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10th NEPAL GEOLOGICAL CONGRESS (NGC-X)

"Geosciences for Sustainable Development and Prosperity"

March 7-8, 2021
Kathmandu Nepal

Organized by
Nepal Geological Society

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Nepal Geological Society is one of the leading professional societies in Nepal that have been working in fostering the research and development in the field of geosciences for the prosperity of the country. It was founded in 1980 and now it has more than 1000 members. It has already received some remarkable achievements and has been honored with different prestigious awards like "United Nations Sasakawa Disaster Prevention Award Certificate of Merit" in 1998; Science and Technology Promotion Award from Nepal Academy of Science and Technology (NAST) in 2013.

Nepal Geological Congress is one of its part of activities to promote the research in the field of geosciences; provide opportunities to the scientists and platforms to the youths in sharing their experience and gain the knowledge by interacting with the international as well as national experts. Nepal Geological Congress is held biennially since 1995; 10th Nepal Geological Congress is the part of this continuation. This congress is being held during March 7-8, 2021 in Kathmandu. However, because of the continuing widespread of deadly COVID-19 pandemic in the world, NGS has decided to conduct 10th Nepal Geological Congress virtually on the web based platform. The women and young geoscientists will be given priority to share their experience in this particular Geological Congress.

The main theme of the Congress is Geosciences for Sustainable Development and Prosperity. The theme of the congress itself is of great significance, which tries to reveal the importance of geology and its applications in the sustainable development and economic prosperity of the nations. For this purpose, knowledge from different sectors of geosciences can be utilized. The Congress will focus on the 12 subthemes including Geological mapping, Stratigraphy and Regional tectonics; Advances in Mineralogy, Petrology and Geochemistry; Exploration and Mining of Mineral Resources, Petroleum and Natural Gases; Engineering Geology for Sustainable Infrastructure Development; Geo-Hazard Assessment, Risk Reduction and Mitigation; Advances in Geophysics, Earthquake Seismology and Seismo-tectonics; Environmental Geology and Climate Change Issues; Plans, Policies and Strategies of Nepal Government on utilizing geosciences; Women and Youths in geological sciences and COVID-19 and Earth Science Studies. Total of 75 abstracts within different twelve subthemes are accepted for the oral presentation in the congress. The scientists from 12 countries in the world namely Nepal, Japan, United States of America, United Kingdom, Australia, New Zealand, Poland, India, Bangladesh, Pakistan and Myanmar will present their research findings and experiences in this international event.

On behalf of the organizing committee of the 10th Nepal Geological Congress, I extend sincere gratitude and acknowledge the important contributions made by all the paper presenters and all the members of Nepal Geological Society. The sincere support and encouragement shown by the Executive Committee of Nepal Geological Society is commendable. The generous support made by the following collaborating organizations, supporting organizations and sponsors is highly appreciable.

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I wish the successful presentations, encouraging participation, fruitful discussions and worthy knowledge sharing among the geoscientists and participants of this important international event.

On behalf of the organizing committee and advisory committee

Subodh Dhakal, Ph.D.
Convener of 10th Nepal Geological Congress
March 5, 2021

Keynote Lectures

Invited Lectures

Geological Mapping, Stratigraphy and Regional Tectonics

Advances in Mineralogy, Petrology and Geochemistry

Hydrogeology and Water Resources

COVID-19 and Earth Science Studies; Women and Youths in Geological Sciences; Plan, Policies and Strategies of Nepal Government on Utilizing Geosciences

Geo-Hazard Assessment, Risk Reduction and Mitigation

Engineering Geology for Sustainable Infrastructure Development

Advances in Geophysics, Earthquake Seismology and Seismo-tectonics; Advances in Mineralogy, Petrology and Geochemistry

Environmental Geology and Climate change Issues in Geosciences

Hydropower Development and Tunneling; Miscellaneous

Keynote Lectures

Geological and geomorphological causes of large-scale landslides along the Kaligandaki River, Nepal Himalaya

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Extending southward through the High Himalaya, Kali Gandaki River represents the deepest gorge of the world (~6000 m), that has been profoundly modified by fluvial and partially glacial erosion and by mass movements. This study investigated the geological and topographic characteristics of large-scale landslides (Dhampu-Choya, Talbagar, Kopchepani, Gadkhan, Gadpar, and Basari) and their occurrence in relation to geomorphological development. Field surveys and topographic analysis were carried out by using ALOS PRISM image with a resolution of 5 m and 5-m mesh AW3D DSM.

Along the Kaligandaki River from Beni to Dhampu, there are three outstanding knick points at Doba, Talbagar, and Kalopani, respectively. The knick points migrate upstream from convex slope breaks at around 200–500 m above the current river bed by undercutting of nearby slope toes. The knick point at Kalopani separates the narrow gorge from the wide braided river floodplain that was formed associated with a landslide dam by the Dhampu-Choya landslide (3 km3, Fort, 2000). Gneissosity of calc gneiss in source area on the right bank of the river strikes NW–SE and dips 38°–55° to the N, however, they were gravitationally deformed to form buckling folds at the sliding surface and the foot of the source area. The observation suggests the landslide was preceded by gravitational deformation beforehand. Talbagar, Kopchepani, Gadkhan, Gadpar, and Basarilandslides were aligned downstream of the knick point at Kalopani on the left bank of the river, where the slopes are mostly infacing slopes. The source area of Talbagar landslide was observed to have gneissosity that trends WNW-ESE and dips to N and high angle joints trending N-S. The bedrock of Kopchepani, Gadkhan, and Gadpar landslides consists of two mica gneiss trending WNW-ESE and dipping 45°–60° to NNE. Flexural toppling had occurred above the slope break. Basari landslide occurred about one month after the 2015 Gorkha earthquake below a slope break at 450 m above the riverbed. This landslide created a landslide dam, which was breached. The bedrock consists of phyllite trending NNE-SSW and dipping 20°–30° to ESE. The rock is highly jointed, trending NNE-SSW and dipping with high angle. Open cracks were predominantly observed within the source area.

Keywords: Large scale landslides; Kaligandaki River; Geological and geomorphological causes; Field survey; ALOS PRISM image

Recent advancement in slope stability and deformation analysis

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Landslides and other mass movement related disasters result billions of dollars of economic loss in addition causing tens of thousands of deaths and affecting millions of people, annually. Historical data demonstrates an increase in the number of landslides with an increase in the number of significant earthquakes and wetter than average annual precipitations. Methods to investigate, monitor, analyze, and design prevention plans for landslides have significantly evolved in recent years with the technological advancement. Specifically, tools used to evaluate safety margins of slopes and potential displacement of the slopes during any movement have also improved significantly in recent years with an added enhancement in computational accuracy and time for analysis as well as prediction. This presentation includes a summary of the recent advances in our knowledge pertinent to the methods of slope stability and deformation analyses – both in micro and macro scale as well as 2D to 3D levels - in the past 25 years. Specifically, this presentation will focus on the improvements in our computational and graphical capabilities that was possible due to the significant enhancement of computational capabilities and widespread availability of computers, internets, and commercially available software - worldwide. This presentation will also focus on robust methods developed in recent years to perform the macro level stability analysis for regions, the advent of probabilistic slope stability analyses, developments in slope stability analyses of unsaturated slopes, and new methods to perform slope deformation analyses. The presentation will be supported by case histories either available in the literature or through the presenter's own research.

Keywords: Slope stability; Deformation analysis; Computational capabilities; Case histories

Landslide management in Nepal: Issues of responsibility distribution in federal system of governance

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Nepal is prone to various types of natural hazards such as earthquake, flood, landslides thunderbolt, forest fire, epidemics, etc. Out of these hazards, landslides are most frequent events that occur almost everywhere in mountainous part of the country each year. Rock exposures, dissected by joints and fractures developing rock blocks of various sizes, in conjunction with high relief and steep topography constitute favorable situation for landslide. Pore water pressure, earthquake tremor, and anthropogenic activities like deforestation and slope cutting for various infrastructure development projects are among the main triggering agents. Size of a landslide may vary from very small affecting just a few square meters area to very large covering several square kilometers areas. These landslides damage physical infrastructures and also kill people each year affecting to the GDP of the country as well. Although attempts have been made to control landslides since several decades, its results are still less than satisfactory. Besides, after introducing federal system in governance, there has been a confusion regarding which government (local / provincial / federal) will take the responsibility of controlling the hazardous landslides. The main objective of this paper is to clarify this confusion. For the purpose, major construction projects that trigger landslides were listed out, relevant legal acts were reviewed, and availability of relevant human resources in government agencies were also analyzed. Results indicated that the landslide issue can be addressed effectively if mandate is given to the local, provincial and federal governments based on, the project type, size and geotechnical nature of landslide, and number of households at risk or likely affected public properties.

Keywords: Landslide management; Federal structure; Roles and responsibilities; Resources

Invited Lectures

Nanda Devi glacier burst triggered avalanche and flood in Chamoli district of Uttarakhand Himalaya, India: Impact of global warming and climate change in Higher Himalaya

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A devastating glacial avalanche was triggered by the burst of a portion of Nanda Devi glacier on 7th February, 2021 around 10.45 a.m. in the Garhwal region of Uttarakhand Himalayas situated in Chamoli district close to Joshimath town. Geologically, it is located near the Main Central Thrust (MCT), a highly fragile, seismically active tectonic zone of Indian Himalaya. The glacier burst at the Raini village has resulted in a flood in the Tapovan area of Joshimath in Chamoli district of Uttarakhand. Consequently, flash flood in Dhauliganga, Rishi Ganga and Alaknanda Rivers reminds us after seven years, the Himalayan tsunami of Kedarnath disaster of 2013 due to glacial lake outburst flood. As a result of recent tragedy, many people again lost their lives and properties, hydroelectric power projects of Rishiganga and NTPC situated in Dhauliganga and Rishiganga were completely damaged. Other infrastructures like bridges and roads were also heavily devastated by massive flood. Rescue and relief operations are still in progress by NDRF, SDRF, ITBP as operation Jeevan and many lives are saved. Many houses situated on the banks of the Dhauliganga River in Raini village famous for Chipko Movement of 1974 to save the local forests by local women got destroyed because of the sudden rise in water level in the river. Impact of global warming, climate change, extreme weather are considered the main causes of such frequent disasters in the Himalayan region (third pole) by IPCC and present author interviewed by Nature in Tubingen, Germany for a paper published in 2013 (Nature, September, 2013) after the Kedarnath tragedy. The causes for the present Chamoli disaster is being studied by satellite images and ground geological information which lies in the seismic zone V, where greater earthquake have occurred in 1991 in the past, besides, flash floods, landslides and Landslide Lake Outburst Flood are common. An early warning system for avalanche prone areas of Uttarakhand is necessary to monitor the glacial avalanche. In the present paper, various factors which may have been responsible for the avalanche has been discussed since there has been heavy snow fall recently and glacial lake outburst in winter is not common. The rise in temperature for melting of Himalayan glaciers is an important issue to understand such avalanche related disasters in future. Since the temperature will rise in summer, there is a possibility of further glacial burst in the area. There are many myths and rumours about the Uttarakhand glacial burst. According to Zee News channel, the villagers of Raini village have said that they noticed a pungent smell in the air muck and rubble rolled down from the Nanda Devi Mountain into the Rishiganga River when flash floods occurred in the area. They have expressed concerns that the disaster might have been caused by a radioactive device (plutonium) that lay buried somewhere in the Nanda Devi Mountain. The device is most likely trapped among the glaciers. It is inappropriate to link the two events. Nepali geologists have also expressed fear that Uttarakhand glacier avalanche raises alarm for similar devastation for Nepal sooner or later.

Keywords: Nanda Devi; Garhwal; Uttarakhand; Chamoli; Avalanche; Disaster; Glacier burst

ISRL ages and possible origin of Late Pleistocene surficial sand deposits in the lower Khumbu region, Nepal

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Several exposures of lake deposits, recently recognized in the lower Khumbu region, around the Namche-Phortse-Tyangboche areas, were examined to improve our understanding of the Quaternary geomorphological history of this region. Five of the six deposits sampled are characterized by well bedded fine sand and are interpreted as lake or pond deposits. One sample lacked evidence of layering and is possibly a windblown sample. Two samples near Namche Bazar post-date the large Khumjung Rockslide Complex (KRC) but are cut by the landslides that created the current site of the Namche village. All six samples were analyzed by utilizing the infrared stimulated luminescence (IRSL) dating of feldspar sand to constrain the depositional ages. Coupling the analytical results with the field stratigraphic relations, it has been estimated that the Namche landslides occurred after 24.24 ± 2.43 to 26.64 ± 2.56 ka. These landslides cut the deposits of the large-scaled KRC, which was triggered prior to 26.64 ± 2.56 ka, and possibly during a mega-earthquake. Towards the north-east, sedimentation on the strath terrace of Phortse began at around 42.61 ± 6.41ka, which marks the end of the glacial stage that carved this terrace. This estimate serves to better constrain the Tyangboche stage I of Finkel et al. (2003), which lasted from 86±6 till 42.61±6.41 ka. Furthermore, the presence of lacustrine deposits in these areas strongly indicate that these high-altitude lakes are common occurrences, a claim that can be backed by modern lake analogues in the Gokyo, Imja, and Hongu valleys. Also, the IRSL feldspar dating technique is greatly reliable and immensely valuable for constraining the depositional ages of these Quaternary landforms in the Himalayan High Mountains.

Keywords: Sand deposit; Quaternary geomorphological history; IRSL dating; Khumbu region; Nepal

Copper ore mineralization belts in the Nepal Himalaya

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Two distinct west-east extending copper ore mineralization belts are identified in the Nepal Himalayas. The Northern Belt lies in the vicinity of Main Central Thrust (MCT), where the mineralization is occurred mostly in garnet amphibolite facies metamorphic rocks in different locations in Khandeshowari and Danfechuli in Darchuli; upper reaches of Bauligad in Bajhang; Sikpashore in Dolakha; Wapsa in Solukhumbu; and Siddhikhani in Ilam. They are fairly rich in copper content (0.8 up to 14%) with or without traces of gold. Locally, they were mined traditionally by local people in very small scale in the past and totally closed after 1951. Detail exploration and evaluation of these prospects is warranted to determine their tonnage and grade for mining possibilities.

In the Southern Belt of the Lesser Himalaya, almost all the copper mineralization occur in the low grade green-schist facies metamorphic rocks at different places from west to east in Bamangaon in Dadeldhura; Rukumkot in Rukum; Pandav Khani in Baglung; Okharbot in Myagdi; Bhutkhola in Tanahun; Dhusa in Dhadhing; Kalitar in Makwanpur; Kurule in Udayapur; Chhirling Khola in Bhojpur etc. Almost all these mineralization are related to hydrothermal disseminated irregular vein type and may have concentrated during the processes of regional metamorphism at the time of Himalayan upheaval. The copper content in them is less than 0.5% in an average and small in tonnage. However, frequent association of gold and presence of other ore minerals of nickel, cobalt, bismuth, tungsten, molybdenum etc. still suggest for further evaluation of some of these polymetallic prospects in terms of their economic viability.

