, but had no idea about keeping necessary items in it. A very limited number of people in the community were aware of earthquake resistant technology but none of them reported that they used the technology during the construction of their residence. Moreover, people are unable to predict the post-shock scenario. Most of them were unaware of the escape routes should an earthquake occur rendering them trapped in their houses. People did not even know about the safe evacuation routes to nearby health centers in case of injuries.

Although knowledge of seismic hazard was found transmitted through relatives, friends and other means of communication, they hardly shared the knowledge within their family members. Since safe places in the community are reducing day by day, an urgent need has been felt to safeguard such locations for conducting rescue operations in post-shock scenario.

Where and how often shall large destructive earthquakes strike the Himalaya?

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Assessing the characteristics of large earthquakes along the Himalayan arc, such as their rupture extent, magnitude, return period and effects, is a major societal concern as well as a challenging scientific issue. To address that issue a number of complementary approaches need be applied to provide constraints on sub-surface structure, detect active faults and assess their slip rates and seismic behavior. The presentation will first review some aspects of the Mw 7.6 Kashmir earthquake of 2005 as revealed from remote sensing measurements of the surface deformation and seismic waveforms modeling. Next we will review learning made from the study of active deformation in the Himalaya of Nepal, in particular thanks to the combination of morphotectonic studies with geodetic and local seismic monitoring. We will discuss how these data can be used to estimate heterogeneity of geodetic coupling along the Main Himalayan Thrust fault, the relationship to potential large ruptures, implications for the return period of large events and the mechanics governing the observed behavior.

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Hunting for the traces of great Himalayan earthquakes: surface break of the M≈8.1, 1934 Bihar-Nepal event?

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Although the Main Himalayan Frontal Thrust (MHT/MFT), largest and fastest-slipping continental megathrust, poses a major threat to the northern Indian sub-continent, seismic hazard along it remains to be quantified. Based on historical descriptions of the two main 20th century earthquakes (1905, 1934), a consensus has emerged that neither produced surface ruptures, a view recently reinforced by paleo-seismological investigations in which only faulting much older than 1900 was found. This leaves us with fundamental, unanswered questions (recurrence times, rupture lengths, geomorphic signature of large events), and the ominous perspective of even greater quakes with displacements in excess of 15 m, potentially on par with M≈9 oceanic subduction events.

Our survey of the area between the Ratu Khola and Arun/Sun Khosi valleys challenges this consensus, and suggests instead the presence of a very young earthquake trace on outcrop and in the surface geomorphology at several sites. In the Sirkhola Valley, ^{14}C calibrated dates from a strath terrace uplifted ≈3 m by one shallow thrust indicate emplacement less than 250 years ago, and thus require the occurrence of a large earthquake in the 19th or 20th century, most likely the 1934 event. Work near the Charnath Khola, where we dug a 12 m-deep mega-trench and where different hanging-wall terraces perched at heights between 4 and 25 m imply successive uplift by distinct, young events, is in progress to confirm that the 1934 Bihar Nepal earthquake was not blind and to constrain its return time. The Sir Khola discovery fosters hope that other great earthquakes along the Himalayas were not blind either. Adapting paleo-seismological techniques to the scale of mega-thrust events should thus help unravel fully the seismic behavior of the MFT in the last several thousand years.

Continuous seismic monitoring of large floods and debris flows along the Trisuli River, central Nepal

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Damage and loss from landslides are considerable in the Himalayas due to the high landslide hazard as well as to the high vulnerability to these events. Some of the slope failures are extensively surveyed to enhance the hazard knowledge and mitigate the risk. However, these surveys generally lack information on the time structure of the events; information sometime necessary to characterize properly the surface processes at work. This lack often results from the difficulty to monitor continuously the mass movements at regional scale in extreme climatic and hydrologic conditions despite the ability to locally sample the sediment load in the rivers or map the landslide scars evolution using satellite imagery.

Meanwhile, the largest events generate significant high frequency seismic noise that can be recorded at local seismic stations. We therefore take the opportunity to study large debris-flow as well as monitor the sediment transport in the rivers using the Hi-CLIMB seismological experiment; a high-resolution seismic array (inter-stations distance: ~ 4 km) crossing the Himalayan Arc along the Trisuli River. This temporary network recorded the seismic signature of numerous surface processes during the 2003 monsoon season. We first reveal from the spectral analysis of the continuous seismic signal, some spatio-temporal variations of its high-frequency content (> 1 Hz) induced by the Trisuli river hydrology. We show that a significant part of the ground vibrations recorded during the river floods is induced by the bedload transport in the river, pointing out the potential of the seismic noise analysis to quantify the river bed load.

We also demonstrate that the cross-correlation of continuous seismic recordings is a relevant approach to locate river sediment (bedload) transport. The spatial distribution of the bedload transport along the Trisuli River deduced from this analysis appears consistent with the river incision rates. Finally, the detailed spectral and temporal analyses of the continuous Hi-CLIMB seismic signals points out the ability to detect and further locate hillslope processes such as landslides and debris flows. The seismic-based analysis performed helps determining the rainfall thresholds that are necessary to trigger such events and are coherent with other regional studies. All together, these results illustrate the ability to study some earth-surface processes using high frequency seismic noise analysis.

Further examination of the continuous seismic signal acquired by the National Seismic Centre network complemented by temporary seismic arrays could help to develop an innovative method to monitor the spatial and temporal activity of large geomorphic events.

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A new seismic model for Kachchh Rift Basin, Gujarat and its implications for crustal dynamics

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Occurrences of several infrequent earthquakes due to existence of hidden and unmapped faults on the surface have become one of the key issues for geo-scientific research, which need to be addressed for evolving plausible earthquake hazard mitigation model for a region. Several pieces of studies on the 26th January 2001 Bhuj earthquake (Mw 7.6) revealed that the mainshock was triggered on the hidden unmapped fault in the western part of Indian stable continental region that caused a huge loss in the entire Kuchchh rift basin (KRB) of Gujarat, India. In order to get deep insight into the crustal dynamics of the KRB we have assimilated new 3-D seismic velocity (Vp, Vs) and Poisson' ratio (ó) models using a new dataset consisting of 576-local earthquakes recorded between November 2006 and April 2009 by a seismic network consisting of 18- numbers of three-component broadband digital seismograph stations of Institute of Seismological Research (ISR), Gandhinagar, Gujarat, India. In this study a total of 5143 arrival times of P-wave (2575) and S-wave (2568) recorded by at least 4-seismograph stations for individual events were inverted to assimilate 3-D seismic models for achieving reliable interpretation of the imaged structural heterogeneities and their bearing on crustal dynamics of the region. Our new models showed that the 2001 Bhuj mainshock hypocenter is located in a distinctive zone characterized by high-Vp, low-Vs and high-ó ratio in the depth range of 20-30 km and extending 20 to 40 km laterally, which vindicates the findings of the earlier studies made by previous researchers using old data set. The high Vp and low Vs may be due to a fluid-filled, fractured rock matrix, which might have contributed to the initiation of the 2001 Bhuj earthquake. The high Vp body may be due to dehydration of hydroxyl bearing rocks of the crustal and sub-crustal layers, presence of olivine rich mafic magma and mafic intrusive with structural uplifts. The mafic intrusive may be related to the Deccan trap activity at 65 ma or the older activity related to the geological settings of the KRB. We also infer that use of detailed 3-D seismic tomography may offer potential information on hidden and unmapped faults beneath the plate interior to unravel what and how the genesis of such big damaging earthquakes caused. This study may help in evolving a comprehensive earthquake risk mitigation model for regions of analogous geo-tectonic settings, elsewhere in the world.

Geological and geomorphological causes of landslides induced by the Iwate-Miyagi Inland Earthquake in 2008

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More than 4,000 landslides occurred due to the Iwate-Miyagi Inland Earthquake (M. 7.2 in JMA scale) in the middle parts of the Ou Backbone Range in Northeast Japan in 2008 (Yagi et al. 2009). Geological and geomorphological causes of landslides have been studied in the densely distributed area of landslides on the foot slopes of the Mt. Kurikoma volcano.

Deep-seated slides and debris slides intensively occurred on the flank slopes that had been formed by river incision of the depositional surfaces of caldera-fill deposits in middle Quaternary. They consist of welded tuff underlain by pumicious tuff, volcanic ash and sand/silt deposits partially of lacustrine origin. Landslides intensively occurred in the area where the river had been incising a little under the pumicious tuff and volcanic ash layers. Slip surface of the landslides were mostly formed in the fine volcanic ash layer or pumicious tuff, both of which were prone to collapse because of high water contents beyond the consistency limits based on soil testing.

There were many numbers of seepage and water spring in the study area before and after the earthquake. Some of the seepages were observed in and just above the boundary of lacustrine deposits. Underground water from large catchment area on the slopes of the Mt. Kurikoma had been supplied to the horizontally deposited pumicious tuff and fine volcanic ash layers.

The valley-side slopes had become unstable due to the existence of weak layers of caldera-fill origin with sufficient groundwater supply and river incision which had made the valley side slopes less stable. Deep-seated slides and debris slides were triggered by the earthquake under these conditions.

