CHAPTER 19

GEOLOGY

Doctoral Theses

01 AlQUAMAR AZAD

Development of Correlations Between Various Rockmass Classification Systems and Evaluation of Various Support types for Rail Tunnel Adits in Parts of Garhwal Himalaya.

Supervisor: Dr. Somendra K Singh

Th 26040

Abstract

Several road and railway tunnels for short and effective routes through steep terrain have been being constructed in Uttarakhand Himalayas. In Garhwal Himalayas a railway track connecting Rishikesh and Karnaprayag is being built, in an area which is prone to landslides. There are many blind curves and steep gradients in this area which is also earthquake-prone. The area's complex geological setting and tectonic framework cause frequent disruptions of traffic. This study documents the correlation of rockmass classification, geotechnical, geological, and numerical modelling for the three adits of the RVNL rail project. Rockmass classifications are integral to tunnels and other underground structures', engineering design and excavation procedures. These have also been directly correlated to the ground reaction and support requirements. Several classifications are used the world over and some of these are largely cited. The inter-correlatability of such classifications is of prime importance as different classifications have different end uses. A few gaps in rock mass addressed by such classifications still exist. This study aims to bridge the gap in the engineering classification of the metamorphic rocks of the Himalayan region. Data for various classification systems were collected at 34 locations along a 618-meter-long railway tunnel's adit-6A. New correlations were developed between different rockmass classifications and a comparison was made between the new and existing correlations between such classifications. The majority of the relationships presented in this study, i.e., Rock Mass Rating (RMR), Q-system (Q), Rock Mass Number (Qn), Rock Condition Rating (RCR), Rock Mass Index (RMi), Rock Structure Rating (RSR) and Geological Strength Index (GSI), are first-time reports. The analysis suggested that some of these correlations such as RMR-Q, RMR-RMi, RMi-Q and RSR-Q, are comparable to one or more of the previously developed relations. In contrast, others, such as RSR-RMR, RCR-Qn and GSI-RMR do not present strong correlations.

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02 DEVI (Kshetrimayum Lakshmirani)

Depositional Modelling of the Laisong Formation (Barail Group), Indo Myanmar Ranges, Western Manipur, India, Using Sedimentological and Ichnological Clues.

Supervisors: Dr. Pramod Kumar and Rajkumar Hemanta Singh

Th 26042

Abstract

Among the delta end-members, tide-dominated deltas are characterized by complex marginal marine facies assemblage that is difficult to document and characterize from rock record. Tide dominated or influenced marine product generates wide range of depositional facies that are combinedly defined as "tidal depositional systems". Tides are strong enough to generate currents that can rework, transport and deposit sediments. Tides impart significant tidal ranges that are strong enough to impact the environment or to drive local marine circulation. Disproportionate interplay of tide, wave and other associated hydrodynamic processes displays challenge in decoding tidal signals imprinted in ancient deposits, as sediments tends to record the youngest superimposed process. The spatial variation in riverine, tidal and storm-driven current systems result in development of complex facies assemblages that poses a great challenge in documentation and characterization of tidal deltas in ancient record. Modern tide-dominated deltas associated with some of the world's largest fluvial depositional systems *viz.* Colorado, Fly, Ganga-Brahmaputra, Indus, Ayeyarwady, and tide-influenced deltas *viz.* Mekong, Mahakam, Changjiang, etc. are well documented and detailed account of their depositional processes are available. This study was conducted in the Laisong Formation, discontinuously exposed in form of cliffs, streams and road cut sections e.g. Imphal-Jiribam Highway, Thongjaorok River, Old Cachhar road cut, Leimatak stream and road cut and Gelmon quarry section in Churachandpur district in the western hill ranges of the Manipur, belongs to southern part of the Naga hill segment of Indo-Myanmar Ranges (IMR). All the studied sections fall to the west of Mao-Churachandpur Thrust (MCT). In western Manipur, India a ~765m thick dominantly fine-grained succession of the Late Eocene-Early Oligocene Laisong Formation, constituted of siltstone-silty shale heterolithic units at its lower part and thickly bedded sandstones in the upper part, allowed documentation of subaqueous part of a tidal delta. From process-based facies and facies succession analysis, five different sub-aqueous environments of delta were delineated which include prodelta (FA-5), terminal distributary channel (FA-4), distal delta front (FA-3), proximal delta front sheet (FA-2) and proximal delta front lobe (FA-1) in order of stratigraphic superposition. The fluctuating progradation in the deltaic succession of the Laisong Formation is inferred from the alternate occurrence of the distal delta front (FA-3) and the proximal delta front sheet (FA-2), whereas, typical coarsening upward cycles of the proximal delta front lobe (FA-1) is a tell-tale evidence of the delta front progradation and lobe switching. The abundant incidence of features including lenticular, wavy bedding, starved ripple trains, syn-sedimentary deformation, reactivation and erosional surfaces, double mud drapes, tangential bottom set contact, rip-up mud clasts bear clear evidence in favour of tidal modulations. A prominent thickening- and coarsening-up progradational facies stacking motif of the Late Eocene-Early Oligocene Laisong Formation bears unequivocal evidence of tide-dominated deltaic setting. From the occurrence of double mud drapes in the foresets of the cross-stratification, a sub-tidal environmental setting is deduced for the Laisong Formation. In a complex tectonic backdrop of NE India, the deposition of the Laisong tide-dominated delta took place along the elongated embayed ocean basin within the embrace of Indian Plate