Keywords: Copper ore; Nepal Himalaya; Polymetalic prospects; Garnet-amphibolite facies

Geological Mapping, Stratigraphy and Regional Tectonics

Post Maastrichian–Palaeocene Tethyan shallow marine orthophragmine (larger Foraminiferal) – Algal paleobiodiversity in the eastern Tethys, Meghalaya, NE India

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Late Paleocene – Middle Eocene Tethyan foraminiferal – algal carbonate biofacies are well developed after the Late Cretaceous – Paleogene mass extinction event in the eastern Tethys, Meghalaya, east India. Tethyan Foraminiferal – algal biotic diversity is recorded from the Lakadong and Umlatodoh Limestones of the Sylhet Group well exposed in East Khasi and Jaintia hills, Shillong Plateau Meghalaya. These Tethyan benthic orthophragmine foraminiferal –algal limestones were deposited in a passive continental margin setting on a shallow marine carbonate shelf in eastern Tethys and Standard Benthic Zones (SBZ) of the Alpine- Adriatic western Tethys are recorded from Meghalaya. These sedimentary basins developed after the separation andcounter-clock wise northward movement of India from Australia and Antarctica in the Late Cretaceous times. The Cretaceous – Tertiary boundary is well marked in these basins by biotic mass extinction. Late Cretaceous mega ammonoid fossils and Sauropod dinosaur bones are abundant in the Maastrichtian Mahadek Formation.

The global extinction event is also substantiated by Carbon, Oxygen and Mercury isotope chemostratigraphy. The larger benthic orthophragmine foraminifera assemblage of Lakadong Limestone is compared with Alpine- Adriatic - Himalayan –Meghalayan Tethyan and Tibetan zones. The algal assemblage of Lakadong Limestone includes Sporolithon sp., Lithophyllum sp., Jania sp., Corallina sp., and Distichoplax biserialis. The overlying Umlatodoh Limestone is characterised by larger benthic foraminifera of Thanetian –Ilerdian age. Calcareous algae include species of Helimeda sp., Sporolithon sp., Ovulites sp. and Spongites sp., These larger benthic foraminifera and coralline algae show a wide biotic diversity in the Paleocene-Eocene eastern Tethyan carbonates of Meghalaya, east India and have been used in paleobiogeographic reconstructions. Global correlation and paleobiogeography of the eastern Meghalayan and western Tethyan sea has been compared on the basis of SBZ of Paleocene- Eocene foraminifera assemblage. The similarities between NE India, NW Himalaya and Southern Tibet suggest that all these regions belonged to a single faunal province during Paleocene – Eocene period. Tethyan Himalaya persisted at the northernmost Indian plate, representing a passive continental margin until the end of the Paleocene. Paleozoic to Cretaceous marine sedimentary strata is widely exposed within the Tethyan Himalaya, whereas the Paleocene-Lower Eocene shallow-water limestones developed mainly in the southern Tethyan Himalaya and Shillong Plateau, Meghalaya. The paleobiogeographic reconstruction during Paleocene – Eocene times in the Western region shows its extension in the Eastern region. The index fossils of the Lakadong Limestone in Mawmluh Quarry section define the standard Paleogene biozones SBZ 3 and SBZ 5-6 respectively of Serra – Kiel et al. (1998). The biozones SBZ 3 and SBZ 4 present *Distichoplax biserialis* Dietrich, Miscellanea. The SBZ 5 and SBZ 6 contain Alveolin Hottinger, *Nummulites* sp. and Discocyclina sp. The biozones SBZ 5 SBZ 6 show *Ranikothalia nuttalli* Davies). Mixed association nummulitids/assilinid and shell fragments encrusted by corallinacean algae are also found.

Keywords: Orthophragmine; Paleobiodiversity; Eastern Tethys; Index fossils

The Triassic–Jurassic transition sequence in the Thakkhola region (Kali Gandaki valley, Central Nepal)

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Along the upper part of the Kali Gandaki valley in the Thakkhola region (central northern Nepal) excellent exposures of Triassic/Jurassic transition of clastic-carbonate units are present. It is a small part of the Early Palaeozoic – Early Cretaceous sedimentary sequence of the highest tectonic unit of the Himalayas, the so-called Tibetan Tethys zone. This part is composed of deepening-upward deposits representing the latest Triassic land-coastal sedimentation episode, which is followed by Early Jurassic shallow-marine conditions, up to the Middle-Late Jurassic full-marine sedimentation. Within the Pliensbachian-Early Toarcian part of this sequence (Jomosom = Kioto Formation) we recently discovered *Lithiotis*-type bivalves, previously unknown in this part of the Himalayas. They construct biostrome-like structures and fit perfectly into the record of such buildups ("reefs") along the southern shelf of Tethys. The overlying Middle Jurassic (Bajocian – lowermost Callovian) carbonate deposits of the Bagung Formation are abundant in tempestite layers (with oyster coquinas and hiatus concretions). Overlying them, Upper Jurassic black shales with spherosiderites are rich in ammonites (famous Spiti Shales – Nupra Formation).

The Jomosom Formation with *Lithiotis*-bivalves-bearing horizons likely indicates either a lagoonal-type palaeoenvironment or marginal part of such lagoons between nearshore regions and open marine conditions. Palaeobiogeographically it belongs to the eastern Tethys *Lithiotis*-facies belt which occurred along peri-Gondwanan margin of Pangea during Pliensbachian – Early Toarcian times (so-called Kioto carbonate platform). Accompanying facies evidence very well such type of regimes by co-occurrence of oolitic (with cross-bedding structures of high-energy sedimentation conditions) and oncolitic limestones, birdseye-structure limestones and/or pedogenic carbonate deposits. The Pliensbachian – Early Toarcian *Lithiotis* buildups are well known from the African High Atlas Mts (Morocco) and the European Alpine-Adriatic-Dinaridic-Hellenic carbonate platforms (Spain, Italy, Slovenia, Croatia, Albania, Greece). They developed in extremely shallow coastal palaeoenvironments on both sides of the Pangea continent.

Keywords: Himalaya: Nepal; Kali Gandaki; Triassic Jurassic transition; Lithiotis

[1] *This abstract corresponds to the IGCP-710 Project of UNESCO*

The Siwalik Group in emphasizing the Hasnot (Late Miocene) Ruminants, Pakistan

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An introductory review of the Siwaliks, based on the previous published articles, is discussed in this study. The Late Miocene ruminants, especially bovids from the Late Miocene sites of Hasnot in northern Pakistan, are discussed. An almost complete picture of the Siwalik's lithology, sedimentology, chronology, formations and faunal elements is cited. Most of the data including figures are incorporated directly from the published articles for the sake of clarity by assuring author's citations and quotations carefully. An effective review creates a firm foundation for advancing knowledge.

Keywords: Bovidae; Tragulidae; Cervidae; Giraffidae; Miocene

Evidences from the volcanic unit of Lesser Himalaya, metamorphic core and foreland basin of the Himalaya for the dual collision of the Indian and Asian plate

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This study on volcanic unit of Lesser Himalaya corroborates the interpretation of Cretaceous rifting and Late Paleocene collision of the Tibetan Himalayan Microcontinent (THM), which was predicted from paleolatitude reconstruction. The Greater Himalayan Imbrication (GHI) is characterized by a number of imbricates apart from the Lesser Himalayan Duplex. Two different stages of imbricated formations are divided by major thrusting of the Greater Himalayan nappe over the Lesser Himalaya along the Main Central Thrust. The emplacement of the Greater Himalayan imbrication over the Lesser Himalayan Duplex took place only after 15 Ma. The implications of collision and exhumation history of the Himalaya based on a change in the detrital zircon pattern of the Eocene Bhainskati Formation and Cretaceous to Paleocene Taltung and Amile Formation need to be revised as the Permian Sisne Formation and Tamrang Formation comprise a similar zircon pattern to the Eocene and Miocene units. The entire Miocene sequence (19.9 Ma to 6 Ma) of the foreland basin in the southern part of central Nepal Himalayan is sourced from the Tethys Himalaya and Greater Himalaya. However, the absence of Asian (upper plate) detrital input throughout examined strata illustrate that foreland basin was completely sourced by the Himalayan crust and input of Asian detrital was restricted. The restriction of Asian sedimentation might be related to the THM collision with Asia and uplift before the final India and Asia closure as predicted by recent paleomagnetic analyses. Final collision of India might be with the THM and timing of the final collision may be much younger than widely cited 50 Ma.

Keywords: Volcanic unit; Lesser Himalaya; Foreland basin; Collision

Study of carbonate rocks of the Lesser Himalaya: issues, challenges and way forward

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Limestone and dolomite are the major carbonate rocks in the Lesser Himalayan sequence of Nepal. These rock units are considered as marker beds for the geological mapping in these areas. The metasedimentary succession of the Lesser Himalaya is devoid of fossils and there is frequent repetition of clastic and carbonate rocks in the region. Therefore, research should rely on lithological criteria to work out the stratigraphy and construct geological maps. Some carbonate horizons consist of well-developed stromatolites. These are strong supporting features to assess the top and bottom of the succession on one hand and the determination of chronology of the succession on the other. However, all the carbonate rocks do not consist of such algal structures. There is a remarkable lithofacies variation in the carbonate rocks from eastern to western regions of the Lesser Himalaya. Moreover, pervasive folding and thrusting complicates correlation of the rock succession from one locality to another. For example, there remains difficulties on the correlation of the rock succession of the Nuwakot Group of central Nepal with the rocks of the Kali Gandaki Supergroup in western Nepal. Similar problems exist in the correlation of siliceous rocks of the Lesser Himalaya. Still, we question whether there is an erosional unconformity between the Dhading Dolomite and the Benighat Slate or not. This has created challenges on the preparation and interpretation of geological maps. As a way forward, the present study has aimed to solve these discrepancies with thorough field work for the preparation of several columnar sections and establishment of the type sections. Also, an attempt is made to classify the stromatolites to correlate adjacent rock sequences. The preliminary finding of study of sequence stratigraphy of carbonate rocks is presented in this paper.

Keywords: Carbonate rocks; Stratigraphy, Stromatolites; Lesser Himalaya; Nepal

Fossil Ficus (Moraceae) from the Middle Siwalik sediments of eastern Nepal and its biogeographical and ecological implication

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The Middle Miocene-Early Pleistocene sediments of the Siwalik Group in the Himalayan belt host an excellent archive to analyze paleofloristic and paleoclimate conditions of the region. This study describes a new leaf impression named *Ficus precunea* Lakhanpal of the family Moraceae from the Middle Siwalik (Late Miocene–Early Pliocene) sediments of Chatara-Barahakshetra area, eastern Nepal. This is the first megafossil record of *Ficus* from eastern Nepal. The present and previous fossil records indicate that the Ficus ancestors most likely originated in Gondwanaland. Based on the habit, habitat,and present day distribution of the comparable extant taxa of *Ficus* also suggest that the ancient Ficus lived and diversified in warm, humid habitats with tropical monsoonal climatic condition.

Keywords: Moraceae; Megafossil; Middle Siwalik; Eastern Nepal

Preliminary findings on geological investigation in Pokhara Valley

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Pokhara is one of the unique intermontane basins located in midland region of west-central Nepal. The geology of Pokhara valley and adjacent areas has been studied by several Nepalese and foreign geoscientists since 1965. However, detailed geological investigation of the quaternary sediments and underlying bedrock is lacking from the viewpoint of sedimentalogy, stratigraphy and structural geology. The debate on the evolution of Pokhara Valley either from debris flow or from tectonic subsidence is still in play. The main objective of the investigation is to explore the stratigraphy of the valley sediments and underlying bedrocks. To achieve this objective, published and unpublished literatures were reviewed thoroughly followed by preliminary field investigations. There is a thick succession of Kunchha Formation in the surrounding region of the Pokhara valley as described by previous researchers. The stratigraphy of Kunchha Formation was revisited in its type locality i.e. the Kunchha region of the Gorkha districts. It appears that the rock succession of Kuchha Formations can be divided into further sub-units based on lithological features. An attempt is made to work out the detail stratigraphy of valley sediments. Some new units have been established. Preliminary investigations are in progress.

Keywords: Stratigraphy; Pokhara valley; Quaternary sediments

Preliminary findings of geological mapping along Tamghas – Hadhade section of Gulmi district: Eastern Boundary of the Jajarkot Nappe

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The Jajarkot nappe is a well-known structural unit in western Nepal, Lesser Himalaya. It lies between the Kahun klippe to the east and the Karnali nappe to the west. It consists dominantly of schist, marble and quartzite in various proportions. Detailed geological mapping at a scale of 1:25,000 was carried out along the eastern boundary of the Jajarkot nappe along the Tamghas-Hadhade section of Gulmi district. The aim of the geological mapping was to constrain the thrust contact of the allochthonous succession along its eastern extremity and work out the stratigraphy and structural framework of the region. An attempt was also made to study the deformation and metamorphism of the rocks. Several columnar sections and route maps were prepared to show the lithologic contacts and geological structures developed in the rocks. Samples were systematically collected for further studies in the laboratory. The present study revealed that the thrust boundary of the Jajarkot nappe is significantly shifted towards more eastern part as compared to the previous studies. Similarly, the stratigraphy of the rock succession is also modified to some extent. Shear sense indicators showed the top-to the south movement of the allochthonous succession of the thrust sheet. The thrust boundary is itself folded and the rock succession shows poly-metamorphism with distinct deformation features. Petrographic study of the rocks is underway to analyze the micro-structures and metamorphism of the rocks in the region.

Keywords: Jajarkot Nappe; Stratigraphy; Micro-structures; Polymetamorphism; Western Nepal

Preliminary geological investigation of the junction of the Jajarkot nappe and Karnali nappe in the Jajarkot district, western Nepal

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The Lesser Himalaya in Nepal has several tectonic and erosional structures in the form of nappes, klippes and windows. The Karnali Nappe and Jajarkot Nappe are well-known nappes in western Nepal. The Jajarkot Nappe is characterized by low- to medium-grade metamorphic rocks similar to that of Kahun Klippe and Kathmandu Nappe while, the Karnali Nappe is composed of high-grade metamorphic rock having an affinity to the Higher Himalayan rocks. Several researchers interpret that the root zone of these nappe is located in the northern region of this tectonic unit. On the basis of lithological characteristics, it can be interpreted that the rocks of Karnali Nappe came from the Higher Himalaya while it is difficult to interpret the root zone of the Jajarkot Nappe due to non-matching lithology of this unit with the Higher Himalayan rock succession. The main objective of this study is to review the structural setting of this area to establish the tectonic relations between these two nappes and to study the potential geological control of mineral resources. To achieve this objective, the literature was reviewed thoroughly followed by preliminary field investigations. It is observed that, the Karnali Nappe is comprised of kyanite-grade metamorphic rocks and the Jajarkot Nappe is composed of garnet-grade metamorphic rocks. It seems that the root zone of Jajarkot Nappe is located somewhere between the overlying Higher Himalayan rock succession and the underlying rocks successions of the Midland Group. Preliminary investigations and detailed geological mapping is ongoing for further verification. Gemstone are found to be concentrated in the pegmatitic vein and whose detail investigation is in progress.