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Diagnostic precursory swarm and earthquake forecast in Indo - Nepal Himalaya

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For earthquake predictions to be most useful, they should indicate four parameters of an impending earthquake: the location, the size, the time of occurrence and the probability of occurrence. The observations presented in this paper along with the tectonic setting of the area can address, though fulfill, the first three of these requirements. First, the precursory activity was closely associated to the main shock epicentres. Such close spatial association may be expected for foreshocks, but not necessarily for precursory swarms, which may be spread over a larger area. Second, the size of the impending earthquakes could be bracketed by the largest event of the precursory swarm and the maximum expected earthquake in the Indo-Nepal Himalayan plate boundary strength (seismogenic layer), which limits the maximum width of fault rupture. The limit could be suggested by the size of the largest earthquakes during the brief instrumental era. Third, the time of occurrence of an impending main shock of a given magnitude could be estimated from the relationship between the swarm main shock time interval and the main shock magnitude. It is observed here that for the shorter duration of the preparatory time period, there will be the smaller mainshock, and vice-versa. Forth parameter was tested by other methodology. Though, as people believe retrospective analysis of seismicity data would not have allowed a prediction within the error bounds. Nevertheless, enhanced risk in the area of the precursory seismicity could have been recognized. Swarms that have been interpreted using seismicity data from 1963-2006 as precursory to large earthquakes have been reported in interplate setting of Indo - Nepal Himalaya region bounded by 28.0^0-31.0^0 N and 79.5^0-82.2^0 E. The four episodic variations in seismicity: Normal/ background (N); Anomalous/ swarm (A); Precursory gap (G) and Mainshock sequence (M), respectively, have been diagnosed for three medium size earthquakes of 1980 (mb 6.1), 1984 (mb 5.6) and 1999 (mb 6.6) that occurred in the region. After critical analysis of the data, it is observed that the seismicity from 1999 onwards fluctuates in the order as low-high-low phases, following NAGM. The mainshocks were preceded by the quiescence period which is an indication for the occurrence of future seismic activity. In the light of these observations and their analyses suggest that a shallow focus ($h \leq 30$ km) moderate size earthquake (M 6.5) may happen at any time in the delineated preparatory area (29.4^0-30.6^0 N and 81.3^0-81.8^0 E) in its southern part till 2011. But surprises and failure is difficult to address at this stage, which can't be ignored.

Post-seismic deformation in Pakistan after the 8th October 2005 earthquake: evidence of after-slip along a flat north of the Balakot-Bagh thrust

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The 2005, October 8 Kashmir earthquake ruptured an out-of-sequence Himalayan thrust, located more than 150 km from the Main Frontal Thrust. The earthquake hypocenter was located at a depth of 15 km on the ramp, close to a possible ramp/flat transition. In the weeks following the earthquake, a dense GPS network was installed to measure post-seismic displacement. The initial measurements in November 2005 were followed by campaigns in January and August 2006, in March and December 2007, August 2008 and August 2009.

Two hypothesis are tested: postseismic displacements controlled by viscous relaxation of the lower crust or controlled by afterslip along a flat north of the ramp affected by the main shock. Numerical simulations of viscous relaxation do not allow to determine a single Newtonian viscosity for the different periods, this may indicate that the viscosity of the lower crust is non Newtonian or that the viscous relaxation do not controlled postseismic displacements.

Numerical simulations using dislocations indicate an afterslip along a flat connected to the ramp. Slip along the northwestern portion of the flat accrued to about 285 mm between November 2005 and Ausgust 2006, while slip along the southeastern portion accrued to 130 mm over the same time period.

The adjustment between observed and predicted displacements indicated that afterslip explains better the observations than the viscous relaxation hypothesis.

The time evolution of afterslip is found consistent with that predicted from rate-strengthening frictional sliding. The model implies that afterslip over the 4th year following the mainshock released a moment equivalent to as much as 56% ±19% of the mainshock seismic moment. The decay of postseismic slip rate compares with the time evolution of aftershocks. Given that the moment released by aftershocks amount to 5% of the postseismic deformation, we conclude that aftershocks are driven by aseismic afterslip.

Simulation of 1934 and 1988 earthquakes: implication to seismic hazard in eastern Nepal

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The Himalayan arc is widely considered as one of the hot spots in terms of earthquake disaster. Nepal Himalaya, which is centrally located in the Himalayan region has been experienced by many medium to large earthquakes in the past, e.g. 1934 Bihar-Nepal Earthquake, 1988 Udayapur Earthquake etc. On the other hand, because of rapid population growth, lack of security and income resources in rural area, considerable number of population has already been migrated to the major urban areas of the country and the trend is still continuing. Because of such population pressure and economic constrain major part of population is residing in weak, non-engineered, and unplanned structures of the urban area. Consequently, this has put large population at high risk of earthquake hazard. It is, therefore, necessary to assess the seismic hazard of urban areas so that proper mitigation measures can be adopted for the safeguard of the population under risk.

In this contribution, seismic hazard analysis for eastern Nepal is carried out with available dataset. Two point sources (e.g. 1934 Bihar-Nepal earthquake and 1988 Udayapur earthquake) are considered in the analysis. The hazard assessment is done using method proposed by Reiter (1990).

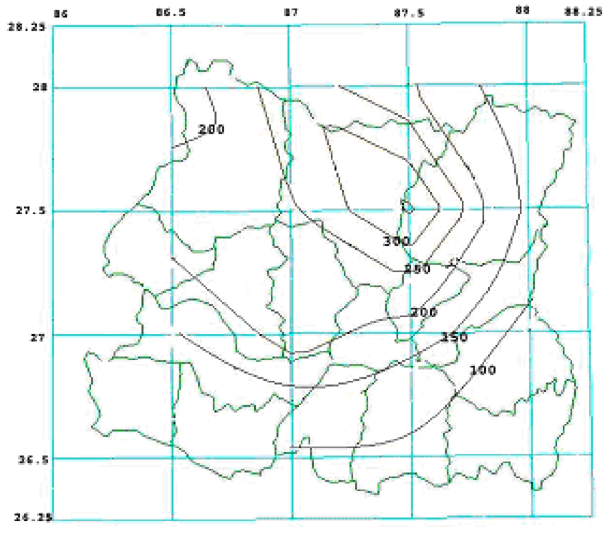

Fig. 1: Peak ground acceleration at rock bed (in gal) due to 1934 earthquake

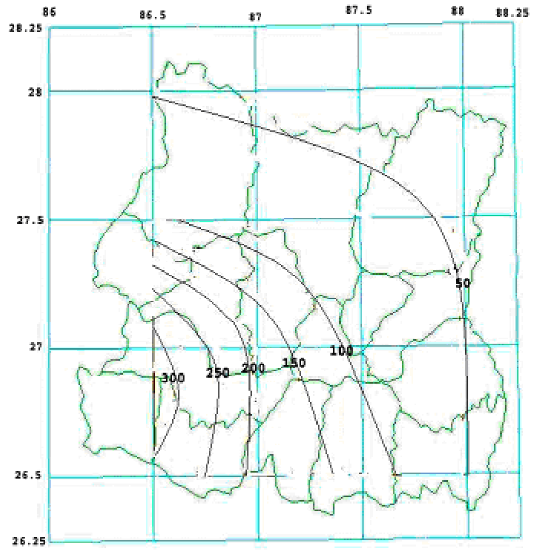

Fig. 2: Peak ground acceleration at bed rock (gal) due to 1988 earthquake

The attenuation relationship of Cornell (1979) is used. For bed rock, the Peak Ground Acceleration (PGA) at southern part of the region is about 100 gal for 1934 earthquake where as the value is as much as 350 gal at sites near the epicenter of 1934 Nepal-Bihar earthquake, i.e., Solukhumbu, Khotang, Bhojpur and Sankhuwasabha dirstricts (Fig. 1). Southern parts of Terai districts in eastern region has comparatively lower value in comparision to other parts of this region. The 1988 Udayapur Earhtquake being in smaller magnitude with 1934 Bihar Nepal earhtquake shows less hazard (Fig. 2). Overall, this study delineates state of earthquake hazard in eastern Nepal. The study provides strong ground motion data for seismic input in structure analysis and risk analysis.

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Tectonic stress field, crustal deformation and seismicity of the fold-and-thrust belt of NW-Himalaya: a numerical modeling approach

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The geological field observations such as geomorphic evidences, pattern of present-day active faults, and moderate size focal mechanism solutions indicate that the Shimla-Rampur region of the NW-Himalaya is undergone complex tectonic forces. Moreover, intense microseismic activity and active nature of the several faults and thrusts in the region exhibit that this part of the Himalaya has been accumulating significant amount stress/strain and prepare for the future devastating earthquake to fulfill the Central Seismic Gap (CSG) of the region. In this paper, a two-dimensional finite element numerical modeling experiments incorporating elastic rheology under plane strain condition with compressional tectonic boundary condition has been applied to investigate the present-day ongoing crustal deformation and tectonic stress regime for better understanding of ongoing complex tectonic activities in the region. Our results of numerical modeling show that the extensional and compressional tectonic stress regimes and normal and thrust faults were simultaneously developed in and around the Rampur-Window at shallow crustal level. This predicted results from numerical modeling show good consistency with geological field observations, microseismicity, focal mechanism solutions and GPS measurements of the study area. The projection of P and T-axis of the focal mechanism solutions show that the maximum compressional stress regime directs toward NW, while extensional stress regime exerts force toward NE direction. This NW-compressional force may develop due to the combined effect of the Main Boundary Thrust (MBT) and Pinjal Thrust (PT), while the NE-directed extensional stress regime developed because of the effect of SW directed movement of Rampur Window. The predicted result of our numerical models and analysis of focal mechanism solutions of the region show that NE-SW extensional stresses are active coeval with NW-SE contraction, which is well consistent with the present-day active faulting and neotectonic activities of the region. The significant amount of maximum shear stress (t_{max}) and strain predicted along the Main Himalayan décollement in the region indicate that the study area is prone to occur moderate and great earthquakes in future.