(towards west) and Burmese micro-Plates (towards east). Inferred narrow, elongated basin geometry possibly allowed accentuation of tidal energy with overarching effect on wave energy. This is possibly the reason behind signatures of the tidal modulations even within the prodelta part of the Laisong delta, which otherwise is uncommon. Presumably the wave reworking was abstained due to embayed shoreline character.

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03 MEKRISHU (Weyepe N.)

Analysis of Landslide susceptibility in parts of phek and Kohima Districts, Nagaland, India: an integrated geotechnical, statistical and GIS-Based Approach.

Supervisor: Dr. Somendra K Singh

Th 26043

Abstract

Landslides are inevitable and quite common natural phenomena in tectonically active mountain chain where they annually recur during monsoonal events. The study area lies in the tectonically unstable Inner Fold Belt of Indo-Myanmar Range (IMR) and is lithologically characterised by weak Disang and Barail Groups of rocks. Asian Highway-1 and National Highway-29 pass through the study area where landsliding occur regularly over the years during the monsoon. The scientific study of landslide susceptibility assumes importance in the backdrop of the nature of its vulnerability, and economic implication for the states of Nagaland and Manipur, and to propose a remedial measure to mitigate the hazards. Two major landslides i.e. Lalmati and Phesema are selected for case study to understand in detail the dynamics of the landslide susceptibility operating in the study area. Towards this, analytical assessment of the geomorphic processes and geological attributes is undertaken to find a quantitative linkage with the landslide. Based on the field investigations and Remote Sensing (RS) study, we suggest that the major causative factors of landslide are: the fragile nature of the lithology, thick colluvial overburden deposits, toe erosion and anthropogenic activities while the main triggering factor is the torrential monsoon rain. Landslides occur when bedrocks and overlying colluviums become saturated with water after the torrential rain. The development of sinking zone in some areas as a result of gravity faults in the hanging-wall of the Disang Thrust and Churachandpur-Mao Thrust that lies in hinterland have made this section of the study vulnerable to landslides. Toppling failure is found in some pockets while planar and wedge failures are commonly observed phenomena in the whole study area. This can be attributed to the influence of highly jointed rock mass and the inclined nature of orientation of the bedding plane with its dip direction facing towards the general slope and the road. Landslide susceptibility mapping is prepared by the method of analytical hierarchy process (AHP). It is a matrix pair-wise comparison method with consistencies in the decision process which involves assignment of weightage to each relevant causative factor of landslides and their corresponding classes based on field's knowledge and experiences. The prerequisite data for the preparation of landslide susceptibility map are topography, slope, geology and structure, land use land cover and hydrology. Themap is eventually validated through physical and statistical methods. The results reveal that the predicted susceptibility model are found to be in concur

with the past landslide occurrences, and, hence, the map is reliable for future land-use planning. Finally, an attempt to estimate the threshold value of rainfall that initiates landsliding in Kohima town and its vicinity was purely motivated by the deficiency of earlier research works in this subject despite of the well-known