Keywords: Karnali Nappe; Jajarkot Nappe; Root zone; Gemstone

Advances in Mineralogy, Petrology and Geochemistry

An evaluation of two Pyroxene (Opx-Cpx) Geothermometer

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In last few decades, for assessment of the original equilibrium conditions of the mantle and deep crustal rocks, several empirical as well as synthetic thermometers have been proposed. Rocks of many types from the earth, moon and meteorites contain two coexisting pyroxenes. Petrologists have long recognized the potential of coexisting high Ca and low Ca pyroxenes to yield thermometric calculations. Several models have been proposed for two pyroxene thermometers in the last few decades. The authors have compared eleven models of two pyroxene thermometer proposed since 1973. 61 sample data of granulites from the global literature were collected and processed through the "Opx-Cpx.EXE" software. We conclude that three models are the most valid and reliable among these kinds of thermometers: Kretz (1982); Bertrend and Mercier (1985) and Nickel et al., (1985).

Keywords: Geothermometer; Pyroxene; Granulites

Economic heavy mineral placers of the Brahmaputra - Jamuna River Basin of Bangladesh

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Placer deposits are detrital sediments which contain potentially economic concentrations of valuable heavy minerals concentrated by hydraulic processes. Discovery of heavy mineral placer deposits in the fluvial environment of Brahmaputra- Jamuna Basin of Bangladesh has recently been reported by various scientific organisations. The sands of Brahmaputra - Jamuna are medium to fine grained having total heavy mineral (THM) concentration varying from 7.76% to 10.71% with an average of 8.92%. Ilmenite, garnet, kyanite and sillimanite are the predominant economic minerals. Other economic minerals are zircon, rutile, leucoxene, magnetite and monazite. The weight percentage of individual economic minerals has been assessed. An estimation has shown the presence of 146 Mt of inferred resource of economic minerals up to a depth of 2 m. Similar concentration of THM is observed up to a depth of 30 m. As such enormous resource of heavy mineral placers is available in the Brahmaputra - Jamuna Basin. Ilmenite of Brahmaputra-Jamuna basin contains lower TiO_2 (49%) compared to the industrial grade. However, it is suitable to produce titania slag which is an important feedstock for pigment industries. Zircon of Brahmaputra - Jamuna has quite satisfactory ZrO_2+HfO_2 content (64.2%) needed for the industrial application but has higher undesirable Fe_2O_3 (1.07%) which would be required to remove through the chemical treatment to obtain marketable zircon. The chemistry of garnet, rutile, and magnetite matches the commercial specification satisfactorily. THM grade of fluvial placer deposits is considered satisfactory by mineral sands industry standards and appear to be reasonable for commercial exploitation. The heavy mineral placers discovered in the fluvial environments of Brahmaputra - Jamuna basin can immensely contribute to the national economy. Based on remarkable results in respect of economic heavy minerals, a pilot plant is going to be installed soon at the Institute of Mining, Mineralogy and Metallurgy (IMMM), BCSIR, Joypurhat, Bangladesh, to study the separation characteristics of the bulk sand samples of Jamuna and other river basins. A detailed feasibility study should be undertaken to determine mineable reserve and to assess environmental impact due to mining.

Keywords: Bangladesh; Placer deposits; River sands; Economic heavy minerals; Eeochemistry; Commercial exploitation

Overview of the tectonics and gold metallogeny of Myanmar

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Myanmar is located at the junction of four tectonic plates, namely Sibumasu Block (SB), West Myanmar Block (WMB), India Plate and Eurasian Plate. In fact, Myanmar constitutes two main blocks – Sibumasu Block and West Myanmar Block. During Triassic-Early Jurassic, Myanmar was suffered by Indosinian orogeny due to Tethyan plate collision and by Himalayan orogeny at the Tertiary period, due to Indian subduction. Primary gold deposits in Myanmar can be grouped into several distinct mineralization styles observed in these two blocks. But, SB had undergone more tectonism and consequently, it had more diverse gold deposits related to orogeny. At SB, slate belt style mesothermal gold deposit mainly occurs in Chaung Magyi Group (uppermost Precambrian) and Mergui Groups (Carboniferous). Skarn type gold deposits can be observed in folded Late Jurassic to mid-Cretaceous marine clastic sedimentary rocks within fold-thrust belts (possible Meso-Tethys suture?) in the western part of the Shan Plateau within SB. Mesothermal and epithermal style gold mineralization is also found in Tagaung-Myitkyina belt (Jurassic Meso-Tethys suture). Au (Cu) skarn and mesothermal to epithermal diverse type gold deposits are found within the Mogok Metamorphic Belt (MMB) (Eocene Neo-Tethys suture). Gold mineralization follows at the end of Tertiary period in MMB related to Indian Subduction. At West Myanmar Block (WMB), porphyry style Cu-Au and its related mesothermal-epithermal Au occur along the central magmatic arc or Wuntho–Popa Arc (Neo-Tethys suture). Epithermal gold also happens in the volcanics and sediments of late Tertiary age in there. Sediment-hosted epithermal gold mineralization also occurs along the Sagaing Fault zone within the WMB during late Miocene time. The most productive gold metallogeny occur along the western margin of Sibumasu Block where deposits are striking with the regional trend of Myanmar.

Keywords: Tethyan plate collision; Indian subduction; Distinct mineralization styles; Gold metallogeny

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Opening up an Iron Mine in Nepal: challenges and opportunities

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Nepal is a country full of various mineral resources such as limestone, coal, natural gas, petroleum, uranium, iron, base metals (copper, lead, zinc etc.), gold etc. Many of these resources such as iron, copper, lead etc. were mined indigenously by our ancestors to make domestic utensils, agricultural tools, weapons, amours, building structures etc. and the use of these resources immensely helped our civilization to push itself further towards progression. When talking about mining iron resources in Nepal, the historical evidence of mining iron traditionally with rudimentary processes can be dated back to the early 19th century. Basically, these were mined to produce household utilities and utensils as well as stronger amours, shields etc. Speaking of modern days, several endeavours were made to start modern iron mining in Nepal with the establishment of Those Iron Factory and Feasibility Study for Phulchowki Iron Deposit. Unfortunately, these projects could not sustain themselves due to various unforeseen circumstances and reasons.

Recently, with the perception of initiating a new project aiming for producing iron and steel within the country, Dhaubadi Iron Company Limited (DICL) was established in order to explore and exploit the iron deposit discovered at Nawalparasi. This project aims to study and if found feasible, mine out the iron deposit, and manufacture iron and steel from the native ore so as to reduce iron and steel dependency in Nepal. This re-emergence of the iron mining project and its success depends solely upon the lessons about the challenges and opportunities that could be learned from previous unsuccessful national ventures as well as international trends of iron mine initiation and progression.

Keywords: Mineral resources; Iron mining; DIC; Feasibility; Challenges; Opportunities

Characterization of construction aggregates in the southern part of the Kathmandu basin

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The sediments of the Kathmandu valley can form good construction material. The principal sources of sand and gravel in the Kathmandu valley are relatively younger and unconsolidated superficial deposits. In order to ensure that the construction aggregates extracted from these deposits are fit for any construction purpose and meet end-use requirements, it is essential to have an understanding of the geology of the deposits and their geotechnical parameters attained through standard test methods. The identification and categorization of the potential sand and gravel resources in the southern part of Kathmandu basin is accomplished through the evaluation of their geological and geo-technical parameters. The shape and size factors, relative densities of most of the samples are found to satisfy the specifications as per British Standard (BS) except water absorption value which is found to be higher than limiting values in some samples. The materials from the Itaiti Formation are unsuitable for construction since the Aggregate Impact Value (AIV) is high. The resource map divides the available deposit into five classes being based on the geological characteristics and geotechnical test attributes. The resource classes from north western part of the study area can be the good resources for sand and gravel aggregates while from the southern part are of less importance.

Keywords: Construction aggregates; Kathmandu basin; Resource mapping; Test specifications

Assessment of a sustainable yield for sediment mining from the River systems in Chure region of Province 2, Nepal

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The Chure-Bhawar-Terai region of Nepal is undergoing rapid infrastructure development and urbanization. The region is inhabited by more than 50% of the population of the country and the population growth rate is 1.72 %. The growing population requires the development of sufficient houses and other infrastructures for economic activities. In rural areas, the traditional houses are also being converted into modern concrete houses. Similarly, several major infrastructure development projects are also planned or under implementation in this region. These factors have increased the demand for aggregate materials and are expected to increase more significantly in the coming decades. About 64 river systems are passing through Province 2, and the river systems flowing through the Chure-Bhawar-Terai are the only source of aggregate material, so far. Most of these rivers originate from the Chure region – a fragile area where soil erosion and landslide processes are very active. As a result, the sediment yield rate from this region is very high and the river systems in this region are wide and abundant in sediment deposits.

A river, in a natural state is in a dynamic equilibrium stage with its flow and sediment regime. Any major human interventions, or extreme disaster events, in the river system, hinders the balance between the water and the sediment regime resulting in river slope and width adaptation. The effect of any major intervention, over time, is observed in river reaches several kilometers upstream and downstream from the point of intervention. There are mainly two major issues related to the sediment management in the river systems of the Chure region in Province 2. The first issue is related to the severe erosion as well as depletion of some catchments induced by unplanned developmental activities and unsustainable livelihood practices. Because of this depletion and erosion, some of the river systems in this area are under acute stress due to high sediment yield from the region. This has resulted in morphodynamic changes in a river such as a channel aggradation, avulsion, and bank erosion/accretion which has significantly affected the agricultural areas, infrastructures, and settlements in the Terai region. The second issue is related to severe sediment mining from the rivers. The proximity of these rivers to the demand areas has resulted in large-scale sediment mining from the river beds. The guidelines and regulations for mining activities are unscientific and are poorly monitored. As a result, mining activities have incised the river bed and possessed threats of bank erosion, flooding, groundwater depletion, and damage to the infrastructure located in the Terai Plain downstream. So, sustainable management of sediment resources from the river systems in the Chure region, most importantly, requires estimation of yield from river reaches. This research presents an estimation of sustainable sediment yield from river reaches using a simple sediment budget method. The sediment budget method is based on the analysis of catchment geology, hydraulics, and morphological characteristics of a river reach, for computing the sediment balance. The method can be potentially used to improve the regulating guidelines of mining practice in this region.

Keywords: Sediment mining; Sediment budget; River system; Chure area

Geological control of mineralization in Birendranagar –Talpokhari area of Karnali Province, Nepal

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Geological mapping is the first step for the study of geological structures and for prospecting and exploration of the mineral resources. Some metallic and non-metallic minerals are deposited in Himalaya due to the secondary concentration during metamorphism, sedimentation and weathering. The control of geological structures and its formation during tectonic deformation has significant role in secondary concentration of minerals. The study area selected was the part of Birendranagar Municipality of Surkhet district and Talpokhari area of Dailekh district of Karnali province covering the Lesser Himalayan Terrain. The detailed geological mapping was carried out on the scale of 1:25,000 and the systematic samples of both minerals and rocks were also collected for the laboratory study. Petrographic studies were made to visualize the mineralogical compositions of some rocks containing mineral deposits. The thin sections were prepared for the analysis (observation of micro structures and mineral composition) to conform the detailed geology and mineral deposits mapped during the field investigation. Similarly, polish sections of ores were studied to identify the minerals along with its association, to assess the mineralogical percentage, texture and genesis. The control of geology and structures on formation and distribution of the mineral resources in this site was established. The secondarily mineralized resources (Azurite and Malachite in Quartz veins) by hydrothermal concentration were identified in the field. Similarly mineral resources like Ore of Iron (Containing both of Hematite and Magnetite), Limestone, Amphibolite and white quartzite (May be potential for Glass Industry) were identified and potential sites of extension with estimated deposits were calculated by cross-section method. This study provides information about the tectonics, available mineral resources, their economic analysis and uses. The resources available in this area will be a valuable source for the prosperity of the Karnali Province as well as for the nation.

Keywords: Karnali Province; Mineral resources; Geological structures; Iron ore

Geological study of soil deposits for brick industry of Ganesh Fix Chimney Brick Udhyog, Manpur, Dang

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Ganesh Fix Chimney Brick Udhyog, a FCBT kiln located in Manpur, Dang is brick manufacturing industry that produces about 7 million of bricks annually. The first concern of the study is to evaluate the quantity and quality of the soil suitable for brick production in the areas. Another concern is that the manufactured brick possesses the problem of distorted geometry and white coatings on its surface. Keeping these issues in mind, the present study was aimed to investigate the genesis of soil formation, its distribution along with physical and engineering characteristics. Field investigations were carried out with detailed geological mapping, in-situ testing and systematic sampling with some questionnaire survey related to the use, handling and heating system of brick production. The reserve estimation of soil deposit made in the field shows that there is large deposit i.e., 61250 cubic meters of soil, which will be enough to run the industry for five years considering the present annual soil mining and brick production rate. The in-situ test shows that soil is rich in calcareous materials, and the proportion of silt is high. For the quality brick, the soil should be rich in alumina and silica with lesser content of lime, iron and manganese oxides in chemical compositions but free from alkalis, organic matter and sulfides as far as possible. Based on the preliminary findings, it can be said that the soil has such technical lacking for healthy brick production. However, full data sets of the laboratory tests are under process. Besides the composition of soil, the firing technique needs certain improvement. The location of soil having high plasticity and less calcareous content should be searched for and mixed with the present quarry product to maintain the required proportion.

Keywords: Brick Industry; Soil deposit; soil-genesis; Soil plasticity

Present status and future scope of drilling and blasting for the development and prosperity of Nepal

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Drilling and blasting works, in general are necessary for underground excavation, mining and other engineering activities. Drilling in Nepal has been extensively used in several sectors like groundwater exploration and extractions, mineral exploration and mining, different geotechnical investigation and development stage of hydroelectric projects and other engineering works. The blasting along with drilling is extensively used in the breaking of rock mainly in the advancement of tunnel and in the mining of limestone in Nepal. In this context, the present study has aimed to study and evaluate the present status and predict the future scope of drilling and blasting works in Nepal. It is also expected to estimate the demand and supply status of drilling and blasting works in near future in Nepal to achieve the national goal of development so that many geologists and geo-technical engineers could make their business and job in this field. To assess the present status, a thorough review of existing publication and collection of relevant information are made through online and library visit. Authors' observations, experiences and surveys are the other factors of data collection and analysis. A preliminary survey shows that the scope of drilling and blasting works are in increasing in Nepal. These days, drilling and blasting works are more focused on the construction of hydropower and road tunneling, mining of limestone and quarrying of some construction materials in addition to making mountain roads and irrigation canals. To gear-up the nation's development, the activities of drilling and blasting will be increased rapidly in near future. Keeping this view in mind, an attempt is made to evaluate the future scope of drilling and blasting works in this research so that many geo-scientists would contribute in this field for the prosperity of Nepal.