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The Caltech-NSC-DASE Nepal GPS Network

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Since 2004, the Tectonics Observatory at Caltech (USA) and the National Seismological Center (Department of Mines and Geology, Nepal) have established a network of continuously monitoring GPS stations in Nepal expanding on a earlier network of 3 stations which had been deployed in 1997 by the Department Analyse et Suveillance de l'Environnement (CEA, France). This network was designed to monitor slow strain build up in preparation of future earthquakes as well as transient geodetic deformation due to earthquakes, slow slip events and other sources of transient deformation.

The network currently comprises 25 sites that cover the entire country. Dual frequency code and phase observations are recorded with Trimble NetRS and NetR8 receivers. Measurements at sampling intervals of 1 and 15 sec are stored internally while the high rate data is also backed up on external serial ring buffers. The majority of stations are manually downloaded at regular intervals. A wireless internet link connects currently one site near Kathmandu. Near-term telemetry plans call for wireless connectivity of a large number of additional sites. The challenging topography demands a combination of various methods, including satellite, cellular, and long range spread spectrum based systems. We review station design and operation and address current challenges. Including data from the three DASE-NSC sites we calculate time series of positions for all stations and present an updated velocity field.

Himalayan tectonic model and the great earthquakes

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The overall definition of the Himalayan Seismic Belt (HSB) is based on the observation of intermediate magnitude earthquakes at regional and teleseismic stations outside the Himalaya. The errors of hypocenter locations are large and most of the earthquakes, as recorded in the catalogs of the US Geological Survey (USGS) and in the International Seismological Centre (ISC) bulletins, are assigned to a fixed depth (33 km) based on the global seismic stations. It has not been possible to correlate the observed seismicity and the tectonic features of the Himalaya with a realistic model, particularly the great earthquakes in the Himalaya, which had scanty instrumental records, are yet to be understood well.

The best known conceptual tectonic model of the HSB suggests that the Basement Thrust Front (BTF) lies beneath the Main Central Thrust (MCT) with a prominent ‘ramp’. The ‘ramp’ is viewed as a geometrical asperity that accumulates the stress due to the Himalayan collision tectonics, and it has been suggested that the past great earthquakes occurred on the plane of detachment. The plane of detachment is the interface between the Indian shield and the Himalayan sedimentary wedge, also known as the Main Himalayan Thrust (MHT).

The recent earthquake data of the local permanent and temporary networks and a re-examination of source processes of the great earthquakes in the Himalaya, however, do not support this model for the entire HSB. The four known instrumentally recorded great (M~8.0-8.7) earthquakes in the foothills Himalaya in India, from west to east, the 1905 Kangra, 1934 Bihar, 1897 Shillong and the 1950 Assam earthquakes occurred by different tectonic processes, and possibly none can be explained as a plane of detachment earthquake; each occurred in its own unique complex tectonic environment. The 1905 as well as the 1934 great event may have a deeper source to the south of the MBT, the 1897 great event is argued to be a shield earthquake rather than a Himalayan earthquake and it occurred by pop-up tectonics of the Shillong plateau, and the 1950 great event is argued to be caused by transform tectonics in the eastern syntaxis zone rather than by thrusting on the plane of detachment.

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Seasonal geodetic strain in the Himalaya induced by surface load variations and implications for shallow elastic structure of the Earth

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We analyse geodetic time series from continuous Global Positioning System (GPS) stations across the Nepal Himalaya. As previously reported, strong seasonal variations are observed on both horizontal and vertical components (Bettinelli 2008). We confirm here that seasonal variations of surface loading, due mostly to continental water storage, is probably the primary cause for these geodetic seasonal variations. In addition we show that this effect can be used to constrain the shallow elastic structure of the Earth. The integrated land water mass determined from the global time variations of the Earth's gravity field measured by the Gravity Recovery and Climate Experiment (GRACE) is used to estimate surface load variations. To test the proposed model we take advantage of a larger dataset of GPS time series in the India – Nepal – Tibet area and a longer time period of GRACE water storage data than previous studies. We model seasonal variations of geodetic surface displacements using first an elastic half-space approximation and find that the observed signal at a number of stations in Nepal and India can indeed be predicted reasonably well. The best fit, in the least squares sense, is obtained for an elastic modulus of 145 GPa. This model is however, difficult to assess given that it ignores the spherical and internal structure of the Earth. We therefore, show simulations based on a more realistic spherical layered Earth structure (Farrell 1972; Guo 2004). We consider an initial model based on the Preliminary Reference Earth Model (PREM), which is found to underestimate seasonal displacements amplitude. We next determine a best fitting model, in the Bayesian sense (Fukuda and Johnson 2008), by adjusting the distribution of velocities and density with depth to best match the geodetic time series. Variations by up to 10%, relative to PREM in the upper 200 km are inferred. The correction of the effect of surface load variations allows estimating better secular geodetic rates. It also enhances detection of eventual transient strain events like slow earthquakes.

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Lithospheric structure model of central Indian Ocean Basin using ocean bottom seismometer data

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The intense deformation zone in the Central Indian Ocean Basin (CIOB), south of Indian continent is one of the most complex regions in terms of its formation, structure and geodynamics. The genesis of deformation zone has been extensively attempted and debated since 1970s. It was suggested that deformation is confined mainly to sedimentary and oceanic crustal layers and deformation attributed to the mid-plate compressional stress in the Indo-Australian plate due to collision of Indian plate to Asian plate or due to defused plate boundary. The coincidence of large wavelength geoidal anomalies and the deformation region is calls for deeper sources. The inter connectivity between deeper and the shallower sources in the deformation zone is not established so far. Here we attempt to resolve the complexities of this region by analyzing deep looking Ocean Bottom Seismometer (OBS) data. The OBS data acquired along a 300 km south-north profile in the CIOB have been modeled and the crustal and sub-crustal structural configuration is obtained using 2-D tomographic inversion approach. Four subsurface layers have been identified, representing the sediment column, upper crustal layer, lower crustal layer and a sub-crustal layer (upper mantle layer). A considerable variation in thickness as well as velocity at all layers from sedimentary column to upper mantle is observed. This suggests that the tectonic forces have affected the entire crust and sub-crustal configuration. The sediments are characterized by higher velocities (2.1-km/s) due to the increased confining pressure. Modeling results indicated that the velocity in upper crust is in the range of 5.7-6.2 km/s and the velocity of the lower crust varies from 7.0-7.6 km/s. The velocity of the sub-crustal layer is in the range of 7.8-8.4 km/s. This high-velocity layer is interpreted as magmatic under-plating with strong lateral variations. The base of the 7.0 km/s layer at 12-15 km depth is interpreted as the Moho.

Strong ground motion, cultural noises and undetected micro seismic events from an accelerometric perspective

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The 21 high gain short period velocimetric stations monitored by DMG/NSC allow detecting and locating every earthquake with magnitude greater than ML=2.2 within Nepal, insuring the trigger of the seismic alert for every event above ML=4.0. However, their dynamics is not sufficient to determine peak ground acceleration, velocity and displacement at short distances from earthquakes epicenter, information which is needed as critical input to seismic hazard assessment models.

In spite of extrapolating at short distances attenuation laws constrained by the weak motion database only, we decided to acquire a strong motion database. The project began with the installation in 2009 of 3 accelerometric lines (AC23 sensors and GSR24 digitizers) in Pokhara (POKHR at sediment), Kakani (KKN at rock) and Kathmandu (DMG at sediment).

Because the temporal variations of the noise level at some of the sites (i.e. DMG and POKHR) were important, due to high levels of cultural noise, a STA/LTA (short time average/ long time average) trigger mode has been chosen. During the first months of acquisition, more than 4000 detections were collected. The characteristics of the mostly cultural-events triggering the detector, as a function of time, are summarized. They allow constraining the envelopes of peak ground acceleration (PGA), velocity (PGV) and displacement (PGD) triggering the detector. Their comparison with the micro-seismic catalogue allows determining the maximum PGA, PGV and PGD generated by every undetected-by-accelerometers earthquake. These results enhance our knowledge of the ground motion they generate in Nepal, giving an upper limit to their reach.

Planned installation of additional stations, both at rock and sediment, and acquisition of the accelerometric signal over long time windows will help constrain a strong motion database as well as evaluate strong ground motion and its variability in Nepal.

Seismic hazard map of Islamabad, Pakistan using newly developed attenuation equation

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The developed seismic hazard map of Islamabad is based on probabilistic seismic hazard computation using the newly developed attenuation equation, historical earthquakes data, geology, tectonics, fault activity and seismic source models in Iran. These maps have been prepared to indicate the earthquake hazard of Islamabad in the forms of iso-acceleration contour lines, and seismic hazard zonations by utilizing to current probabilistic procedures. They contain the probabilistic estimates of Peak Ground Acceleration for the return periods of 50 and 475 years applying the newly developed attenuation equation of the site. The map has been divided into intervals of 0.25 degrees in both latitudinal and longitudinal directions for calculating the peak ground acceleration values at each grid point and drawing seismic hazard curves. The Main Mantle Thrust, Mansehra Thrust, Oghi Fault, Banna Thrust, Balakot Shear Zone, Main Boundary Thrust, Panjal Thrust, Jhelum Fault and Muzaffarabad Fault and, further to the south, the Sanghargali, Nathiagali, and Thandiani Thrusts are the most critical tectonic features within the 50 km radius of Islamabad. The results presented in this study are to provide a base for preparing of seismic risk map, the estimation of earthquake insurance premiums, and the preliminary site evaluation of critical facilities.