Contents

1. Introduction 2. Geology and Structure of the study Area and its Relation to Landslide susceptibility 3. Case Studies on the causative and triggering factors of Multiple Landslides in Lalmati and phesema areas, Nagaland and development of a Sinking Zone 4. Landslide Susceptibility Mapping in the Jostama-Pfutsero Section along the Asian Highwa-1 and National Highway-29 under Kohima and Phek districts, Nagaland, India 5. Study of Characteristics of Rainfall Spell in relation to landslide Events and an Attempt to Estimte the threshold value of Rainfall that triggers landslides in Kohima town, Nagaland and its Vicinity 6. Conclusion and Scope of future work.

04 NAIK (Aditya)
Metamorphic Evolution of North Delhi Fold Belt and its Relationship With Metallogenesis.
Supervisor: Prof. Naresh Chandra Pant
Th 26036

Abstract

Aravalli-Delhi Mobile Belt (ADMB), extending in the NNE-SSW direction for 700 km, is one of the most prominent physiographic features in the north-western Indian Peninsular Shield. Three major components comprise the ADMB where supracrustal belts, i.e., older Aravalli and younger Delhi Fold Belts, unconformably overlain on the Banded Gneissic Complex basement. The younger Delhi Fold Belt is divided into northern and southern parts by an NW-SE trending fault near Ajmer. North Delhi Fold Belt (NDFB), the subject of this study, comprises metamorphosed volcano-sedimentary exposed in an NNE-SSW trending series of synclines and anticlines. It has been traditionally subdivided into three sub-basins, Khetri, Alwar and Lalsot-Bayana, from west to east. The easternmost sub-basin, i.e., Lalsot-Bayana, has been reported to be nearly unmetamorphosed, while medium-grade metapelites, calc silicates, and metavolcanics constitute the rocks of Alwar and Khetri sub-basins of the North Delhi Fold Belt (NDFB) in southern Haryana and adjacent western Rajasthan. Relatively high-grade copper (1-1.5 wt.% Cu) deposit occurs at Khetri Copper Belt (KCB) of Khetri sub-basin while lower grade (~0.4 wt.% Cu) at Golwa-Gangutana (GG) of Alwar sub-basin. In KCB, garnet chlorite schist and amphibole schists are the primary host lithologies for copper mineralization, while in GG, calcareous quartz biotite schist, considered a metamorphosed volcanic tuff, is the primary host rock. The role of mineralizing fluid in both the sub-basins is uncertain. Present works attempts to decipher and compare the metamorphic evolution of the Khetri and Alwar sub-basins as well as understand its Spatio-temporal relationship with metallogenesis and constrain the nature and if possible, source of mineralizing fluid. Lalsot-Bayana sub-basin was not considered for this study as it is effectively unmetamorphosed.

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1. Introduction 2. Geological Setting 3. Petrography and Mineral Chemistry 4. Fluid Inclusion Studies 5.Geochronology 6. Pseudosection modelling of metapelites and P-T-t Path Reconstruction 7. Disscussion and conclusions. References and Appendices.

05 PIUTHAIMEI (Gonmei Zenus)

Insight into the Landscape development of the Himalayas and the Neotectonic Influences on the Anthropocene Ghaggar-Saraswati Drishadvati River Basin.