Keywords: Drilling; Blasting; Tunneling; Mining; Quarrying

Hydrogeology and Water Resources

Deep aquifer characteristics of Northern Groundwater District in the Kathmandu valley

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The Northern part of the Kathmandu Valley is unceasingly under water stress due to the increase in population. The main objective of this study is to evaluate the deep aquifer characteristics of the Northern Groundwater District (NGD/JICA, 1990) in Kathmandu valley. To obtain this objective various characteristics maps and the subsurface lithological cross-sections were made. The study indicates that the aquifer is thicker towards the northern and central parts of the section comparing to the southern part. The thickness of the aquifer encountered is very low in the Attarkhel and Bhaktapur areas, and the highest in the Gokarna, Gangabu and Nayapati areas. The aquifer is unconfined in the bank of the rivers where there are sand and gravels in the upper layers and the aquifer is confined in the other parts. The depth of the water table varies from place to place which is higher towards the north and is lower towards the south and near the bank of rivers. The highest yield of groundwater is observed at the Gongabu and the lowest at the Katunje area. The maximum hydraulic conductivity (K) is in the Kapan and Nayapati area where aquifer material consists of gravel and coarse-grained sand. The lowest transmissivity (T) value is obtained at Maharajganj and Golfutar area and the highest is in Bode and Dhobi Khola area.

Keywords: Aquifer; Hydraulic conductivity; Transmissivity; Water table

Aquifer mapping and geological sensitivity analysis of the Budhi Khola watershed, Sunsari/Morang district, Province-1, Eastern Nepal

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Aquifer mapping is a holistic scientific approach for the characterization of hydrogeology. Aquifer mapping along with the geological sensitivity mapping was conducted on the Budhi Khola watershed with an area of about 176 square km from Amjhoki to Darlami. This study is aimed to assess the geological and hydrogeological feasibility for the construction of artificial recharge pond in water-scarce zones and to appraise the geological hazards like floods and landslides. Geological sensitivity maps were prepared in 1:25,000 scales including the present status of geo-hazards like landslides, bank cutting and floods. Similarly, hydro-geological maps were prepared in 1:25000 scales including the detailed investigation of springs, wells, seepages, water bodies like wetlands, lakes etc. Other parameters like the depth of the water table and groundwater flow direction were also demarcated within the study area. The Main Frontal Thrust is the major geological structure mapped in the area which separates the rocks of the Sub Himalaya from the Terai Plain on the south. Electrical Resistivity Tomography (ERT) survey was conducted for delineation of the depth of the water table as well as other sub-surface information. Geological as well as hydrogeological investigation along with the social survey affirmed that some places of the Bhabar zone were found to have the most water scarcity problem. Based on the detailed geological investigation, suitable locations for the construction of artificial recharge ponds were recommended to raise the water table in the area. Similarly, integrated mitigation measures were recommended to prevent the watershed from geological hazards like a landslide, debris flow, soil erosion and bank cuttings in the Siwalik region while from floods in the Terai region. Scientific utilization of mountain aquifers and local water bodies, rainwater harvesting and artificial recharge ponds are suggested for sustainable watershed development.

Keywords: Aquifer mapping; Geological sensitivity; Artificial recharge pond; ERT investigation

Geological, hydrogeological and sensitivity assessment of Patu Khola watershed, Midwestern Nepal

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A geological and hydrogeological investigation was carried out in the Patu Khola watershed of mid-western Nepal to assess the aquifer status of the region. The Patu River originates from the Lesser Himalaya and is a source for groundwater recharge to the Dang Valley-a Dun Valley of Nepal Himalaya. In recent years, there is a depletion of groundwater in Dang Valley. The depth of water table in the existing wells in the region is lowering day by day. Many of shallow wells remain dry in the winter. The present study aimed to assess the causes and possible solutions for lowering the water table in this populated valley. For this purpose, hydrogeological maps were prepared and analyzed. Detailed geological mapping on a 1:25000 scale was carried out along the watershed. The cone of depression is also determined in the area. The depth of the aquifer was determined using Electrical Resistivity Tomography (ERT) investigation. As the best possible solution for controlling the speedy depletion of groundwater, some areas for artificial recharge ponds are also suggested based on surface and sub-surface geology. Similarly, geological sensitivity assessment is also carried out in the watershed area. The status of the mountain aquifer lying north of this Valley was investigated and the potential discharge of water from these aquifers was evaluated. Finally, the potential water-bearing aquifers and water bodies are demarcated in the Lesser Himalaya as an alternative source of water supply to Dang Valley.

Keywords: Geology and hydrogeology; Sensitivity assessment; Electrical resistivity tomography (ERT); Patu khola; Mid-western Nepal

Aquifer and geological sensitivity analysis of the Khutti khola watershed, Siraha district, eastern Nepal

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About 139 square km area from Biharpur to Chatan of the Khutti Khola watershed was studied with the aim of aquifer mapping and geological sensitivity analysis of the region. There is a huge threat to cultivated land and residing communities due to flood and bank erosion of the Khutti Khola in several locations. The main scope of the study was to carry out a detailed geological mapping, determine the groundwater flow direction, distinguish different types of aquifers, assess the water table depth and delineate the sensitive area within the watershed. The methodology includes desk study, fieldwork, laboratory work, data analysis and interpretation. Geological, hydrogeological and geological sensitivity maps were prepared on a 1:25,000 scale. The Main Frontal Thrust is a major geological structure mapped in the area that separates the Sub-Himalaya in the north and Terai Plain in the south. The Sub Himalaya is comprised of a complete and thick succession of upper, middle and lower Siwalik while the Terai plain is composed of the Bhabar zone. Three types of aquifers are distinguished as the Mountain aquifer, Bhabar zone aquifer and Middle Terai aquifer. The major geological sensitivity in the area is the landslide, riverbank erosion and water scarcity in the Siwalik zone while bank erosion and inundation in the Terai zone. Locations for the rainwater harvesting and suitable sites for artificial recharge pond are selected in the water scarcity zones. Similarly, some suitable methods for control of landslides, bank erosion, floods and soil erosion are proposed.

Keywords: Aquifer mapping; Geological sensitivity; Water scarcity; Recharge pond; Khutti khola

Geological and hydrogeological study and sensitivity assessment of the Rohini khola watershed, Rupandehi district, western Nepal

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A geological and hydrogeological investigation was carried out in the Rohini Khola watershed of Rupandehi district, western Nepal to assess the groundwater status of the region. This river originates from the Middle Siwalik in the north. Rohini Khola is one of the major sources of recharge to the Bhabar zone and middle Terai in the south. Due to several causes, there is the depletion of groundwater in the Rupandehi area. The depth of water table in the existing wells in the region is lowering day by day. Many of shallow wells remain dry in winter. This study aims to find the causes and possible solutions for the depletion of the water table in and around the area. For this purpose, geological mapping and a hydrogeological investigation were carried out and data were analyzed. The depth of water table and aquifer materials was determined by direct measurements in the wells and using Electrical Resistivity Tomography (ERT) investigation respectively. The speedy lowering of groundwater is supposed to be controlled by providing artificial recharge through ponds. The locations for the construction of artificial recharge ponds are suggested based on surface and sub-surface geology. A geological sensitivity assessment is also carried out in the watershed area. The status of the mountain aquifer and the potential discharge of water from these aquifers were evaluated. Finally, the potential water-bearing aquifers and water bodies are demarcated in the Siwalik as an alternative source of water supply to the community.

Keywords: Rohini Khola; Aquifer mapping; Artificial mapping; Artificial recharge ponds; Rupandehi district

Geological mapping and aquifer analysis in Belkhada area of Humla district, Karnali province of Nepal

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Humla lies in the remote region of Nepal from the viewpoint of transportation and topography. It lies in the Karnali province of Nepal. Belkhada area of Humla is a famous village with a dense population. However, water is scarce for the villagers. The present research was carried out to find a sustainable solution to the scarcity of water from the viewpoint of geological study. The main scope of the study was to prospect the saturated aquifer for tapping the groundwater in the region. Other specific objectives were to prepare the geological map and cross-sections at the scale of 1:50000 to clarify the stratigraphy and geological structure and link these data to prospect the mountain aquifer in the area. An attempt was also made to collect the data related to geomorphology, discontinuities, lineaments, and topography. One month was spent in the field for the purpose of geological mapping and the collection of structural data. The status of water resources was mapped and analyzed. The present study revealed that there is significant geological control for the development of springs. Most of the existing springs are released from the geological contacts and thrust zones. Sites for well development are recommended based on the geological structure and lithological control of the aquifer.

Keywords: Geological mapping; Mountain aquifers; Humla; Karnali Province; Nepal

Investigations of spring line along the foothill of Siwalik in Rupandehi and Parasi districts, western Nepal

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The formation of spring is controlled by the geology, topography and climate of that place. Series of springs and seeps appear on the northern part of Terai, are investigated in some parts of Rupandehi and Parasi Districts of Western Nepal. Primary data of spring inventory and secondary data like satellite imagery, topographic map and lithologs are collected and analyzed through GIS to accomplish the study. It is found that the northern part of Terai is composed of coarse-grained unconsolidated material deposited as debris during the high flood. The sediments size decreases toward the south making coarsening upward sequence of deposition. The fine sediments deposited as outwash of the piedmont fan on the flat plain is Terai. In a gently slopped land, lithology changes from conglomerate to clay, similarly hydraulic parameters such as hydraulic conductivity, transmissivity and porosity change by the grain size of sediments so that series of seeps and springs are formed at the transitional zone of coarse-grained material of Bhabar and fine-grained materials of Terai. In the study area, springs are distributed in liner patterns confined in the elevation ranges of 130-145m and the slope ranges 2-3 degrees. The major significance of the occurrence of springs in the northern part of Terai is the demarcation of the southern limit of Bhabar Zone from Middle Terai.

Keywords: Springs; Spring line; Rupandehi; Parasi; Terai Zone

COVID-19 and Earth Science Studies; Women and Youths in Geological Sciences; Plan, Policies and Strategies of Nepal Government on Utilizing Geosciences

Preparation, risk reduction and response to COVID-19 pandemic

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The introduction of the Novel Corona Virus on December 31, 2019, followed by the WHO announcing the global pandemic on March 11, 2020, there have been numerous developments and methods that have then been proclaimed to be a new standard, having a significant impact on our lives. On January 13, 2020, the first positive case of COVID-19 was seen in Nepal. Since then, there have been 2, 72,055 total registered confirmed cases as of February 8, 2021, a total 2, 68,266 recovered cases, and 2,045 total deaths due to COVID-19 On 31 January 2020, the National Society for Earthquake Technology -Nepal (NSET) launched its precautions by developing advisory services for the regular functioning of official activities. NSET has an emergency response plan that also includes a medical emergency response where the COVID-19 also complies with the response plan. NSET runs the USAID/BHA-funded Emergency Response Program (PEER) program, which offered online response courses for medical practitioners, emergency responders and community volunteers from four PEER partner countries: Bangladesh, India, Nepal and Pakistan. The total number of beneficiaries was 244, and they benefited from the expertise gained in responding to COVID-19 patients and updated information on disinfection and sterilization. In addition, NSET collaborated closely with municipalities to construct quarantine and isolation facilities. From the daily update of Coronavirus news from the globe and Nepal to the mapping of hospitals and clinics in Nepal through maps and location tracing, NSET was prepared for the expected chaotic situations. As the PR3 to COVID-19, NSET, with references to the Government of Nepal and WHO guidelines, drafted several guidelines and innovative interventions that can work as guiding references for other similar organizations in the context of current global pandemic

Keywords: COVID-19; Emergency response plan; Online courses; Risk reduction

Bacteria and viruses in the history of the planet earth and global pandemic Corona Virus (COVID 19 / SARS-CoV-2)

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COVID 19 pandemic has created global panic in last more than one year and affected the rich to poor nations and cold to hot climate countries in all the continents. COVID 19 well-identified as the **SARS-CoV-2 Virus** is the most dangerous and disastrous pandemic on earth. The year 2020 was like a world war between the Coronavirus and humanity struggling for their survival on mother earth. India is the nation with the third highest number of COVID 19 cases in the world. SARS- CoV2 virus is also undergoing mutation as reported from UK, therefore, a great challenge in controlling the pandemic. In the present paper, the structure of the earliest prokaryotic and eukaryotic cells on early earth and their comparison with size of the virus, its origin and characteristics are presented. The impact of recent COVID 19 Coronavirus on human health and climate change has been discussed. Vaccines are a crucial tools in human health and in the prevention of virus and the eradication of diseases. The recent development of vaccines in India and other parts of the world has been also presented.

Keywords: Corona virus; History; Global pandemic; Mutation

Female geologists in Nepal: Present status, challenges and opportunity in Nepal

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While there is about 55% female in a total population of Nepal according to 2068 B.S. census data, the presence of females in higher education and higher profession is still very less in number. The study has aimed to explore the database of female geologists working in Nepal. It has also aimed to find the prime cause of gender inequality in the profession of geology. To fulfill the objective, an attempt is made to consult the record of female students in Tribhuvan University since its establishment. A survey is also made to assess the number of female geologists working in geology. Broadly speaking, there is about 5-10 % of females in the geology profession in Nepal. In 45 years long history of geology study in Nepal, the maximum girl students in the Master's degree program never exceeded 30%. The unimpressive number of female students in geology could be attributed to long working hours in the field, labor-intensive nature of the work, etc. Fortunately, these days the female geologists have shown good performance both in governmental as well as non-governmental institutions contributing the hydropower, mining, tunneling and other engineering sectors. This proves that the geology profession is not only for boys but also for girls as in other countries. The government of Nepal should make a strong policy to minimize gender discrimination in the geology profession. Some of the immediate steps for females may include scholarship in study, development of field security guidelines and systems for females, facilities during and after the pregnancy time and controlling the gender discrimination in terms of salary and opportunities. The real concept of gender inclusive will provide sustainable harmony and progress in the field of the geology profession in the future.

Keywords: Female geologists; Gender discrimination; Geology profession; Nepal

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Present status, rules and regulations, and future scope of explosive works for the development and prosperity of Nepal

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Explosives are reactive substances used to generate a great amount of energy in a short time. Its use is primarily specific to developmental works in the present world. Explosives are equally important for the removal of overburden in underground mining as well as for the opening of tunnels in road construction and hydropower projects. The main objective of the present research was set to assess the present status, rules and regulations and future scope of explosives in Nepal. To achieve the objective, a thorough review of available publications and interviews with potential stockholders is caried out in this research. An attempt is also made to explore the rules and regulations in our neighboring countries as well as some of the developed countries. Till the date, in Nepal, the total responsibility of handling the explosives is given to Nepal Army as per the Army Act, 2063 (2006). The control of importing and manufacturing of explosives is within Nepal Army according to this act. Nepal has entered to its rapid stage of development. Mining, as well as tunnel construction for hydropower and roads, is a formidable task for us. In this regard, it can be said that we have a great scope of explosive handling and proper use for the rapid development and prosperity of the country. As in other countries, the responsibility of explosive handling can be given to license holder private parties in addition to Nepal Army. It removes the monopoly system and delay the process of explosive works in Nepal. In the present situation, if the Nepal army fails to provide the required explosives in time, the project has to incur huge loss. Permitting licensed people in import and use of explosives in such developmental projects could fasten the work and the development and prosperity of the nation can be speed up.