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Variations in the magnitude of completeness and 'b' value for the Indian Himalaya region during the catalog period 1964-2007

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The Indian Himalaya Arc extending from Naga Parbat in the west and Assam syntaxial region in the east is one of the most seismically active regions of the world. An earthquake catalog for the period 1964-2007 comprising of 3812 earthquake events in the magnitude range 3.6 to 6.5 for this region has been compiled from International Seismological Center (ISC), and India Meteorological Department (IMD) databases. The body wave and surface wave magnitudes of the catalog events have been converted into the unified moment magnitude of GCMT by using corresponding regression relations given by Scordilis (2006). The catalog prepared in M_w is then analyzed to determine variations in the magnitude of completeness M_c, and Gutenberg-Richter regression parameters 'b' and 'a' values with time in three different catalog periods, namely 1964-2007, 1974-2007 and 1984-2007.

The magnitude of completeness (M_c) and its uncertainty for the three catalog periods have been determined using the Maximum Curvature method (Wiemer and Wyss 2000) and the Entire-Magnitude-Range method (Woessner and Wiemer 2005), and the results obtained are given in Table 1 below. Comparison of the M_c values obtained from the two methods reveals that the M_c value decreased from a higher value for 1964-2007 period to a lower value in case of 1984-2007 period indicating improved detectability of the seismic events with time in this region. The lowest value of 4.1 for M_c is given by the Maximum Curvature method with an uncertainty of 0.02.

Gutenberg-Richter regression parameters have also been determined for the complete part of the catalog for each of the three catalog periods using the same two methods and the results are given in Table 1. The values of the parameters 'b' and 'a' are found to gradually increase with time implying increase in seismicity above the M_c threshold magnitude and with a higher proportion of lower magnitude events relative to large events.

The results obtained in this study for the Indian Himalaya arc region for the catalog period 1964 to 2007 has important implications with regard to precise estimation of seismic hazard for the region.

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Table 1: Magnitude of completeness and 'b' and 'a' values for three catalog periods

Method	1964-2007	1974-2007	1984-2007
Maximum Curvature Method	b = 0.91 ± 0.01, a = 7.36, M_c = 4.3 ± 0.01	b = 0.99 ± 0.001, a = 7.66, M_c = 4.3 ± 0.01	b = 1.12 ± 0 .01, a = 8.14, M_c = 4.1 ± 0.02
Entire Magnitude Range Method	b = 0.96 ± 0 .012, a =7.61, M_c = 4.4 ± 0.15	b = 1.01 ± 0 .09, a = 7.77, M_c = 4.3 ± 0.09	b = 1.16 ± 0 .11, a = 8.33, M_c = 4.3 ± 0.06

Morphotectonics and paleoseismology of the Main Frontal Thrust in the Nepal Himalayas

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Quantifying the seismic hazard and return times of large earthquakes along the Himalayan arc remains a major challenge. Knowing the precise geometry and earthquake rupture histories of active faults is critical to assessing such hazard. Two great historical earthquakes, in AD 1934 (M8.2) and AD 1255 (M>8), have occurred in central Eastern Nepal, but no surface rupture was reported for either. Moreover, except for the 1505 events in western Nepal, the ages of ruptures found thus far in paleo-seismological trenches do not match with historical records. Thus, unambiguous answers to simple questions are still pending. How complete is the record for M>8 earthquakes in the region? What faults or fault patches generate such earthquakes and which of the corresponding ruptures reach the surface?

To address such questions we have engaged into high-resolution geomorphic and paleoseismic studies of Main Frontal Thrust (MFT) in eastern Nepal. Long wavelength warping of river terraces show that late Pleistocene/Holocene deformation is well expressed across frontal folds above the thrust, but the surface trace of the MFT, where sharpest, remains the best location to document whether large earthquakes break the ground and to determine their sizes and recurrence times. We began a new search for the rupture of the January 15th 1934, M≈8.2 Bihar-Nepal earthquake at places where only one older event had been found. We focussed on the region between the Ratu Khola and Sun Kosi River, an area entirely within the 1934 isoseismal VIII. Two small trenches were first dug, and a natural river-cut section was refreshed in the western part of the area. The Sir Khola river-cut exposes shallow thrusts particularly well. ^{14}C dating indicates the occurrence of two events more than 500 years apart, with the last one post-dating AD 1750. To test these first results, we opened a H≈60 m-long, >12 m deep mega-trench across a 25 m-high cumulative scarp of the MFT near Charnath Khola. We also refreshed a nearby river-cut that revealed inverted and faulted Siwalik beds in the MFT hanging wall. Five smaller pits were dug in terrace surfaces of different elevation to constrain their abandonment by ^{14}C dating. The paleo-seismological study was complemented by detailed topographic surveys, seismic profiles, and Electrical Resistivity Tomography. Such an integrated approach should help to solve pressing questions concerning Himalayan mega-quakes, decide whether the 1934 event was blind or not, and provide an improved time sequence of catastrophic events in Nepal.

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Interseismic strain build up in the Nepal Himalaya revealed from relocated local seismicity

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It has long been observed that deformation associated with interseismic loading on the Main Himalayan Thrust fault is associated with intense microseismic activity. In this study we analyze in detail this seismicity to explore in more details how it relates to Himalayan tectonics. We have used the double difference relocation to relocate local earthquakes recorded by National Seismological Centre (NSC) in the period between 1995 and 2002. We used handpicked travel times from the 21 seismic stations operated by NSC. The quality of the relocated hypocenters is assessed for comparison with a subset of earthquakes, which were recorded by additional 3-component stations deployed in 1995. The result depicts a narrow belt of intense seismic activity, at depth between 10 and 20 km, which can be traced along the entire NW-SE stretch of Nepal and this better follows the topographic front of the Higher Himalaya. The intense seismic activity at the front of the Higher Himalaya generally ceases, as the elevation of topography gets higher than 3500 m above msl. The seismicity pattern suggests that the Main Himalayan Thrust fault is segmented and that the segmentation correlates with well-known grabens in South Tibet. Far-western Nepal stands out as an area with particular complexity and intense microseismic activity. Elsewhere along the Nepal Himalaya, sections of earthquake density show a much simpler pattern. We determined fault plane solutions for some earthquakes, which occurred in the Nepal Himalaya and the Tibet region, based on the waveforms modeling and first P-motion data. These new focal mechanisms were analyzed in combination with those determined from local data by other groups or determined from teleseismic waveforms. The majority of shallow earthquakes, which occurred along the front of the Higher Himalaya of Nepal, are of thrust earthquake type. Most earthquakes in the Tibetan Plateau are shallow normal faulting earthquake and the deeper earthquakes are strike-slip type earthquakes. The variation of focal mechanisms reflects the effect of topography on the regional stress field. This provides a simple explanation for the seismicity cut-off where the elevation is less than 3500 m along the High Himalaya, the maximum principal stress component is horizontal and perpendicular to the range front. This stress component increases along the down-dip end of the locked portion of the Main Himalayan Thrust during the interseismic period and thus seismicity is promoted. The opposite occurs where the elevation is higher than about 3500 m, because the maximum principal stress direction is vertical there as indicated from the focal mechanisms. This study provides constraints on the amplitude and orientation of the stress field, and provides a mechanical relation to interpret the spatial distribution and temporal evolution of seismicity.

Understanding seismic hazards in Nepal Himalayas: major problems and issues

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Ongoing collision of India with Eurasia in the Himalayan front has posed a high seismic hazard manifested by many moderate to great earthquakes from the historical times in the Himalayan territory. However, the source, path and site parameters of a single event are not well resolved in Nepal Himalayas. Further, Nepal does not have strong-motion recording system in spite of frequent damaging earthquakes and the broadband recordings are still in trial phase. The earthquake catalog is incomplete for historical times. Based on the vivid seismic scenario obtained from the instrumental data for the last three decades together with available historical earthquake database and geodetic inferences, a large detachment earthquake in the Himalayan territory is most inevitable. Since earthquakes are natural phenomenon and most rarely predictable in short time scales it is important to understand the basic components of seismic hazard to reduce their aftermaths and societal impacts. For this purpose it is most crucial to estimate the level of ground shaking in the settlement areas. The input motion at the base of the engineering structures is largely controlled by the immediate and deep sedimentary structure of the site. In sedimentary basins such as the Kathmandu Basin (Kathmandu Valley), the three-dimensional structure of the basin can generate basin surface waves with large amplitudes and prolonged duration. The size of the sedimentary basins in Nepal varies from small shallow basins such as the Banepa Basin to large deep basins such as the Terai plain. Detailed velocity structures for none of these basins are resolved that pose a big problem to estimate the ground-shakings in these vulnerable areas. However, considering the past devastations and recent rapid development of mid-rise and high-rise buildings in the Kathmandu Basin, it is of immediate importance to understand the possible site effects of the thick bed sediment deposits in the Kathmandu Basin for the future large earthquake. In this paper, the existing problems, issues, and concerns related to the estimation of earthquake hazards will be briefly discussed in the context of Nepal Himalayas.

Testing earthquakes nucleation models from the response of Himalayan seismicity to secular and periodic stress variations

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Shortening across the Nepal Himalaya proceeds at a rate of about 2 cm/yr and is mainly absorbed by one major fault, the Main Himalayan Thrust fault (Lavé and Avouac 2000). Geodetic measurements show that, over the last few decades, this fault has remained locked from the surface to a depth of about 15-20 km (Bilham 1997; Jouanne et al. 2004).

The background seismicity is driven by the slow motion of India into Eurasia, responsible for the interseismic stress buildup in the period separating big (M > 8) earthquakes (Cattin and Avouac 2000; Bollinger et al. 2004). In addition to this secular motion, strong seasonal variations in the seismicity have been reported (Bettinelli et al. 2008), with a number of events about 30% higher in the winter. Similar seasonal variations have been observed in various contexts and related to factors such as snow load or variations of the water level (Costain et al. 1987; Heki 2003; Saar and Manga 2003).

We analyze the relationship between seismicity and temporal stress variations in the Himalaya to constrain earthquake nucleation process. In addition to the secular stress load induced by crustal shortening across the range, the Himalayan arc is also submitted to 2 periodic stress variations of comparable 3-5 kPa amplitudes but different periods: 12.4 hours period variations are induced by earth tides, while 1-year period variations are induced by surface load variations associated with the seasonal hydrological cycle (Monsoon). The seismicity shows no apparent correlation with earth tides, but seasonal prominent seasonal variations. These observations are used to test models of earthquake nucleation and infer frictional properties of natural faults. We find that Dieterich (1994) model can reproduce the correlation between seasonal variations of seismicity and hydrological cycle, but fails at explaining the absence of correlation with earth tides.

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Strong ground motion observation at damsite of middle Marsyangdi Hydroelectric Project, Lamjung, Nepal

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Middle Marsyangdi Hydroelectric Project (MMHEP) site in Lamjung District, Western Nepal has been equipped with four strong motion seismometer (accelerometer) at its headworks. The instruments are GURALP CMG5TD. The instruments are broadband strong motion seismometers, which record ground motion in three axis, north-south, east-west and vertical. Accelerometer SA4 is located on hard bedrock. Similarly, Acceleerrometer SA1 is located on the top of rock-fill dam, SA2 is located at spillway gate 3 and accelerometer SA3 is located at bed load flush gate at about 20 meters below the elevation of SA1 and SA2.

The site is situated close to the seismicity belt in Nepal that runs almost all along the Nepal Himalaya at the front of the Higher Himalaya. The instruments have recorded a number of very small earthquakes after the network started to function in March 2009. On 13th of April 2009 two earthquakes of Local Magnitude (Ml) 4.3 and 4.1 (Local magnitude, Department of Mines and Geology) occurred at about 15 km hypocentral distance from the dam respectively. The maximum Peak Ground Acceleration (PGA) among these four stations has been recorded by N-S component of SA1 and the value is 28 gal. Similarly, the N-S component of SA2 has recorded a value of 27 gal. N-S components of SA3 and SA4 have recorded PGA of 4.5 gal and 3.2 gal respectively. The ratio of PGA at the rock-fill dam crest (SA1) to the PGA at bedrock (SA4) is about 8.7 and similarly the ratio of PGA at SA2 to PGA at SA4 is 8.6. Among the four stations SA4 site is the quietest which is located at the de-sander and is on strong quartzite beds. The noisiest site is at the top of the dam.

New method of earthquake magnetic precursors detecting

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The earthquakes (EQ) remain one of the most dangerous natural hazards, often resulting many human victims. Because of this any progress in their forecast is of great importance. According to present conception, confirmed by many authors, the ultra low frequency (ULF) band (0.001-3 Hz) gains in importance at monitoring of lithospheric magnetic activity in seismo-hazardous areas for application to short-time EQ forecasting.

The technology of measurement these signals has several peculiarities. First, the lithospheric ULF EQ magnetic precursors are as a rule, very weak and their frequency range is totally overlapping with much more powerful signals of magnetospheric, ionospheric or artificial origin. Second, for resolution of magnetic precursors at the background of more powerful signals it is necessary to have magnetic field sensors with wide dynamics and minimum possible spectral noise density level in ULF band. The requirements to a dedicated magnetometer and its main parameters are discussed and the example of the realization of such instrument is given. Additionally, monitoring of lithospheric activity should be provided in close proximity to probable EQ area in real-time regime. Fulfilling last both requirements, there is a chance to register the ULF magnetic precursors of EQ, but the problem of their selection at the background of natural or artificial signals of much greater amplitude remains.

The newly developed technology of EQ-related signals selection is reported. The peculiarities of polarization ellipse parameters formation in frequency range 0.001 - 0.5 Hz at synchronous reception of magnetic field signals from distant points have been analyzed. Then the attempts of the use of this technology in order to select the candidates for EQ precursors are discussed, basing on the experimental data, collected in India and China by multi-point synchronized magnetometer network.

Study on soil erosion in the south bank of the Brahmaputra River in and around Hatishal, Jorhat District, Assam, India

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The Brahamaputra River is a major river in Indian subcontinent. Flood and bank erosion in the Brahmaputra River is a serious problem all along its course. The present study is an attempt to understand the nature of sub-soil and causes of bank erosion in and around Hatishal area in Jorhat District of Assam, India. The study shows that the large scale erosion took place in the area between the years 1915 and 1967 and the likely effect was due to 1950 Assam earthquake of magnitude 8.5M. The bank line migration is due to change in thalwegs in the Brahmaputra. The bank materials dominated by poorly graded soil (SP) with little clay signify poor binding force for the materials and are the causes of bank erosion. The erosion related land and property losses are mainly due to active flood plain occupation by the people where the Brahmaputra River erodes and builds the bank periodically, the period may have time range in decades.

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Discovery of Tsunami deposit in the paleo-Kathmandu Lake, central Nepal Himalaya

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Kathmandu Valley is an intermontane basin located on the basement rocks of Kathmandu Nappe in the central Nepal Himalaya. The study is focused on the fluvio-deltaic sediments deposited around the Gothatar area, which is situated to north-east of the Tribhuvan International Airport in the Kathmandu Valley in order to understand the sediment stacking pattern. Stratigraphically, the deposits in the studied area belong to the Gokarna Formation (50-34 ka). The sedimentary deposit of the area can be separated into lower, middle and upper part consisting of very thick, cross-stratified, coarse to medium grain sands of dominantly delta front origin; thick, ripple cross-laminated, very fine sand and silt with thick, parallel laminated, dark grey mud of dominantly prodelta and partly interdistributary origin; and alternating layers of thick sands, silt and mud of fluvial and small deltaic origin, respectively. For the first time peculiar sedimentary deposits have been discovered in the middle and upper part of the deposit at three distinct stratigraphic levels corresponding to the Gokarna Formation. Such deposits were observed in five different sites in an area of 500 x 500 m.

The peculiar sediments of 0.5 to 1.5 m thick deposit are characterized by:

- reverse direction of sediment transportation than the normal regional flow,
- syn-sedimentary soft-deformed structures like ball-and-pillow, disc and flame structures with small shear zones,
- gravels to very fine sand size sediment,
- deposits located at delta front zone, and
- interfinguring of normal and reverse flow sediments

The deposits are interpreted as “Tsunami deposits” in the paleo-Kathmandu Lake that appeared at around 37-38 ka.

Holocene variability of the Asian monsoon inferred from a sediment core obtained from Lake Rara, western Nepal

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The Asian monsoon is an important component of the Earth's climate system that influences the societal and economic activity of roughly half the world's population. The main driver of large-scale monsoon change over the past 10,000 years has been thought as a slow decrease in summer-time solar radiation (insolation) at 30° N owing to changes in Earth's orbit. However, some monsoon records show abrupt and/ or stepwise changes in shorter timescale (Overpeck and Cole 2007).

Understanding mechanisms of monsoon required high-resolution paleoclimate records. Potential mechanism controlling monsoon changes was proposed previously. Geochemical analyses of a maar sediments revealed that there has been inversely correlated between summer and winter monsoons during the Bølling-Allerød, the Younger Dryas, and the early Holocene and was attributed as the movement of ITCZ (Yancheva et al. 2007). However, these relations are not evident from the maar sediments during the late Holocene.

Here we present a new sediment core record from Lake Rara, western Nepal (82°052 E, 29°322 N). Lake Rara today is located at 3,000 m above sea level and has a maximum water depth of 168 m. The age model of the sediment core is based on AMS ^{14}C dating on organic materials. Concentrations of major elements were measured by X-ray Fluorescence Analysis (XRF). Intensity of chemical weathering in the catchment area was reconstructed by geochemical indexes such as CIA (chemical index of alternation). Bottom-water redox condition was also reconstructed by Mn/Al ratio. Based on the results, we will discuss evolution and variability of the Asian monsoon during the late Holocene.

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Deterioration of Nakhu Khola: impairment on dynamic and recreational functions of the river

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The Nakhu Khola, which stretches about 25.98 km from the south to the north, drains the southeast part of the Kathmandu Valley and forms one of the major tributaries of the Bagmati River. The Nakhu Khola is a fifth order drainage with an average gradient of 3 degree and watershed area of 58 sq. km. Like other rivers of the Kathmandu Valley, the Nakhu Khola is also threatened by rapid changes in land use and watershed hydrology, resulting in deteriorated and unstable stream with poor environmental condition. To identify the status of the river, four representative segments, namely, Nakhipot, Bhanisepati, Chapagaon and Nallu, respectively from downstream to upstream, were investigated for fluvial morphological and hydraulic parameters, and the whole segments of the river was surveyed for assessing various disturbances to the river.

Entrenchment ratio of the river segments ranged between 2.10 and 3.37 and thus the river segments are not much eroded. Width/depth ratio ranged between 30.19 and 78.03 showing that the Nakhu Khola is more laterally unstable. Several reaches of the river have undergone deterioration, which includes excess erosion of stream banks and channels, disturbed habitat, river encroachments, sewer disposal, vegetation clearing on banks, etc. Some causes of river impairment include man-induced disturbances, deteriorating watershed hydrology, and change of agricultural lands to human settlement areas and forest areas to rock quarries. Impacts of these disturbing effects are directed to reduction of dynamic function; reduced flow condition during lean flow period, increased sediment load and erosive power during instantaneous flow. Pollution of surface water by waste disposal and other human activities, and excessive encroachment of the river channels and banks with removal of bank vegetation have affected recreational functions of the river. To bring back the river close to its natural function and to gain optimum advantages from the river resource, all the concerning governmental and non-governmental authorities are required to come with prospective visions on to an academic platform to establish a long-term program for river rehabilitation.