Keywords: Explosive; Drilling and blasting; Nepal Army act

Need for post-COVID-19 pandemic multi-disciplinary research for the safety of human civilization

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In the reality of global COVID-19 pandemic that affected all walks of life of human civilization, to keep away from future recurrence we must think about our safety. According to UN report the pandemic caused the global economy to shrink by 4.3% in 2020, the sharpest contraction in global output since the Great Depression that began in 1929, and its impact will be felt for years to come. On 21 February 2021 WHO updates the number of COVID-19 confirmed cases as 110,609,979 including 2,452,510 deaths across the globe and displays world map showing the current situation of the disease in their dashboard where they classified the transmission of the disease into three. From the appearance of the most affected countries on the map if considered with other-related facts one question may arise whether there exists any connection between the geographic location and their natural attributes with the disease. However, few research show that there might have link between such infectious diseases and land use, and others indicated the relationship among climate, geographical, geomorphological and geological settings, immigration and migration rate and pattern, cultural solidarity and anthropogenic behavior and lifestyle etc. and the current event. But for better understanding of the complex interactions among the diversified factors and strengthening our knowledge need for more independent researches cannot be overlooked. The researches would integrate geophysical characteristics and processes, climate and environment; demographic makeup, anthropogenic characteristics and habits, biodiversity and ecology etc. of particular territory as well as other relevant data such as immigration rate and style. Since this is a global issue we have to share our experiences and knowledge come out the researches.

Keywords: COVID-19; Geographic setting; Geophysical characteristics; Human behavior; Landuse

Geo-Hazard Assessment, Risk Reduction and Mitigation

Preparation of spatiotemporal landslide inventory of 14 the most earthquake-affected districts after the 2015 Gorkha Earthquake

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The 2015 Gorkha Earthquake mostly affected 14 districts of central Nepal. The earthquake triggered a large number of landslides and adversely impacted the stability of hill slopes more widely, rendering them susceptible to future failure. Normally landslides in Nepal are triggered by monsoon rainfall, but after 2015 an increase in landsliding during the monsoon in the years following the Gorkha Earthquake was anticipated. To observe these landslide patterns, time-series mapping of the 14 most affected districts in both pre-and post-monsoons windows was prepared. Each landslide was digitized using visual interpretation of Landsat-8 and ESA Sentinel-2 satellite imagery, with verification using contemporaneous Google Earth Imagery, spanning 2014 to 2020. This landslide inventory documents evolving pattern of landslides after a large continental earthquake for the first time. The occurrence of new landslides along with changes to existing landslides through time is described by this inventory. The mapping confirms the ratcheting effect of the earthquake on landslide rate as the number of landslides during each monsoon season following earthquake event remains higher than on the day of the earthquake throughout the mapped period. Importantly, most studies on landslides are focused on individual landslides or those in a small area at a particular point in time, and so are rarely suitable for the analysis of landslide hazards over large area or for tracking wide-scale recovery to pre-earthquake conditions. This inventory is therefore a valuable tool providing base data for carrying out susceptibility analysis, monitoring landslide hazard and risk through time in Nepal, and for informing wider understanding and anticipating of the legacy of earthquake impacts on landslides after future earthquakes worldwide.

Keywords: 2015 Gorkha Earthquake; Co-seismic landslides; Landslide inventory; Time-series

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Disaster risk reduction in Nepal: A success or a failure and why?

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Nepal remains in the front line to have an instrument towards reducing the impacts of natural disasters since the early eighties through the Natural Calamity Relief Act 1982. Since then, the state, as well as non-state agencies, have massively implemented projects and programs under "National Action Plan on Disaster Management in Nepal 1996, Ninth Plan 1997-2002" NPC, Hyogo Framework for Action (HFA) 2005–2015, National Strategy for Disaster Risk Management 2009, Disaster Preparedness ECHO Programme, Nepal Risk Reduction Consortium (NRRC) - UN International Strategy for Disaster Reduction (ISDR) 2011 and Sendai Framework for Disaster Risk Reduction 2015-2030 and many more. More importantly, Disaster Risk and Management Act 2017 and National Disaster Risk Reduction Policy 2018 have been enacted in recent years resulting in the establishment of much-awaited National Disaster Risk Reduction & Management Authority. Key question, however, remains to be answered - are disaster risk reduction efforts in Nepal a success or a failure and to what extent? This paper intends to discuss the results of the desk and qualitative research on this key question amalgamated with my own experience.

Keywords: Disaster risk reduction; Qualitative research; Disaster Risk and Management act

Potential flood hazard areas along the Seti River valley, Kaski, Nepal, vs. anthropogenic activities: Assessment and recommendations

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Seti River, originating from the Annapurna Massif and flowing south through Pokhara valley, has been subject to disastrous flood events in the past. The latest one has occurred on May 5th, 2012 causing the death of 72 people, obliterating dozens of homes, and damaging infrastructures worth millions of dollars. Despite the 2012 flash flood event and several warnings by researchers and scientists for more yet bigger scale future floods in the Seti valley, anthropogenic activities such as unplanned human settlement, the encroachment of river banks, haphazard construction of road, drinking water, and hydropower projects are taking place in potential flood hazard areas along the Seti River. Covering some 40 km distance from the Seti headwater (Sabche Cirque) down to Pokhara city, the study is carried out based on hydro-geomorphological mapping, hydrological analysis including HEC-RAS, and ArcView GIS modelling, historical archives and interviews with local people. The study shows that anthropogenic activities along the Seti valley are responsible convert flood events into disasters. Nine study sites (including five settlements) have been identified that are prone to flooding and damming and four other sites vulnerable to riverbank toppling which might invite further natural disasters along the Seti River. Furthermore, necessary precaution and suitable mitigation measures (i.e. land use and urban planning, engineering structures, early warning systems, education, etc.) have been recommended to reduce or mitigate the impact of possible flood events along the Seti River.

Keywords: Seti River; Flooding; Anthropogenic activities; Natural disasters

Seismic hazard, risk and economic loss of Metropolitan Vancouver Southwestern British Columbia, Canada

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Southwest British Columbia is located in a seismically active region as a result of the subduction of the oceanic Juan de Fuca plate beneath the North American Plate. Geologically Metropolitan Vancouver is underlain by Tertiary sedimentary bedrock. Pleistocene glacial deposits cover this Tertiary sedimentary bedrock, which is overlain by Holocene deposits consist of sands, silty clay , and peat. The potential of ground shaking is measure across a region with probabilistic seismic hazard assessment using sixth-generation Canadian seismic hazard model using Openquake engine developed by Global Earthquake Model Foundation. Peak ground acceleration and spectral acceleration at different period are computed for Vs30 values of 450m/s assuming the Metropolitan as site class C. Results are presented in the form of hazard maps, uniform hazard spectra and damage state probabilities for 2% and 10% probabilities of exceedance in 50 years. Meanwhile, the seismic risk of Tsawwassen city in Metropolitan is measures based on calculated hazards curve, building exposures, and structure and non-structural vulnerability components which provide damage states and loss exceedance curve of each asset. Similarly, loss assessment and financial calculation of wooden building in Tsawwassen area are calculated using a surrogate statistical model. The Value at risk and conditional value at risk modelling is calculated considering insurance policy with the deductible and limit ratio of 0.1 and 1.0. The results of this study are intended to help municipal planners and emergency managers to better understand the earthquake hazard and risk within their jurisdiction, and to stimulate appropriate planning activities to minimize damage from earthquakes

Keywords: Site effects; Impedance contrast; Hazard; Loss assessment; Surrogate statistical model

Delineation of slope units in the central Nepal for landslide susceptibility mapping

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Nepal Himalayas is an active tectonic region whose geology is diverse. Among many natural hazards, landslides are frequently occurring in the Himalayan Belt, which has a huge impact on human lives and properties. Earthquakes, rainfall, and anthropogenic factors can induce landslides. The 2015 Gorkha earthquake and its aftershocks triggered numerous landslides in the central Nepal Himalayan belt. Assessment of earthquake-induced landslides is a significant step towards preparedness of such disasters in the future. Most of the landslide susceptibility and hazard maps are pixel-based because of the simplicity of grid cells, however, we employed slope units as mapping units because they have physical relevance and better describe landslide phenomena. We generated slope units over 14 districts in the central Nepal that were worst affected by the Gorkha earthquake as well as adjoining districts. The slope unit map contains 91,964 polygons with an average area of 0.38 km^2 per polygon, which will be available for download. We categorized each slope unit with geomorphometric factors and presence/absence of landslides, using the published landslide inventories. We applied a logistic regression model to each inventory to obtain the accuracy rate of the landslide susceptibility model in terms of area under the curve. The comparison analysis shows that landslide susceptibility maps are correlated with not only the landslide inventory's accuracy but also the number of landslide polygons and the completeness of the inventory.

Keywords: Central Nepal; Gorkha Earthquake; Slope units; Landslide susceptibility

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Relationship between the earthquake-induced landslides and road network: a case of the Haku village, Rasuwa district, Nepal

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Gorkha Earthquake 2015 was the source for several other secondary hazards which severely affected the livelihood of people. After the earthquake disaster, a huge number of landslides and mass movement activities were noted. Rasuwa district was also one of the most earthquake-affected districts where numerous new landslides were also created and the existing landslides were widened. This study investigates the relationship of earthquakeinduced landslide and their proximity to road network by taking into account Haku village of Rasuwa district as the study area. Several studies in regard to the direct impact of event landslides on the road-networks are still not seen to be enough despite preparation of several landslide based inventories and data. This study analyses the exposure of road-networks to earthquake-induced landslides to draw a relation between these two factors. A GIS-based method is used to generate the road network and landslide inventory map of the specified study area. A total of 101 earthquake induced landslides were digitized during this study. Google earth facilitates to determine the Pre-earthquake and Post-earthquake situation of the study area. The correlation between the road network and earthquake-induced landslides was analyzed by statistical method. This study further depicts the vulnerability of road slopes to such earthquake disasters by a overlay of the road networks with the landslide inventory for further analysis. Studies on the impact of such event based landslides on road networks can be very beneficial for geoscientists, planners, stakeholders, and policy makers to combat the adverse effects of such disasters.

Keywords: Earthquake induced landslides; Proximity; Road network; Landslide inventory; Statistical method

Landslide susceptibility mapping of Sunkoshi watershed, Sindhupalchowk, Central Nepal

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Landslide is one of the main geo-hazards in Nepal which is generally triggered by rainfall, seismic activities, and human activities. Sindhupalchowk district has been facing frequent events of landslides every year causing huge loss of lives and properties. To reduce the vulnerability and risk due to landslide events, it is crucial to identify the area with the most potential for landslide in near future. The present study presents the results of landslide susceptibility mapping in Sunkoshi Watershed of Sindhupalchowk district. Landslide susceptibility map identifies those areas which are subjected to landslide and measures the extent of the events. A large number of landslide events have been observed in the study area. Altogether 128 landslides were identified in which 80% landslides were used for analysis and the remaining 20% were used for validating purpose. Landslide susceptibility map was prepared with the help of factor maps and inventory map using ArcGIS 10.3. Altogether ten causative factors namely slope angle, slope aspect, elevation, curvature, geology, distance from the road, distance from river, drainage density, rainfall, and land use were considered. The weight of evidence model was applied for landslide susceptibility mapping which is one of the bivariate statistical methods. It is applied when sufficient data is available to estimate the relative importance of evidential themes. The total weight of cell value ranges from (-17.71) to (+11.93). The values obtained were classified into five classes according to the level of susceptibility. The result shows that 23.4%, 30.55%, and 40.87% of the study area lies in moderate, high and very high susceptible zones respectively. The validation was done by the overlay method and area under curve method. The prediction accuracy through the overlay method and area under curve method was 94.74% and 91.72% respectively. Therefore the methodology applied appears to be highly applicable for the susceptibility mapping in the study area.

Keywords: Landslides; Susceptibility mapping; GIS; Sunkoshi watershed; Sindhupalchowk

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Landslide susceptibility analysis using frequency ratio method in Dharche Municipality, Gorkha, Western Nepal

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This study is about the landslide susceptibility analysis in the Dharche Municipality of the Gorkha district, which is one of the most landslide-prone areas of Nepal. The study area lies near Barpak which is the epicenter of the Gorkha Earthquake 2015. The study covers a total area of 651.52 Km^2. For the susceptibility analysis, the frequency ratio method was used. The landslide distribution was identified by the Google Earth pro to generate a landslide inventory map. The causative factors used for the susceptibility analysis in this study areslope gradient, slope aspect, land use, hill shade, drainage density, and distance from the road, elevation, geology, distance from thrust, distance from the river, plan curvature, and profile curvature. The obtained susceptibility map was divided into five susceptibility classes namely very low (0.03%), low (4.45%), medium (47.36%), high (47.89%), and very high (0.27%). Out of the mapped landslides, 75% landslides were used in the model for training data and the remaining 25% landslides were used for validation. The relative landslide density (R-index) method was used for the validation process. The consistency of the R-index indicates good performance of the susceptibility map. In this method, the result shows that landslide densities gradually increase from very low susceptibility zone to high susceptibility zone which reflects the validity of the landslide susceptibility map.

Keywords: Landslides; Susceptibility analysis; Frequency ratio method; GIS, Gorkha

Cause of spatial localization of landslides: An overview from Nepal Himalaya

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It is intended to synthesize the evidential outcomes of the different case studies for an overview from Nepal Himalaya to evaluate the spatial localization of landslides. Diverse geo-environmental conditions, human interventions, and extreme events (cloudburst or earthquake) are the main causative and triggering factors. The inherent characteristics of litho-tectonics have made the Himalaya fundamentally susceptible to landslides in specific geological regions which have been revealed by the periodic extreme weather events (torrential rainfalls of 1993, 2002, 2013, 2020) and the 2015 Gorkha Earthquake. Engineering properties of rocks and soils (shear strength and material properties), degree of jointing or fracturing, weathering process, the proximity of thrust/fault, interlayering of competent and incompetent rock strata, daylight conditions of natural or cut-slope, etc. play a vital role for initiation and spatial localization of landslides. The coupling effect of weakening processes and geometric configurations of hill-slopes (slope gradient, orientation, curvature, etc.) are controlling the distribution pattern of landslides in various geological units (Siwalik, Lesser Himalaya comprising Mahabharat and Midland zones and Higher Himalaya) with forming the varied engineering geological settings in terms of the probable extent regarding adjoining areas. For instance, several landslides are found to be located along the weak zones formed by major thrusts (MFT, MBT, MCT). Many landslide occurrences are concentrated in thin soil resting on bedding or foliation planes, granular soils in steep hill-slope, dip-slope conditions, folding and fracturing belts. The landslides are also clustered in hill-slopes where the presence of seepage and spring or underground water are contributing to the development of pore-water pressure. The recent trends of land use practices (haphazard road construction and improper cultivation practices) further aggravated the landslide problems. Thus, the localization of landslides is due to the nested inter-relationship of causative and triggering factors in spatio-temporal domains.