Microfacies and stable isotope analysis of lacustrine carbonates from the Thakkhola-Mustang Graben, central Nepal Himalaya

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The Thakkhola-Mustang Graben represents the Cenozoic extensional tectonic phase of the Tibetan Plateau and the whole Himalaya lies at the northern side of the Dhaulagiri and Annapurna Ranges and south of the Yarlung Tsangpo Suture Zone. More than 850 m thick graben sediments are stratigraphically divided into five formations, namely the Tetang Formation, the Thakkhola Formation, the Sammargaon Formation, the Marpha Formation and the Kaligandaki Formation. The oldest sedimentary units are the Tetang and Thakkhola formations (Miocene) while the Sammargaon, Marpha and Kaligandaki formations lying disconformably above these formations represent younger units (Plio-Pleistocene). Different lacustrine carbonates and calcretes are present in these formations within different alluvial units. In this study, depositional environment and paleoelevation have been investigated by studying lacustrine deposits.

Geological mapping, preparation of columnar sections and sampling of carbonate rocks were carried out in the field whereas measurement of $CaCO_3$ concentration, stable oxygen and carbon isotope analysis and limestone thin section analysis were done in the laboratory. Lacustrine facies contain abundant charophytic algae and oncolitic algal micritic palustrine limestones with ostracodes and micritic mudstone with root fragments. The percentage of $CaCO_3$ of the limestones from different horizons of these formations ranges from 24-95. Carbon and oxygen isotope analysis of carbonates give the value of $\delta^{13}C$ from -0.62 to 11.08‰ (V-PDB) and $\delta^{18}O$ from -13.53 to -24.96‰ (V-PDB).

Calcretes were formed in arid climate whereas palustrine carbonates were deposited in sub-humid condition. Discontinuous growth of oncolites with minimum quartz grain content in the carbonates suggests that they are developed a considerable distance away from the mouth of a river. Spherical pellets (25 to 40 µm in diameter) in micritic limestone, algal mats and charophyte algae show both shallow and deep water carbonates. Ostracodes in dark micritic carbonates indicate quite and calm water condition. Microfabrics of the carbonates suggest that they are deposited in flat and shallow lacustrine environment. Based on lapse rate (-0.41 permil/100 m) of $\delta^{18}O$ in Himalaya (Poage and Chamberlain, 2001), the paleo-altitude of the Thakkhola-Mustang Graben varies from 3300 m (Marpha Formation) to 6087 m (Thakkhola Formation) and the $\delta^{18}O$ values of the limestones of the Thakkhola-Mustang Graben reflect that the Thakkhola-Mustang Graben attained the current elevation level prior to the east-west extension of the Himalaya. The relatively high $\delta^{13}C$ values of the carbonates suggest that these carbonates formed in the methanogenic zone where the bottom water conditions were dysaerobic in the lake.

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Rara Lake, its bathymetric feature and origin, Jumla District, western Nepal Himalayas

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Bathymetric survey of Rara Lake was carried out in September 2009, using the ultrasonic sounder and GPS and clarified bathymetric feature of the lake and the depth Rara Lake is situated in the wide valley that opens to the east. Its surrounding mountains are higher in the west and south. Eastern bank of the lake is closed by hills of less than 50 m height above the lake level. However, the bathymetry of the lake is quite converse. Western half of the lake is deeper than its eastern part and shows flat bottom deeper than ~160 meters. However, its eastern half shows V-shaped submerged valley. The deepest part of the bathymetry is located just adjacent to the western coast of the lake. The deepest point was ~169 meters below the lake level on 10th Sept. 2009. Therefore, calibrated depth of this lake is deeper than ~168 meter because the lake level was only 34 cm higher than the mean level. We call this deepest point as the Rathour Deep after the commander of the Rara Lake base of Nepal Army.

Present outlet of the lake is situated at the north-western corner of the lake and a shallow stream incises the bed rock. Consequently, submerged wall of bed rock is located along the western fringe of the lake. Such steep cliffs are developed also in the north and south side. A rectangular box type deep and a flat bottom are submerged in the western part of the lake. Fluvial system in this watershed could flow to the east because of the topographic outline. However, the lake water spills to the west from the outlet. Such bathymetric and terrestrial topography imply that western part of Rara Lake has been basically developed as a tectonic basin related to the Imikot-Talphi active fault system with dexstral displacement.

Eastern part of the lake is fringed by the detritus of which origin are glacial or mass movements. Such deposits seem to be damming up the wide valley to make the water level higher. Thus Rara Lake is presumed to have evolved through multi causative processes.

Lost mountains and the collapsed 15th 8000 m-peak of the Himalayas– evidence from lithotectonics and rockslide's internal structures

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Erosion and denudation are common processes of morphodynamics acting at rockslide deposits. That is why in many cases high erosion rates have rendered large rockslide deposits nearly undetectable by remote sensing methods, digital elevation data, or morphologic interpretations alone. However, erosion processes create outcrops, which allow detecting the remnants of a rockslide despite frequently occurring extensive (glacial) erosion of the deposited mass. Pre-existing lithotectonic structures and rockslide dynamics do not only leave their marks in the interior structures of a rockslide deposit but moreover in its morphologic shape and the development of a valley. Typical features such as brecciated sliding planes (in certain cases 'frictionite') and different shattered parts of the mass can be preserved for (tens of) thousands of years with important implications for the stability and longevity of rockslide dams too. In this work we give information about extension and relative age of several large rockslides in the Dhaulagiri, Annapurna, Langtang, Khumbu and Kangchenjunga regions of the Nepal and Sikkim Himalayas. Detection of these large mass movements was done by finding the rockslides' base facies as well as their internal structures. Landsliding must have occurred during post-glacial period respectively much earlier, before the last main glaciation. The mass-movements seriously influenced mountain relief in this high altitude region by dislocating cubic-kilometers of rock material as well as damming up the main valleys. As a result it is presented that landscape evolution in the Higher Himalayas is not only a matter of continuous erosion processes but also a matter of catastrophic events: giant rockslides mainly occur along tectonic overthrusting, and lithologic discontinuities with leucogranites. The world's highest mountain range has so lost dozens of high mountains including an 8000 m-peak.

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Last Ice Age glaciation of the Himalaya–investigations of trim-lines, ice thicknesses, lowest ice margin and ELA in the Khumbu Himal (Cho Oyu, Mt. Everest and Makalu-S-slopes)

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In the Mt. Everest and Makalu-S-slopes an ice stream network and valley glacier system has been reconstructed for the LGP (MIS 3-2, 60-18 KaBP) with glaciogeomorphological and sedimentological methods. It was part of the glacier system of the Himalaya and communicated across transfluence passes with the neighbouring ice streams towards the W and E. It also received inflow from the N, from a Tibetan ice stream, by the Kyetrak-Nangpa-Bhote Koshi Drangka in the W, the W-Rongbuk glacier valley into the Ngozumpa Drangka, the central Rongbuk glacier valley into the Khumbu Drangka and by the Arun Nadi Valley in the E. The thickness of the glacier sections above the snow-line amounted to 1000-1450 m. The most extended parent glaciers measured 70 km (Dudh Koshi), 67 km (Barun-Arun) and 80 km (Arun). The Arun glacier tongue flowed down to 500 m that of the Dudh Koshi glacier to 900 m. At heights of the catchments of 8481 m (Makalu), i.e. 8848 m (Mt. Everest) this is a vertical distance of 8000 m. Faces up to 2000 m above the névé areas of the 6000-7000 m-high ice streams were located 2000-5000 m above the ELA. From the maximum past glacier extension up to the current glacier margins, 14 glacier stages have been differentiated and in part ^{14}C-dated. The current climatic, i.e. average glacier snow-line in the research area runs about 5500 m. The ELA of the LGP (Würm) calculated by four methods has run about 3870 m, so that an ELA-depression of 1630 m was determined. This corresponds to a lowering of the annual temperature by 8, i.e. 10°C according to the specific humid conditions at that time.

Uplift of Tibet and the mountains of central Asia above the snowline, their Ice Age glaciation and influence on the Quaternary climate: an overview with results from 2003 to 2010

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The Ice Age glaciation of High- and central Asia has been reconstructed on the basis of glacial forms and sedimentological (sorting coefficient, C/N, lime content), grain size- and morphoscopic analyses. 8 new areas in the Himalayas, S-Tibet, and Karakoram have been investigated.

New data obtained since 1973 prove a 2800 m-thick ice-stream network and a Tibetan ice sheet of 2.4 million km². Data were collected from the Zagros in the W to the Minya Konka and from the Himalaya to the Sajan in the N.

Datings classify this glaciation as MIS 3-2. From the maximum past glacier extension up to the current glacier margins, 14 glacier stages have been differentiated and in part C^{14}-dated: four glacier stages of the late glacial-, three of the neoglacial,- six of the historical period. The number of glacier stages since the maximum glaciation agrees with that in the Alps, Andes, Rocky Mountains since the last glacial period. This is an indication of the Würmian age of the lowest ice margin positions.

Radiation balance measurements up to 6650 m indicate highest energies, making Tibet today's most important heating surface. At glacial times 70% of the energies were reflected by that High Asian-glacier area, i.e. 32% of the entire global cooling. 2.5 Ma ago, when Tibet was lifted above the snowline and glaciated, this cooling effect gave rise to the global depression of the snowline and the first Ice Age. The interglacials are explained by the glacioisostatic lowering of Tibet by 650 m so that the Tibet ice, which had evoked the build-up of the lowland ices, melted away in a period of positive radiation anomalies.

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Remote sensing and Holocene tectonics in the Padma River, Bangladesh

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Holocene tectonics in the Padma River area has been studied using time series Landsat images. Analysis of these images revealed a zone in both banks which is under extensive erosion. A lineament map has been prepared to correlate with this zone and this map shows the same directional trend as the zone shows. 45 years earthquake data of the study area have also been plotted and some of the earthquake epicenters directional trend correlates with the zone and the main river course. Fieldwork and laboratory analysis show the material difference in both bank; more silty material is observed in left bank while right bank shows more sandy material. Integrating all those data including field samples and 3D visualization model, it is obvious that Holocene tectonic of the region controls the river erosion as well as river course.

Sediment budget and hillslope-channel coupling in a Himalayan Valley (Middle Kali Gandaki, Nepal)

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Solid particles transported by rivers dominate the mass transported out of continents to oceans. This is particularly true in steep, active mountains that supply the largest sediment fluxes experienced on earth, as estimated at global scale. At mountain range scale, sediment budgets are controlled by rock uplift and by a wide range of erosion processes (detachment, transport and deposition), all operating within drainage basin units. The time and spatial patterns of these processes can be quite complex, with stages/sections of efficient sediment transfer alternating with stages/sections of sediment storages, depending on landforms (both present and inherited ones) and water fluxes. Such patterns are commonly observed in the Himalayas, where the sediment cascade is particularly efficient, as favoured by high, glaciated peaks, together with narrow valleys and steep hillslopes, in a monsoon-contrasted, climatic context. At local scale, landslides interaction with valley bottom may cause river channel diversions, short-lived dams and sediment traps, whereas remnants of ancient landslides may play an important role in the location of present instabilities and the control of sediment fluxes. Thus a sediment budget approach appears appropriate to specify the varying pathways and processes involved in the sediment cascade.

We document here debris storages and interaction patterns with fluvial activity as observed in the Middle Kali Gandaki valley (upper Myagdi and lower Mustang Districts, Nepal Himalayas). We focus on the Pairothapla-Talbagar landslide (about 16 million m3) that dammed the Kali Gandaki probably a few centuries ago. On the basis of diachronic (1974-2000-2008) geomorphic surveys and mapping, and thanks to DEM facilities, we reconstructed the extent of the landslide deposits, characterized the material (debris avalanche, including >350 m^3 blocks), estimated the volume of the resulting lake (9-14 million m^3), and of sedimentary wedges formed by later superficial reworking and downstream redistribution of debris. We assessed the recent evolution of the landslide mass. Current instabilities (rainfall triggered shallow landslides) are large enough to supply debris to the river and increase the density hence the transport capacity of the downstream flow; armouring boulders may in turn be set into motion again, accelerating erosion of the Talbagar landslide mass in a positive feedback. We estimated the volume of debris eroded and exported by the Kali Gandaki during the last three decades, illustrating an efficient hillslope/channel coupling that considerably reduces the residence time of sediments in the temporary, spatially limited traps of the valley bottom. We end up with a sedimentary budget related to this event. Comparison with other features, either older (Dhumpu-Kaiku rock-avalanche) or more recent ones (Tatopani landslide, Dana debris-flow), observed along the middle Kali Gandaki valley suggests that landsliding plays a major role in the overall process of denudation and sediment transfer outward from the mountain zone. Such a context is eventually responsible for increasing threats to newly developed settlements following recent completion of the Kali Gandaki road.

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Dhaka City water supply management, Bangladesh

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The Dhaka City is the capital of Bangladesh having the total population of over 14 millions and about 2.3 Mm^3 of water is required every day to fulfill the demand of Dhaka city dwellers. Amongst this demand, about 2.0 Mm^3 of groundwater have been withdrawing from the Plio-Pleistocene Dupi Tila Formation, presently serves as the main aquifer system of the area. About 510 tube-wells belonging to Dhaka Water Supply and Sewerage Authority (DWASA) and more then 2000 private different depths and levels of tube-wells have been withdrawing groundwater from this aquifer at the rate of 2-3 cusec and 1-3 cusec, respectively. The uncontrolled abstraction of groundwater creates management problem of water resources in the city.

The rechargeable areas are being reduced gradually due to un-plan urbanization. Thus, the process of natural water recharge to the aquifer has not kept pace since three decades and the water withdrawal from the aquifer further causing declination of water table in upper aquifer. Private owned tube-wells and 4 surface water treatment plants of DWASA meet up partial fulfillment. Compared to the over exploitation of groundwater, the renewable recharge of aquifer is very negligible. As mentioned that the rechargeable surface area is decreasing day by day due to construction of buildings, roads and concrete pavements, etc. and besides, the subsurface 6 to10 m thick compact upper clay layers, which is about 40 m in the eastern part of the city, is also responsible for very low vertical recharge. As a result, the lowering trend of groundwater level since last 38 years is from 20 to 30 m in upper aquifer with an average decline of more than 1.0 m per year. The recent investigation shows that water pollution is also an additional great problem in the city area. Municipal liquid and solid wastes and the local industrial wastewater are the major components that are playing active role in the contamination processes.

Under the present abstraction scenario the groundwater level would continue to decline at a rate of 3.0 m/year in the densely populated areas. This continuous lowering of water table has already caused problems to abstract water from upper or 1^{st} exploited aquifer and demands the necessity to explore deeper aquifers. In this context, consideration on the Dhaka Water Budget (DWB) is an important role for the better supply of water to city dwellers. This DWB includes surface-water, groundwater, rain water harvesting, etc. and take care of groundwater aquifer management systems, and also a guide-line for safe water, are needed for sustainable use of the limited resources to avoid further shortage of water in the deeper aquifers of the Dhaka City.

Lithological and mineralogical variations: indicator of provenance and paleoenvironmental change of the Kathmandu Basin fill sediments, Nepal

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Contemporary study of the lithology and mineralogy within the basin-fill sediments could provide the provenance, paleoenvironment and paleoclimatic change of the basin. In order to reconstruct the provenance and paleoenvironmental change of the Kathmandu Basin fill sediments, detailed lithological units and their mineralogical variation were studied. For this purpose detailed geological survey was carried out and the total amount of mineral variation within the sediments was estimated. XRD analysis was performed for the mineralogical study.

Mineralogical composition of the three different stratigraphic units of the Kathmandu Basin-fill sediments was investigated. Non-clay and clay minerals were identified by XRD methods. On the basis of the variation of the non-clay and clay fraction, here the interpretation for the provenance and paleoenvironmental condition during the deposition of the lacustrine facies of the Kalimati and the fluvio-lacustrine facies of the Sunakothi Formation is done. Both Kalimati and Sunakothi sediments contain same mineral composition while Thimi sediments did not contain carbonate (calcite) minerals and the amount of mica is higher than in the Sunakothi and Kalimati formation. Higher amount of smectite within the clay fraction and presence of calcite within both clay and non-clay fraction in the basal part of the Sunakothi indicates seasonal and prolong dry climatic condition was occurred during the deposition of the Kalimati to Sunakothi Formation. On the other hand, lower amount of kaolinite/smectite ratio, and excess amount of carbonate mineral within the basal part of the Sunakothi formation shows depositional environmental changes from deep to shallow, and lake water became more alkaline. Gradually lacustrine condition changes into the fluvio-lacustrine condition. On the other hand, higher ratio of the kaolinite/smectite within the Kalimati to lower ratio of the kaolinite/smectite within the basal part of the Sunakothi sediments indicates climatic condition was more seasonal and cold/dry than the Kalimati Formation. Both kaolinite/smectite and smectite/illite value indicates paleoprecipitation of the Kathmandu Valley was higher during the Kalimati phase than the Sunakothi.

The XRD analysis of the non-clay fraction from the Sunakothi Formation (covering from bottom to top) reveals mica, quartz, feldspar (plagioclase and K-feldspar) and a minor amount of chlorite. Quartz and feldspar are the main constituent minerals with a range of weight percent, respectively, from 40 to 80 and from 1 to 24 of bulk sediment. Quartz is dominant in lower part of the formation, while feldspar is more or less homogeneously distributed in the sediments of the formation. Remarkably, calcite is dominant (46 wt%) in the basal part in contrast chlorite is dominant (14 wt%) in the lower to upper part. The surrounding mountains to the south of the basin are comprised by meta-sandstone, shale and limestone (Stocklin and Bhattarai 1977). Gneiss and granites comprise the Sheopuri Mountain to the north of Kathmandu Valley. Dominant proportion of quartz and a weak amount of feldspar with absence of tourmaline in the sediments indicate the major source of the sediment to the mountains of southern and its surroundings region. Moreover, dominant detrital calcite in the basal part of the formation attest its source to the southern mountains as the basement rocks are confined to only south of the basin. Chlorite could have two types of origin, a product of weathering from micas in the sedimentary basin or the flux from the low grade metamorphic rocks of Phulchoki Group. The underlying Kalimati Formation is rich in quartz, feldspar and mica, while calcite fragments have 8 wt% signifying the major input of sediment from north is changed to south during the deposition of Sunakothi Formation.