Keywords: Nepal Himalaya; Landslides; Spatial localization; Causative and triggering factor

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Spatio-temporal distribution of fatal landslides and early warning system in Nepal

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The occurrence of the landslide in the Nepal Himalaya is a common phenomenon due to fragile landscape, rugged topography, non-engineered road construction, poor or intensive agricultural practices, improper drainage management, and climate change. Moreover, reoccurrences of small to large scale earthquakes due to seismo-tectonic activities had weakened the geology and created many co-seismic landslides in this region. The weak terrain then reactivated by the strong Indian monsoon for the generation of landslides and debris flow every year causing many casualties. The fatal landslide data available in the United National Office for Disaster Risk Reduction and the Nepal Risk Reduction Portal show that 4994 fatal landslides were recorded from 1971-2020. These fatal landslides claimed 6349 lives, affected 604611 families, and 2536 injured people. The landslide fatality events show an increasing trend, however, there is no particular relationship between events and death numbers. This study shows that the number of deaths not only depends on the number of landslides but also depends on the size and the extent of landslides and the distance of settlements from the landslides. Different kinds of structural as well as non-structural mitigation measures were applied for the landslide risk reduction in the Nepal Himalaya. Among them, the landslide early warning system (LEWS) is one of the effective methods for risk reduction. There were some existing LEWS practices but most of them have vanished after the completion of the project. The low-cost and low-tech LEWS are the most effective due to their easiness to handle and operation by the local community.

Keywords: Landslides; Spatio-temporal distribution; Early warning system; Community

Identification of Deep-seated gravitational slope deformation in the Himalayan landscape: A case study in upper reaches of Trishuli River basin

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Nepal Himalayas is situated in the central part of the Himalayan Arc, which is under the active tectonic belt. Together with the local geology and tectonic activities has caused numerous deep-seated gravitational slope deformation (DGSD) often triggered large-scale landslides. Among the Himalayan districts of Nepal, Rasuwa is sitting in the fragile landscape of mountains where DGSDs have impacted the infrastructures and livelihood activities. This study attempted to map the landslides along the right bank of Trishuli River between Mailung and Trisuli Khola confluence. Remote Sensing data were used to detect the DGSDs, which were field verified. The mapping depicted 81 landslides of different types among which 5 were verified to be the DGSDs. The verification depicted two types of DGSDs; creeping of old landslides and newly triggered landslides after April 2015 earthquake. These DGSDs are critical in terms of stability during the monsoon, if triggered the damage will be substantial. Detail investigation of sub-surface using geophysical methods such as Electrical Resistivity Tomography (ERT) could be cost-effective method to understand the depth of the potential failure and possible failure mechanism of large-scale landslides. The approach will be helpful to plan for the mitigation measures.

Keywords: Deep-seated slope deformation; Creeping; Rasuwa

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Landslide hazard analysis along Bardaghat-Daunne-Dumkibas Area: Western Nepal

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Shallow landslides are one of the major natural hazards during the monsoon season in Nepal. In the Siwalik belts, landslides are the major problems along highways due to the water softening properties of soft rocks (i.e. mudstone and sandstone) having differential weathering degrees. The main objective of the study was to prepare landslide hazards and carry the cut-slope analysis. The Bardhaghat–Daunne–Dumkibas, Western Nepal along the road section of the Siwalik belt of about 16 km was the studied area. During the study, the deterministic landslide hazard analysis, hydrological model, and slope stability model was used to evaluate the factor of safety along slope profiles and describe the landslide hazard. The hydrological modelling was mainly focused on rainfall data of 25 years periods and infiltration rate in different slopes. The most dominant soil types present in this study area were: GC, GM, ML, SM, and SC which exhibited low to medium plastic behaviour having maximum porosity. The road alignment between (40 + 000) km to (54 + 300) km of Bardhaghat Daunne and Dumkibas road lies in the Siwalik belt consisting of rocks of Lower and Upper Siwalik. A portion of road section having (52+ 600) km and (53 + 100) km along the road is vulnerable due to the highly jointed rocks of Upper Siwalik Group. High hazard zones were mostly associated with landslides and slope instability was due to intense rainfall, weak lithology, and steep hill slope and soil thickness in the study area. Thus, the research can be further applied in the study of cut slope design to stabilize thick soil slope during the extension of four-lane road.

Keywords: Infiltration; Landslides; Hydrology; Factor of safety; Boreholes

Geological evaluation and slope stability assessment of Jharlan Landslide in Chhyamthali area, Dhading district, Lesser Himalaya, Central Nepal

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Jharlan Landslide is commonly called 'Jharlan Pairo' and it is one of the active, large-scale landslides located in North West of Dhading District. This paper presents details of geological evaluation, slope failures risk assessment and introduces the mitigation measures. The landslide area lies in the Lesser Himalayan belt of Central Nepal. Meta-sandstone, Ulleri Augen Gneiss, and phyllite are the major lithological units of this area. The landslide is being a continuous threat to the local inhabitants causing damage to settlements, cultivated land, foot trails and vegetation. The 2015 Gorkha Earthquake has affected the area by opening new tension cracks, the rise of slope failures, and propagating the landslide towards nearby villages. High-density soil masses overlie the weathered Ulleri Augen Gneiss, phyllite and meta-sandstone leading to slope failures. Preliminary and detailed studies of the landslide were carried out by desk study and field investigation. A aield investigation was carried out by fieldwork and collect essential data, and information of slope failures. Knowledge-driven approach, kinematic analysis, visual inspection, satellite image, and topographic map interpretation are the major source of evaluation. It is a combined form of a rotational slide, debris flows, and debris slide. The length of tension cracks is a significantly large and propagating trend of the landslide is towards the villages. Based on the study, the major causes of the landslide are identified as weak rock-mass, unconsolidated and oversaturated soil mass, heavy precipitation, tectonic activities, and anthropogenic causes. The field assessment and nature of the slope failures revealed the landslide to be unstable especially during the monsoon period. The installation of continuous monitoring devices is emphasized to prevent the hazard in future.

Keywords: Landslide; Lesser Himalaya; Slope failures; Rotational slide; Debris flows

Landslide susceptibility mapping of Birendranagar area, Surkhet, Nepal by using statistical approach

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The landslide has been the main geohazard in the mountainous terrain of the Nepal Himalaya, and with population growth and settlement and road network expansion, loss and damage due to landslides are on the rise. Here we investigate landslide susceptibility of Birendranagar area, Surkhet, Nepal, to understand the likelihood of landslide occurrences, by using a statistical approach and GIS techniques. A dataset was generated from ten terrain parameters closely associated with landslide occurrence, namely: geology, slope, aspect, land use, distance from fault, distance from the road, distance from the stream, topographic wetness index, elevation, and normalized difference vegetation index, and was validated with field data. Relationships between historic landslides and predictor datasets were quantified using a weightage function. A weightage system with weightage operators was applied to assess the relative likelihood of landslide occurrence. 107 landslides were identified in the study area and 80% of them were used for the calculation and the remaining 20% to validate the results. The model outputs, in the form of landslide susceptibility maps, were then evaluated by correlating training landslides and validating landslides. To validate the susceptibility map, landslide hazard classes were correlated with the existing landslides. The results show 16%, 11%, 37%, 28%, and 8% areas of the Birendranagar area fall in the very low, low, moderate, high, and very high susceptibility zones, respectively. About 91% of the validated sample landslides lie in the high and very high susceptibility zones. Thus, the model used in this study is reasonably validated indicating the correctness of the output.

Keywords: Landslides; Susceptibility; Statistical approach; Birendranagar

Detailed investigation of roadside cut slope stability with proper mitigation measures along Mugling-Kali khola road section of the Lesser Himalaya, Central Nepal

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The road corridor in the Nepal Himalayas has suffered from a variety of cut slope failure including rockslides, rock topples, rockfall, debris slide/flow, and some combination of these. Mugling-Kali Khola road section are heavily congested highway which connects the capital city Kathmandu to the outside world via Terai. Over 90% of the daily consumer goods, commodities, industrial raw materials, and fuels are being transported along this road section. Every year this road section experiences a number of cut slope failures causing damage to life and properties. Stability assessment of road cut slopes along such highways is therefore very important. For the present study, two rockcut slopes have been selected from the road stretch of 5 km from Mugling Bazaar to Kali Khola village, for the detailed geological and geotechnical investigation and evaluation of slope stability with different approaches. The region falls in the close vicinity of major active thrust faults and folds making the slopes inherently unstable. Field, laboratory investigations, and modelling were conducted to identify stability conditions of the selected rock cut slopes and provide appropriate mitigation measures. Rock mass rating has been utilized for the assessment of rock mass strength, which is further been utilized for the evaluation of Slope Mass Rating. The kinematic analysis was also employed to identify the potentially unfavorable planes. Similarly, SLIDE 5.0 software has been used to determine the stability of rock slopes with suitable mitigation measures. The results indicate that selected rock cut slopes along Mugling-Kali Khola road section were partially stable condition and they need immediate mitigation measures. Thus, the performance of rock anchors and selection of suitable rock cut slope angle was conducted to stable these slopes. The rock anchor with an installation angle of -150^0 degree and cut slope angle of 63^0 (0.5H:1V) with benches are the two effective measure for stabilization of cut slopes.

Keywords: Slope stability; Road cut slopes; SMR; Kinematic analysis; Slide 5.0 software

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Engineering geological consequences of the white clayey silt deposit in the marginal lake zones of Pokhara valley

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Pokhara valley bears a catastrophic depositional history. Past researchers have revealed, multiple catastrophic events between (700-1700 AD) which caused high aggradations in the valley. The debris from the Annapurna range flowing along the path of the Seti River blocked most of its tributaries, giving birth to many marginal lakes. Phewa, Rupa, and Begnas are the larger, existing marginal lakes in Pokhara valley. Understanding the nature of the sediments of marginal lake zones is a must before the construction of infrastructures. The study areas largely comprise the white clayey silt and sand with alternating fluvial deposits. Nearly two dozen samples were collected and general geotechnical tests and in situ tests were carried out as a part of research. The Atterberg limits, moisture content ranges from 13-40% and specific gravity (2.76-2.78 in average). The general geotechnical tests carried out for the soil sample reveal various outcomes. The medium ranged moisture content bearing sediments possess illite, kaolinite, micas, etc. Less compressible in nature of the soil signifies that the areas undergo long-term consolidation settlement. Loose to stiff property of the sediment layers possesses varying California Bearing Ratio values to the depth of 2.3m as given by the DCP test. Various empirical relations applied for this calculation concludes that the value fluctuates from 12.5% - 298.55%. The grain size analysis showed the availability of 70-80% silt, 6-8% clay, and 10-15% sand. Thus, the soil was characterized as the low plastic silt by the soil characterization chart.

Keywords: Debris flow; Marginal lakes; Settlements; Clay minerals; California Bearing Ratio

Post-disaster evaluation on fireworks hazard in Enschede, the Netherlands

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Enschede is a municipality situated in the eastern Netherlands, a province of Overijssel. An unexpected violent explosion-fireworks disaster occurred on 13 May 2000 in the SE Fireworks depot amid a residential city district Roombeek neighborhood at 13:00 GMT. In the depot, the company was storing and repacking some 900 kg explosive products. On that day, in two explosions approximately 177 tons of explosive was detonated. The blast was felt up to 30 kilometers away. The final explosion caused a ball of fire with a diameter of over a hundred meters. The company kept those fireworks for recreational purposes imported from China. Some 400 apartments were reduced to cinders, another 1000 were damaged. Due to explosion, there was a release of hazardous asbestos. 18 civilians and 4 firefighters were killed, 947 were injured. A damage map was produced to show the affected area with various information to understand the disaster intensity. The number of people affected and the amount of damage in terms of Euro for each living unit points were calculated. From the spatial join analysis, a total number of 197 Residential buildings were identified in the three different damage categories. A total number of living units is 300, among 100, and 43 are the maximum and minimum number respectively. The case study was conducted using an integrated approach of both GIS and RS. Such approaches are very effective to represent quick result. The disaster was a macabre wake-up call nobody expected. From the study, the total damaged cost was approximately about 1749000.00 euro. Notably, most of the buildings and the living units were within the 200m buffer area, so the priority should go to this fully destructed area in terms of emergency service as the affected people are urgently in need of such services.

Keywords: Fireworks hazard; Post disaster evaluation; Residential city; 13th May 2000; The Netherlands

Engineering Geology for Sustainable Infrastructure Development

Parameterization of infinite slope stability model and evaluation of safety factor for the rainfall-induced flow like landslide in Harpan village in Phewa Lake watershed, Kaski, Nepal

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Flow like landslides are often catastrophic events that can travel considerable distances in the mountain region of Nepal. On the mid-night of 30th July 2015 a huge flow like landslide was triggered in the Harpan and Chainpur village cluster in the Phewa Lake watershed in Kaski District that killed nine people. The landslide initiated at an altitude of 1445 masl near Harpan Village that runs all the way to Dunde Phant (845 masl) and damaged four houses and one on its way at Chisapani. The landslide was shallow at its initiation point, which was the deposit of the spoils from the road excavation some 10 years ago. Analysis of daily rainfall data from the region indicate that there was continuous rainfall of some amount in the preceding days and week that has substantially increased the soil water content. Local people reported that the rainstorm on 30th July night was high which was supported by the 24 hour recorded rainfall (315 mm) at the nearest (5.5 km) rain-gauge station in Bhadaure-Deurali (Nr. 813) while the recorded rainfall in Pokhara-Airport (Nr. 804) and Lumle stations (Nr. 814) was 116 mm and 288 mm respectively. The self-recording weather station installed at Gharelu Village (10.2 km) showed 33 mm/hr. of rain intensity at 10 PM of the day. To model the landslide, the area was mapped and soil physical and hydrological properties were obtained through the in-situ and laboratory tests as well as literatures. Topographical variables were derived from 12.5m resolution digital elevation model (DEM). Rain-intensity was derived from the Intensity-Duration-Frequency (IDF) model suggested for the region and wetting-front depth was estimated according to Green-Ampt. Infinite slope stability model (ISSM) was parameterized and implemented for the four scenarios (no-rain, 2.64cm/hr., 4.65cm/hr. and 5.7cm/hr. rain intensity) considering 80% initial degree of saturation (DS) of the landscape soil. The model depicted the Safety Factor (SF) was near to 1 at no-rain condition, that indicated the impact of soil-moisture on slope stability. As the rain-intensity increased, SF decreased considerably and the landslide triggered when the rain-intensity reached 33 mm/hr. The adopted approach suggested that the flow-like landslide can be modelled through ISSM considering the initial soil-moisture and rain-intensity induced wetting-front depth. The approach can be improved and up-scaled to design rainfall-induced shallow landslide early-warning system for watershed/sub-watershed scale that considerably decreases the landslide disaster-risk.

Keywords: Flow-like landslide; Harpan village; Wetting-front; Safety factor; Nepal

Undrained strength behavior of compacted clay-sand mixed soils used for river dyke construction

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Determination of strength and stiffness of compacted clay-sand mixed soils with varying water content and dry unit weight is required for the design and stability analysis of embankments. For the interpretation of the strength of such soils, a widely applicable linear Mohr-Coulomb strength criterion can be used, but the strength parameters, particularly apparent cohesion as a result of dilation in densely compacted specimens produced an uncertainty in the calculation of factor of safety for the shallow slope stability analysis. In this study, the undrained strength behavior of compacted clay-sand mixed soils at different states on a wet side of optimum were investigated by performing a series of constant-volume direct shear tests and unconfined compression tests. The undrained strength parameters in terms of effective and total stresses were derived, which indicated that the apparent cohesion was significant for the state close to the optimum but decreased gradually towards the wetter side, but the angle of internal friction did not show significant variation between the states. The unconfined compressive strength and deformation modulus increased with decreasing water content, increasing dry unit weight and increasing degree of compaction following power functions.