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Geology of alluvial fan sediments, southwest part of the Kathmandu Basin, Nepal

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The southwest Kathmandu Basin is bounded towards south by the Chandragiri Range, which is a syncline and at the north by the southern limb of the anticline that extends NW-SE through Indrasthan. It is basically a hanging valley with the basement rocks of metasandstone, metasiltstone, phyllite, shale, quartzite and limestone belonging to the Phulchowki Group of the Kathmandu Complex. The thick and irregular fluvio-lacustrine sediments floor the basin, whereas a thick and irregular blanket of alluvial fan sediments of Holocene covers the basement rocks as well as the fluvio-lacustrine sediments (rich in thick black clay and silt) in the southern part of the basin along Thankot-Macchegaon. The alluvial fan approaches more than hundred metres in the southern part close to the ridge, and gradually becomes thinner towards the inner part of the basin. The alluvial fan sediment is characterised by very poorly sorted angular to subrounded boulders and cobbles to poorly sorted muddy cobble-pebbles intercalated with clast-supported cobble-pebbles from the south to the north of the deposit. The clasts of the deposit are composed mainly of metasandstone, metasilststone, shale, quartzite, limestone and phyllite and show their provenance towards the Chandragiri Range. These clasts along with muddy matrix were derived as a result of upliftment of the Chandragiri Range and supply of sediments through debris flows along several S–N flowing streams, indicating torrential rainstorms at the past environment. The alluvial fan deposit is a huge resource or the construction material. The Balkhu River and its tributaries incise the alluvial fan deposit as well as the basement rocks and fluvio-lacustrine sediments and still headward erosion is actively continuing. The elevation of the fluvio-lacustrine sediments and their relationship with the alluvial fans indicate that the southwest Kathmandu Basin could have existed as a separate basin from the major portion of the paleo-Kathmandu lake, but this has to be confirmed by dating of the sediment horizons.

Effects of human distrurbances and climates on morphological changes of Bagmati River, central Nepal

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Rivers are significant geomorphological agents, which show diversity of form and behavior. The Bagmati River flowing from north to south originates from the Shivapuri Range and flows over the Kathmandu Valley. The Bagmati River of the Kathmandu Basin is 6th order drainage of length of about 28 km. This river, which has been suffering from unmanaged urbanisation and industrialisation, and growing population pressure on catchment, undergoes serious deterioration in terms of its natural function. Several anthropogenic activities as channelisation, sediment excavation, effluent discharge, dumping waste on and along the river banks, building roads etc. are responsible for alteration of meander belt width, meander length, sinuosity and radius of curvature. Present study assesses morphology, morphometry and disturbing conditions in the river course providing overview of river channel management, illustrating why an understanding of fluvial geomorphology is vital in channel preservation and restoration of degraded river channel.

Plant macrofossils from the Late Pleistocene sediments of the Kathmandu Valley, central Nepal: implications for palaeoclimate

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The lacustrine sediments of the Kathmandu Basin is one of the best archive to study the palaeovegetation and palaeoclimate based on plant macrofossils (seeds, fruits and leaves) in the local level. Samples were taken from different well-exposed sections of the Gokarna and the Thimi formations. Generally plant macrofossils were well recorded in silt, silty sand and micaceous fine sand layers. A single seed is used for ^{14}C dating, and the AMS age obtained from Besigaun section is 53,170±820 years BP and that of Gokarna landfill section is 52,150±740 years BP. The microscopic analysis of the macrofossils revealed that more than 50% of taxa are common in Dhapasi, Besigaun and Gokarna Landfill section, and 85% of the taxa noted as palaeoclimate indicators were same. With the constant and abundant occurrence of subtropical and warm temperate taxa like *Eurya*, *Ficus*, *Rubus*, *Quercus* cf. *Cyclobalanopsis*, *Zizyphus*, *Pyracantha* and *Carpinus* in the lower and the middle horizons indicated the warm climate, however the higher contents of cooler climate indicators like *Abies*, *Pinus*, *Picea*, *Tsuga*, *Taxus*, *Corylus*, *Quercus* cf. *lepidobalanopsis* and *Betula* in the upper horizons suggest the change of climate from warm to cold phase during the deposition of the Gokarna Formation. This cold phase continued in the plant macrofossil assemblages in Thimi Formation as well. The common occurrence of *Abies*, *Pinus*, *Picea*, *Tsuga* and *Taxus* throughout the lower and the middle macrofossil horizons from the Madhyapur Thimi section indicated the cold climate. Decrease in conifers in the upper horizons and dominance of warm climatic taxa like *Carpinus*, *Eurya*, *Rubus*, *Viburnum*, *Pyracantha* and *Sambucus* indicated the amelioration of climate (i.e. shifting of climate from cool to warm phase) during the deposition of the Thimi Formation.

On the basis of plant macrofossils, it is assumed that there was change of climate from warm to cold phase and again to warm phase in and around the Kathmandu Basin during the Late Pleistocene.

Slumped beds in the flood plain deposits of the Pleistocene Gokarna Formation, Kathmandu Valley, and their origin

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Widely traceable slumped beds were found in flood plain deposits in the Gokarna Formation (ca. 50–34 ka) around Gothatar Village, east of Pasupatinath, Kathmandu. The most distinctive of these beds was recognized at 1,340–1360 m above sea level. Weakly deformed parts of these beds are 0.5 m thick, and consist of root-bearing pale-green mud with desiccation cracks. Thickness of the more deformed parts range from 0.1 to 3 m, and slumped structures such as slump folds are common. The sediments below the slumped bed are generally disturbed by liquefaction. At the western end of the Gothatar sand mining site, the bed is steeply inclined and passes into the delta front deposit. Possibly correlative slumped beds were also found at the same topographic level in the Mulpani and Arubari areas, 1 km east and 2 km north of the Gothatar site, respectively. This suggests that a single mud bed slumped over a wide area of the eastern Kathmandu Valley.

A large earthquake was the most probable trigger for this slumping. The slumping may first have occurred in the delta front, leading to dragging of the flood-plain muds near the lake margin, and subsequent failure and sliding of more inland parts of the flood plain muds toward the lake. Slumping over a wide area of the flood plain must have been induced by liquefaction of the sediments below the mud bed by an earthquake, thus acting as a lubricant for the moving mud bed. To date, three slumped beds have been identified in the sediment interval deposited between 40 and 34 ka; the recurrence time for large earthquakes is therefore roughly estimated to be about 2,000 years.

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Dynamics of the Greate Caucasus Mountain Lakes, Russia

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Numerous mountain lakes are widespread over the Great Caucasus territory. At present there are 1852 lakes with a total area of 95.8 km^2. The largest lakes are Kazenoyam, Abrau, Big Ritsa, Kelistba, Bazaleti (Table 1). Most of the mountain lakes (60%) have an area <5000 m^2. These smaller lakes account for 11.5% of the total lake water surface (Efremov 1993).

Mountain lakes are very sensitive to changes occurring in their watersheds. Changes connected with climate, glaciation and river run-off are particularly important. According to existing ideas the formation and development of glacial lakes in high-mountain areas is a consequence of climatic variability, expressed in the process of glacier degradation. The area and a number of glaciers are decreasing. Periglacial lakes are formed in favorable geomorphologic conditions where glaciers have vanished. Studies have shown that most of the periglacial lakes appeared during retrogressive phases of glaciation: 2500–3000 years ago and in the 19th century. Analysis of literature sources, topographic maps of 1881-1910 and topographic interpretation of aerial photos from different years have shown that glaciers existed to the end of the 19th century in many places now occupied by modern glacial lakes.

Lake formation in the Great Caucasus is continuing today as glaciers recede. So, over the last 50 years about 100 new periglacial lakes have appeared in the West Caucasus.

Morphometric indexes of lakes also depend upon climatic conditions, as do water regime indexes. For instance, lake levels are raised when rainfall increases but so, in consequence, are depth, area, width, length of shoreline and others characteristics.

Table 1: Major lakes of the Caucasus

Lake	Area (km^2)	Altitude above sea level (m)	Maximum depth (m)
Kazenoyam	1.7	1870	72
Abrau	1.6	83.7	10
Big Ritsa	1.49	884	102
Kelistba	1.28	2914	63
Bazaleti	1.22	878	7

We conclude that mountain lakes are indicators of environmental changes. However, specific relationships between indicators and climate and glaciation changes for individual lake have not been studied in enough detail to make more than this generalized conclusion. We propose that this available information can form the basis for further studies.

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The Development of an Online 3D Compound Virtual Field Trip system

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A 3D Compound Virtual Field Trip (3D-CVFT) online system developed by a group of researchers at National Taiwan Normal University, Taiwan is not only functioning as multimedia virtual-reality software which supplies close-to-real geological field trip experiences, but also tries to tailor the 3D-CVFT to diverse students' learning needs by leveraging on auto grading and feedback interfaces in the system. In the online 3D-CVFT system, users have ample opportunities for exploratory and observational activities, which are prominent activities in field trip. Some possible educational implications in terms of the use of virtual reality technology as alternative to actual field trips in the area of earth science are also discussed.

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Geobiology and geomicrobiology: an emerging field in earth system science

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The physical and the biological processes continuously interact and influence one another, where as in the academic world, we have classified the geological sciences and biological sciences as separate entities. This has led to poor understanding of the coupled earth-biosphere interactions. In order to understand the Earth's past history or to predict its future, scientists must investigate how the geosphere and the biosphere co-evolved. In this context, in addition to the conventional biological and geological courses, new cross-disciplinary courses in geobiology should be developed. Geobiology is the study of the interactions that occur between the biosphere and the geosphere. Geomicrobiology deals with the interaction between microorganisms and their metabolic processes with geological and geochemical processes. Understanding geobiology and geomicrobiology, is critical to solutions aimed at many societal issues, including groundwater quality, environmental contamination, global warming, in addition to their applications in waste degradation, bioleaching. They are tools which will provide exciting intellectual and practical rewards.

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