Keywords: Compacted soil; Compaction states; Undrained strength; Apparent cohesion; Dilation

A quick overview of construction of mechanically stabilized earth walls (MSEW) to realign State Highway 1 in Kaikoura region, New Zealand following Kaikoura earthquake 2016

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An earthquake of the magnitude 7.8 hit Kaikoura, a small town located by the east coast of Canterbury region of the South Island, New Zealand in November 2016. Many slope failures occurred and damaged State Highway 1 north of the township. North Canterbury Transport Infrastructure Rebuilt (NCTIR) Alliance was then formed to re-establish damaged infrastructures including three major realignments of the State Highway 1. The realignment included Mechanically Stabilized Earth Seawalls (MSEW). The walls were designed to withstand the high earthquake demands and the ocean force. One of the main priorities of NCTIR was to re-open the State Highway 1 at the soonest possible time. The design approach of the wall included optimization of the material use, time frame and the quality of the wall. This paper discusses the construction of the foundation and structure of the seawalls from the Construction Phase Services (CPS) engineer's perspective.

Keywords: Earthquake; Canterbury; State highway 1; Earth seawalls

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Geotechnical investigation of soils from the landslides of Siwalik Hills, Nepal

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Soil consists of various geotechnical properties which are highly responsible for occurring landslides in the hill slopes. In this study, geotechnical investigations of soils from the landslides of Babai River catchment of Siwalik zone are analyzed. Altogether 100 soil samples were collected from 100 different landslides distributed throughout the study area. The specific gravity, moisture content, void ratio, dry unit weight and degree of saturation are also obtained from laboratory analysis. The direct shear test was conducted for the calculation of internal friction angle and material cohesion. The Karl Pearson correlation coefficient was obtained between the variable and linear regression analysis was conducted to obtain the significance of the relation between individual variables. The result shows that angle of internal friction and moisture content has a significant negative relation whereas dry unit weight and material cohesion has a significant positive relation. Specific gravity and material cohesion also shows positive correlation. The void ratio and angle of internal friction shows an inverse relation. The degree of saturation is highly correlated positively with moisture content whereas highly correlated negatively with void ratio. The results will be useful to understand the role of fundamental geotechnical properties for landslide mechanism in the Siwalik Hills of Nepal.

Keywords: Landslides; Geotechnical investigation; Phase relations; Index properties; Siwalik

Design consideration of Concrete Dam Face Rockfill Dam in fragile geology: A Case of Dhap dam, Kathmandu

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Exponential growth in population and accelerating economic development increases the use of healthy water extensively following the depletion of naturally availability for consumption and has put great pressure on the water resources. At the same time, the trend of new technologies emerges to fulfill such necessities. During the dry season, around 80% of the Bagmati River flow is diverted for different purposes leaving very little downstream flow inadequate to carry waste effluents out. Thus, there is a vital need to protect and enhance water resources and increase water discharge to the Bagmati River to conserve terrestrial and aquatic biodiversity and maintain the Bagmati River water quality. In addition, the concept of Concrete Faced Rockfill Dam (CFRD) is evolved to reserve water upstream hill and release it in winter season as required. This paper presents the progress and results of this project of rockfill dam. CFRD of 24m height of Dhap Dam which is located at the northern belt of Kathmandu that lies in the Shivapuri Nagarjun National Park (SNNP), is the first ever such dam in Nepal which is in the construction phase and was halted a while due to the Covid-19. CFRD is considered to be safe, economically low cost, and fundamentally fitted to fragile geology to inhibit the leakage providing curtain grouting. However, the design of CFRD is empirical and based on precedent of past experiences. This project is designed on the basis of ICOLD Bulletin 141, 2010 and other relevant standards.

Keywords: Concrete Faced Rockfill Dam (CFRD); ICOLD; Spillway; Plinth

Analyzing the effect of non-persistent rock joint with various rock bridge intensity and configuration on shear behavior using direct shear test on PFC3D

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Structural defects such as joints or faults are inherent to almost any rock mass. Such defects can control the possible failure mechanisms. Extent of discontinuity within the plane and roughness of the structure (morphology of the joint surface) are the major contributors to influence the shear strength of a rock mass. Due to various geological processes, intact rock bridges could occur on the joint surfaces by merging the pre-existing fractures. The objective of this study is to understand the effect of rock bridge intensity and it's configuration on shear behavior (shear strength, modulus and displacement) of joint. The direct shear test by using particle flow code PFC3D is used to establish the coplanar non-persistent joint model. Planar joint geometry can be prepared using PFC3D and if joint roughness is considered, real morphology of the exposed joint can be accessed with 3D laser mapping. Discrete element method would create the synthetic rock joint. Failure in rock mass may not only occur through sliding along persistent discontinuities, but also through combination of sliding along non-persistent discontinuities and bridging across unbroken rock. This complex interaction between natural discontinuities and brittle fracture propagation through intact rock bridges can be predicted well using Jennings criterion.

Keywords: Non-persistent discontinuities; Rock bridges; Shear properties; PFC3D

Preliminary engineering and geological investigations of a construction site for an international airport located in Bhatte Danda, Lalitpur, Nepal

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Tribhuvan International Airport (TIA) handles more than 7 million domestic and international passengers with nearly 130,000 take-offs and landings yearly. Considering gradually increasing number of international passengers and available existing limited space and facilities at TIA, it has been argued that Nepal needs to construct another fully facilitated international airport as early as possible. In this context, the main objective of this research is to evaluate the feasibility of an international airport in Bhatte Danda area by collecting data from literature review, field assessment and expert consultation. It is found that geologically the area belongs to Kathmandu Complex of Central Nepal consisting of rocks in the Markhu formation, Chandragiri Limestone, Sopyang Formation and Tistung Formation along with the Palung Granite. Topographically, a flat rocky ground of about 7 km^2 can be constructed by cutting down the existing hills at 2000m of elevation (maximum elevation: 2300m). With this space, two runways (5km length and 400m wide, and 3.5km length 250m wide) can be constructed, but at some locations it has to be filled up by sediments to make the surface flat. To avoid the probable settlement, hills can be cut down up to at an elevation of 1900m, which results in enough space for constructing the airport. The volume of the excavated materials is estimated to be about 700 M m^3 consisting of slate, phyllite, metasandstone, and limestone, which can be used as construction materials for various purposes. The value of the excavated material in international market is 1400 billion NPR (12 billion US$) which is about 4 times the capital cost of the airport. Detail engineering geological, hydrological and environmental studies; study from aeronautical engineering perspectives and cost benefit analysis are yet to be conducted to confirm the feasibility of the project.

Keywords: Preliminary study; International airport; Bhatte danda; Geology

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Railway track structure and rock types used in railway track ballast

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Railway tracks are one of the essential and suitable means of transport for socio-economic and industrial growth of the nation. Railway track network and services are required to improve transportation efficiency and save fuel energy used in the transportation sector of the country. The ballast layer is the most important component of the railway track infrastructure. Rail track is a fundamental part of railway infrastructure. Ballast is produced from natural deposits of granite, quartzite, dolomite or limestone. The correct choice of ballast for railway tracks is still considered critical because aggregates progressively deteriorate under traffic loading and environmental exposures. Therefore, proper understanding of ballast properties and suitable tests are prerequisites for minimizing maintenance costs. The ballast characteristics which need to be investigated beforehand are; firstly, to assign ballast functions, secondly need to clarify ballast requirements and thirdly to map appropriate tests to evaluate ballast characteristics. Point Load strength, aggregate impact value, aggregate crushing value help to identify the factors affecting rocks strength, whereas Los Angeles abrasion value, slake durability index and Sulphate Soundness value are suitable for predicting railway ballast performance with respect to deformation and degradation. Strength and durability tests are made to distinguish clearly between the superior quality and inferior quality materials. In this study, various tests, rock types suitable for ballast, and specification were reviewed and discussed.

Keywords: Railway track ballast; Strength and durability; Los Angeles test; Sulphate soundness test; Slake durability test

Durability of sandstones from Sub-Himalaya of central Nepal

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The Sub-Himalaya of Nepal experiences sub-tropical climate in which geologically young and fragile sedimentary rocks are prone to weathering and consequent erosion. The main aim of this study is to identify and evaluate the durability characteristics of some sandstones against physical weathering environment, i.e., slaking, freeze thaw and rock abrasion. Lithosomes were characterized, and physical properties and durability of sandstones were tested in the laboratory for dry density, specific gravity, and water absorption, Slake Durability Index (SDI), Sulphate Soundness and Los Angles Abrasion. Sandstones from the Lower Siwalik Subgroup (LSS) were massive to cross-laminated, very fine- to medium-grained, and occasionally calcareous, and those from the Middle Siwalik Subgroup (MSS) were mostly cross-laminated to few massive, medium- to coarse-grained salt-and-pepper textured, and infrequently calcareous cemented. Sandstones possessed high to extremely high SDI, and slaked giving four kinds of deterioration patterns, of which two are common to both. Majority of the sandstones showed similar slaking characteristics. Under the five-cycle Sulphate Soundness Test, majority of sandstones from both LSS and MSS experienced low weight loss (below 10%) at the end of the test, and two from the LSS and three from the MSS experienced greater weight loss. The Los Angeles Abrasion values ranged from 29.66% to 99.14%, and except for two sandstones from the LSS, the rest of the sandstones gave the values exceeding 45%, showing that they were incompetent in the abrasion test, and were highly susceptible to abrasion. The uniformity factor ranged from 0.21 to 0.44 showing that all the sandstones were of non-uniform hardness. Correlation among physical parameter and durability indices was weak to moderate probably because of varied nature of sandstones.

Keywords: Siwaliks; Sub-Himalaya; Slake Durability Index; Point-load Strength Index; Los Angeles Abrasion; Sodium Sulphate Soundness

Advances in Geophysics, Earthquake Seismology and Seismotectonics; Advances in Mineralogy, Petrology and Geochemistry

Seismic hazard assessment of the Kathmandu Valley and its adjoining region using the segment of the Main Himalayan Thrust as a source, whose partial rupture produced the 2015, Mw 7.8 Gorkha Nepal Earthquake

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An attempt has been made to evaluate seismic hazard in the Kathmandu Valley and its adjoining region. A segment of the Main Himalayan Thrust, whose partial rupture produced the 2015 Mw 7.8 Gorkha, Nepal Earthquake, is used as an earthquake source. Two rupture models of the earthquake source have been utilized assigning unequal weight to estimate seismic hazard for engineering rock site condition. The first model considers entire north-south rupture of the source that is similar to that of the 1934 Bihar-Nepal Earthquake (Mw 8.2). The second model considers the northern-half rupture of the source, which is similar to the rupture area of the 2015 Gorkha Earthquake (Mw 7.8) and possibly the 1833 Nepal Earthquake (Mw 7.6). Seismic hazard maps have been prepared for 500 and 200 year return periods at engineering rock site and a comparison of probabilistically estimated peak ground acceleration (PGA) is made with the recorded (PGA) of the 2015 Gorkha Earthquake measured at Kirtipur (a rock site) in Kathmandu Valley and its empirically estimated PGA in Nijgadh. The result shows that the probabilistically estimated PGA corresponding to 200 year return period agrees with the recorded PGA of the 2015 Gorkha Earthquake in Kathmandu. Ground motion (PGA) record is not available in Nijgadh, which is to the south of Kathmandu Valley and in the south of the Main Frontal Thrust; therefore an alternative approach is adopted to estimate PGA in Nijgadh. Human perception was utilized to empirically estimate PGA in Nijgadh for the 2015 Gorkha Earthquake. The empirically estimated PGA (0.07 g) in Nijgadh agrees with probabilistically estimated PGA (0.1 g) for 200 year return period.

Keywords: Peak ground acceleration; Probabilistic seismic hazard analysis; Main Himalayan Thrust; Human perception; 2015 Gorkha earthquake

Integration of geophysical and geotechnical approaches for seismic site characterization: A case study of Tangail city, Bangladesh

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Seismic site characterization is an integrating part for seismic hazard assessment as well as site-planning strategies for earthquake damage mitigation. The seismic risk of an area can be reduced significantly by seismic design of structures based on the intensity of the ground motion parameters. For this purpose, in the present study, the seismic site characteristics of Tangail city, Bangladesh is identified by integrating geophysical and geotechnical approaches. To measure shear wave velocity Standard Penetration Test (SPT), PS logging (Downhole seismic method) and Multi-channel Analysis of Surface Waves (MASW) are used. For this purpose 20 locations are selected in Tangail city. In every location, Standard Penetration Test is carried out up to a depth of 30m and later in the same hole a 3inch PVC pipe is installed. Among them, PS logging is carried out in 15 locations. MASW and Micro-tremor survey are performed in 18 sites.

The study reveals that the average shear wave velocity to a depth of 30 m (AVS30) varies from 163 to 221 m/s, and according to US National Earthquake Hazards Reduction Program (NEHRP) soil site classes belong to D and E are predominant, peak ground acceleration (PGA) at the ground surface is 0.28g, the predominant period ranges from 0.39 to 1.0s and liquefaction potential index (LPI) is also evaluated from borelog data ranges from 5 to 40. Combining all the parameters a site characteristics map for Tangail city is constructed. This will help to prepare an earthquake risk-sensitive land use plan and to design earthquake-resistant structures for future urban development.

Keywords: Seismic site characterization; Geophysical approach; Geotechnical approach; Tangail city; Bangladesh

Exploring deep-seated rock mass characteristics for construction of high dam reservoir- A case of the proposed Budhigandaki Storage project

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The huge water resources in Nepal has immense potential to generate hydroelectricity. This can be achieved through building high dams such as the proposed Budhigandaki storage project (1200 MW) in the mid-hill region of Central Nepal. The 263 m high dam retains 4500 million m3 of water behind. The project requires in-depth investigation of subsurface geology for better implementation. Geologically, the dam site is oriented N-S and relatively narrow river valley with steep slopes and favorable orientation of the main geological structures, which are near perpendicular to the valley. However, the morphology of the dam site indicated that the slopes of both the banks triggered deep-seated landslides in the past. The dam site was delineated by two noticeable tectonic deformation zones, located immediate up-stream and downstream from the proposed dam axis. Between the two deformation zones, the tectonic stress was accommodated mostly by second order fractures and shear zones with different orientations and variable persistence. Observation tunnels of about 1150 m (total of 6 galleries) on either side of the river depicted that the bedrock of the location consists of quartzite, phyllite and siliceous dolomite. Further, through the observation tunnel it was noticed that wide open joints in the upper part of the left abutment are interpreted as a consequence of stress relief subsequent to a landslide. Analysis of the bed rock characteristic and interpretation indicated no imminent risk of large instability; however, the fractured and wide joints observed in the deeper depth indicated the presence of deep-seated deformation of rock mass in the area. The investigation further identified the unfavorable discontinuities on the left side of the dam axis based on observation in the test galleries. On the right bank, no evidence of large instability any deformation were observed. The left bank abutment of the dam must be treated to reduce the threat of deep-seated deformation and instability.

Keywords: High dam; Rock mass characteristics; Deep-seated deformation; Instability; Reservoir

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Recognition of seismogenic nodes in Eastern Tibet and adjacent regions

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Eastern Tibet and adjacent region is one of the seismically active areas in the Himalayan- Tibetan region. Proper recognition of seismogenic nodes capable of producing strong earthquakes is essential for seismic hazard assessment in this region. In this study, seismogenic nodes capable of producing strong earthquakes ($M_S \geq 6.0$) in Eastern Tibet and adjacent regions were identified using the morphostructural zoning and pattern recognition methods. A morphostructural zoning map consisting of a total of 98 morphostructural nodes was delineated for Eastern Tibet and adjacent regions in which, 66 (about 67 %) of these delineated morphostructural nodes are recognized to be potential seismogenic nodes (Dangerous nodes) where earthquakes with surface wave magnitudes equal to and greater than 6.0 may occur in the future. The results of this study demonstrate that most of the recognized seismogenic nodes are found to be located in the western and south-eastern segments of Eastern Tibet and adjacent regions.

Keywords: Pattern recognition; Seismogenic nodes; Eastern Tibet; Morphostructural map

Characterization of secondary mantle convection from geophysical data and models

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Small-scale convection or secondary convection has been studied using the geophysical data and models such as seismic tomography models and geoid anomalies. We used three seismic tomography models, SEMUCB-WM1, SAVANI and S40RTS to infer the lithosphere/asthenosphere boundary, and the destabilization of the lithosphere, induced by secondary mantle convection. Former studies, based on numerical and experimental models report that secondary convection would occur as sub-lithospheric longitudinal rolls, induced by the shear associated with the lithospheric plate motion, or as helices, formed when sinking cold plumes, falling from the base of the lithosphere are sheared away by the large-scale flow. Our study shows that the secondary convection under the Pacific plate occurs in the form of 3D plumes and helices. The lithospheric drips observed in the tomography models first appear as small wavelength anomalies beneath a 30-40 M.y. old and 75-90 km thick lithosphere. They are observed as longer elongated patterns beneath 105 M.y. old and 138 km thick lithosphere. Most of the lithospheric anomalies are associated with negative geoid anomalies of order and degrees 8-40. No clear correlation between lithospheric destabilization and volcanism is observed.

Keywords: Tomography models; Lithosphere destabilization; Geoid; Seafloor age; Mid-oceanic ridges

Magma mingling and mixing evidences from Kyrdem Granitoids, Meghalaya

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The Kyrdem Granitoids (KG) pluton covers an area of about 230 sq. km. in the Ri-Bhoi district of Meghalaya. The KG (479±26 Ma) which intrudes the Shillong Group of metasediments represents one of the granite plutonism episodes of Meghalaya plateau. Mineralogically, KG can be grouped into coarse-grained porphyritic granite with grey and pink K-feldspar phenocrysts and aplite without phenocrysts. The aplite intrudes the porphyritic one as small pulses at several places. KG exhibits textural evidence for magma mixing and mingling during its evolution. Two types of enclaves are hosted in the KG viz. the country rock xenoliths and the microgranular enclaves (ME). Xenoliths which include amphibolites, granite gneiss, and quartzite of the Shillong Group are noticed in the porphyritic granite of KG. Microgranular enclaves (ME) hosted in KG are confined to the porphyritic granites and they are absent in the aplite. They are mesocratic to melanocratic, fine to medium grained and ranges in size from a few centimeters to few meters. The ME shows different shapes ranging from subrounded, ovoid, and discoidal to ellipsoidal. The contacts between the host rock KG and the ME are sharp but occasionally diffused contacts are also noticed. In some cases, the ME shows finger liked projections with a convex face towards the host rock. Elongated, tabular, and sub-rounded K-feldspar megacrysts with a corroded margin are observed in the ME. These K-felspar megacrysts are commonly resemble with that of the host rock. The above features suggest the origin of KG by magma mixing. Furthermore, textures including quartz ocellli, acicular apatite morphology, inclusion zones in feldspars and mafic clots also indicate that magma mingling and mixing plays a significant role in the evolution of KG.

Keywords: Kyrdem granitoids; Microgranular enclaves; Magma mingling and mixing; Meghalaya, quartz ocelli

Petrogeochemistry of Mylliem granitoids from Meghalaya Plateau, Northeast India

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Petrogeochemical studies of Mylliem granitoids suggest the source of evolution of Mylliem granitoids. Petrographically, the essential minerals are quartz, alkali feldspar, and plagioclase while biotite, muscovite, and opaque's occur as accessory minerals. The SiO_2, Al_2O_3, Na_2O, K_2O, and CaO content varies from 61.06 to 68.38; from 12.10 to 15.11%; from 1.71 to 3.04; from 3.87 to 7.32 and from1.09 to 3.77% respectively. Similarly MgO, MnO, TiO_2, and P_2O_5 range from 0.53 to 3.64%; from 0.02 to 0.07%; from 0.13 to 0.53% and from 0.04 to 0.27% respectively.

The total alkali content ($Na_2O + K_2O$) ranges from 6.00 to 9.22 % and K_2O / Na_2O ratio ranges from 1.37 to 3.85 depicting the potash-rich character of Mylliem granitoids. It is characterized by slightly steep to almost flatten light rare earth element (LREE) pattern with average La/Eu ratio 8.429, relatively flat to slightly enrich heavy rare earth element (HREE) pattern with average Eu/Lu ratio 8.991 and slightly negative Eu anomaly with an average concentration of 2.255 ppm. Geochemical parameters (MALI, ASI and Fe) suggests its magnesian, peraluminous and calc-alkalic to alkali-calcic character. Critical correlation between petrography and geochemistry indicates that Mylliem granitoids have S-type characteristics.

Keywords: Mylliem granitoids; S-type granites; Peraluminous

Environmental Geology and Climate change Issues in Geosciences

Recent trend of glacial surface lowering and evolution of supraglacial ponds in Khumbu glacier, Everest region, Nepal

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The study area lies in the northernmost region of Sagarmatha National Park, Nepal. The aim of this study is to know the glacial surface lowering and changes in number and area of supraglacial ponds from Everest base camp to terminus of Khumbu glacier. Statistical method and DEM co-registration method are used, where digital elevation models of Advanced Land Observing Satellite Phased Array type L-band Synthetic Aperture Radar (ALOS PALSAR) (2006 and 2009 AD), High Mountain Asia (HMA) (2015 and 2017 AD) and Light Detection and Ranging (LiDAR) (2019 AD) were reprojected and resampled using Quantum GIS. Then, the DEMs were corrected for elevation differences with respect to the Ground Control Points (GCPs) taken on boulders of right lateral moraine of Khumbu glacier. Finally, the flowline along the glacier was drawn to extract the elevation profile of DEMs using QGIS. The average of elevation differences between DEMs is the surface lowering of glacier which is -2.0 ± 0.69 m/year for the period of (2019 - 2006 AD). In DEM co-registration method developed by Nuth and Kääb (2011), python algorithm developed by Shean et al., (2016) was used to correct the horizontal and vertical biases to co-register the DEMs. Using this method, the surface lowering of the co-registered DEMs for the period (2019 - 2006 AD) is found to be -1.44 ± 0.04 m/year. Also, the increment in number and area of supraglacial ponds is obtained by manually digitizing ponds using Google Earth Pro. The increment of ponds is seen from 108 and 0.106 km2 in 2009 AD to 206 and 0.252 km2 in 2019 AD. The increasing coalescence of ponds is visible near the lower eastern margin which shows a trajectory towards a large lake development near the terminus of Khumbu glacier.

Keywords: Surface lowering; DEM co-registration; Supraglacial ponds; Khumbu Glacier

Time series analysis of snow loss from the glaciated high mountain area of Kaligandaki River Watershed using global scale modeling and reanalysis products

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Assessment of mass balance of water from the glaciated mountains is critical for understanding the sensitivity of Himalayan glaciers to climate change and the effects of rapid glacier retreat. High-mountain glaciers are the major water houses, which upon melt supply drinking, irrigation, hydropower generation, and ecological water demands. The intense and excessive glacial melt may cause glacial lake outburst flood, avalanches, downstream river flood, and sea level rise, which eventually affect the lives and livelihood of the people and damage our infrastructures. Our understanding of the processes and quantification of hydrologic balance in several glaciated regions of the world are still poor owed to the scanty field measurements in complex and harsh terrains. This study aims at improving our understanding of snow accumulation and snowmelt processes occurring over high-mountain glaciers and presents results of time series analysis from global scale modeling products based on remotely sensed and observed data. Snow depth from MERRA-2 (Modern-Era Retrospective analysis for Research and Application, Version 2) model is analyzed over the glaciated high mountain region of Kaligandaki River Watershed, in the Western Nepal to investigate annual rate of snow loss and to estimate its trend using 38 years of time series data from 1982 to 2020. The selected site spreads over 10.6 km2 where about 25% of the area has ≥ 50 % snow cover. The study shows that total depth of snow in the summer months is about 5.28 m less than in the winter months over the entire study site. Averaging over the period, annual snow loss in summer is 3.38 (±1.18) cm/year ($p = 0.01$). Over the study period, 29 out of 38 summers showed a snow loss ranging from 1.15 cm to 12 cm per year, while only one year had snow surplus of less than 2 cm. This imbalance of snow depth in the glaciated portion of Kaligandaki region indicates a strong influence of climate change in high mountain Himalaya and suggests its impact in overall river flow while warning us towards the depletion and potential shortage in amount and the degradation in quality of our fresh water supply.

Keywords: Climate change; Glacial melt; Snow loss; Kaligandaki

Prediction of future Land Use and Land Cover change of Ilam district, far-East Nepal Himalaya

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The Himalayan region has been adversely affected by several natural and anthropogenic phenomenons that have a common link with geological, environmental and Socio-economic change in the livelihood of local people. In recent year the pattern of livelihood and practice of traditional social behaviors has been driving toward urban settlement from their ancestor land due to economic reasons or by the natural effect linked with climate change, natural disasters. etc. The Land use and Land cover (LULC) is slow and continuous process displaying the range of human behavior in a certain area giving the knowledge of exploration and exploitation of the geomorphology for settlement, agriculture and different activities of human to be utilized from the nature. The dynamic change of the Land use and Land cover (LULC) pattern is helpful in maintaining the sustainable management of the natural resources, analysis of the changing climate in the region and pattern of human activities change in an area. The Ilam district of far-eastern Nepal has been chosen for the interpretation and prediction of land use land Cover analysis with the aids of remote sensing and GIS. This study focuses on evaluating the progressive change of LULC change and detection of total area of 1,703 km² for the time period of three decade ranging from 1990-2020 using different Landsat (USGS) satellite images. These data are capable of projecting the future scenario of LULC from 2020-2030 of the respective areas with the use of Markov Chain analysis technique. GIS and remote sensing technique has been widely used and useful tool in analysis of the LULC change and its future prediction. The possible outcome of the 2030 LULC pattern could be useful for systematic and sustainable use of available Natural resources, urban planning, infrastructure development and effective policy making agendas if national priority.

Keywords: Land use land cover change; Ilam; Landsat images; GIS

Hydropower Development and Tunneling; Miscellaneous

Excavation of vertical shafts in the Nepal Himalaya: A case from Upper Tamakoshi Hydroelectric Project

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Upper Tamakoshi Hydroelectric Project (UTKHEP) is the national pride project under construction in Dolakha, Nepal with 456 MW power output and gross head of 822m. It has four vertical shafts: Upper Penstock Shaft, Lower Penstock Shaft, Surge Shaft and Bhaise Intake Shaft with respective heights of 310m, 372m, 67m and 59m. Excavation of shaft is always a challenge in hydropower projects and is further complicated in the high-head projects. This paper is focused on the applied excavation methods and its progress rate in the aforementioned shafts. The shaft excavation of UTKHEP has achieved by the application of conventional shaft sinking, raise climber and Raise Boring Machine (RBM). Excavation in the conventional shaft sinking method is carried out from top to bottom and the excavated material is removed from top of the shaft. In the raise climber method, excavation is conducted from bottom to top direction with the aid of monorail system. Excavated materials directly fall down to the shaft-bottom and are taken out from the haulage system. The RBM, at first, drills small-diameter pilot hole in downward direction. The crushed material is taken out from top of the shaft. The small-diameter bit is then replaced by larger reaming bit and pulled upwards. The accumulated sludge at the shaft-bottom is taken out from the haulage system. Within UTKHEP, total 337m shaft, having diameter of 4.4m, is excavated by conventional shaft sinking with daily progress of 0.8m. Total 344m shaft, having diameter of 2.1m, is excavated by raise climber with the rate of 1.4m per day. Similarly, 126m high shaft of 1.4m diameter is excavated by RBM with daily rate of 6m. The project experiences difficulties dealing with RBM in deeper shafts but found suitable in shallower ones (<100m) in competent rock. The earlier two methods are found appropriate for deeper shafts.

Keywords: Upper Tamakoshi Hydroelectric Project; Shaft excavation; Raise climber; Excavation

Present status of school level geoscience curriculum in Nepal

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This paper has aimed to analyze the current status and issues in the existing school level geoscience curriculum in Nepal. A thorough review is made on the existing curriculum and text books of geoscience in school level. Earth science section has started from grade two covering the disciplines of geology, astrology, geography and the environmental science in Nepal. The content in syllabus is insufficient in compression to the SAARC countries and other developed countries. Earth science section covers only 3% to 4% of the whole science curriculum. Another most remarkable thing is that there exist several academic errors in the existing textbooks. Field and laboratory-based teaching courses are lacking both in the syllabus and text books as the geology is field based applied science. Chapters related to geo-disasters like earthquake, landslide, and flood are not given priority in the syllabus. The contents like the origin of Nepal Himalaya, most potential geo-disasters of our nation like earthquake, landslide, river flooding, Glacier Lake Outburst Floods (GLOF) and land subsidence, etc. should be included in the course of earth science systematically. The students should make aware on geo-hazards, natural resources, sustainable development, and to get informed on the scope and role of geologists in nation building. Unfortunately, there is no "Earth-Science" subject in grade 11 and 12. It has created a gap in geoscience teaching and learning in school level. It is urgent to revise and modify the syllabus of school level geoscience from the experts of the geology background in both the syllabus as well as textbook preparation. School teachers should be trained to teach geology course.

Keywords: Earth science; School syllabus; Geo-disaster; Nation-building; Nepal

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The articles must be sound in scientific contribution not published or submitted for review elsewhere. The manuscript should be addressed to the Editor-in-Chief of Nepal Geological Society (E-mail: jngs.editorial@gmail.com) and should not exceed 30 pages in length, including all the text, references, annexes, figures and tables. The paper must be properly edited for spelling errors and typos. The acceptance or rejection of a manuscript is based on appraisal of the paper by two or more reviewers designated by the Editorial Board. Critical review determines the suitability of the paper, and its originality, adequacy and conciseness of the presentation. The manuscripts are returned to the authors for revision or final polish. After the manuscripts have been accepted, the editors may ask authors for final changes if any, must be made at this time, because no galley proofs are sent to authors.

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Acknowledgements: should be of less than 100 words.

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