Supervisor: Prof. Shashank Shekhar

Th 26044

Abstract

The thesis gives an insight into the landscape development of the Himalayas and the neotectonic influences on the Anthropocene Ghaggar-Saraswati-Drishadvati River basin. Firstly, it aims to update the litho-stratigraphic-tectonic correlation of the Himalayas and identify geological variations along its strike, which in this case was not attempted by earlier workers. Secondly, updation of the tectonic map of India, by tectono-geomorphic evaluation of transverse tectonics and active faults in India and surrounding regions was attempted. It was accomplished on a GIS platform using, secondary data; satellite imageries; seismic data; geomorphic indicators, and landscape. Thirdly, to give an insight into the landscaping processes of the Himalayas, as inferred from the correlation of structural shortening and un-roofing, with special emphasis on the Eastern Himalayas of India. From the projected geological cross-sections, it emerged that the easternmost Arunachal Himalaya experienced a remarkable amount of arc-normal shortening and maximum un-roofing. Thereby inducing an active erosional process and complex tectonic set-up in the region. Finally, the research addresses, the neotectonic influences on the Anthropocene Ghaggar-Saraswati-Drishadvati River basin. The uplift of the Main Frontal Thrust (MFT) and Out-of-sequence Thrusts (OST) in the hinterland, Siwaliks, and further up in the Himalayas, forced the alignment of rivers parallel to the major thrusts. The younger folds and faults controlled the processes of river piracy or shifting of the NW Indian rivers. The river network adjustment, in tune with the landscape; geogenic processes, and anthropogenic activities, indicates that the evolution and collapse of the Indus civilization cannot be assigned alone to the climatic changes. Rather, neotectonics activity-induced changes in the regional land and waterscape also played an important role. Besides, the anthropogenic forcing like canal construction, altered the river flow and contribution of surface runoff to the rivers from their natural catchments; thereby converting perennial rivers into seasonal Nalas (streams)

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06 PREM KUMAR

Deciphering Variation in River Discharge, Suspended Sediment concentration Precipitation Pattern and Controls on the Extreme Events of the Western Himalayas.

Supervisors: Prof. Shashank Shekhar and C.S. Dubey

Th 26037

Abstract

The study showcases process based research giving insight in to the variation in River discharge, suspended sediment concentration (SSC), precipitation pattern,

snow melt, runoff, river discharge and sediment flux and controls on the extreme events of the western Himalayas. The data was analyzed to understand the interlinkage between the variation in these variables and hydrological processes of the study area. The Tectono-climatic controls on the orographic precipitation and its relation to the extreme events was also researched. The thesis establishes an increasing yearly trend in the temperature of the Sutlej basin. Where during late winter to the onset of monsoon, the River discharge is mainly contributed by snow melt, while during the rest of the year it is dominated by glacial melt and rainfall. Further, only top 1% of summer extreme event sediment flux contributes 45% of the suspended sediment load. The SSC of the Sutlej River increases exponentially in response to the increase in temperature. Hydro-meteorological data of the Chenab basin showed a rising temperature trend, and good longitudinal connectivity of the River, with dominance of the erosional processes in the upstream and depositional activity in the downstream. The research establishes decline in the Chenab discharge through decades, albeit, an exponential positive correlation of discharge with the temperature has been observed. Over time snow melt is significantly contributing to the runoff, with shift in peak discharge of Chenab River from middle to year end. Further, the extreme events of the Western Himalaya, are localized to high precipitation areas with elevation in the range of 2000-3000 m.a.s.l. around the MCT zone; having slope in the range of 20-40°, which has been classified earlier as the landslide-prone area. The study showcases an integrated approach for climate change- River science study together with the extreme events linked to the natural hazards.

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07 RASIKH BARKAT

Architecture of Neoproterozonic Continental to Shallow-Marine Sedimentation From the Siliciclastic-Carbonate Succession of the Kurnool Group, India.

Supervisor: Dr. Partha Pratim Chakraborty

Th 26041

Abstract

The Archean-early Paleoproterozoic Indian Peninsula hosts a number of Proterozoic sedimentary basins (traditionally known as the 'Purana' basins) those range in age from late Paleoproterozoic to late Neoproterozoic-Cambrian transition and offer an unique opportunity to understand many unique and irreversible changes in the Earth's lithosphere, atmosphere, hydrosphere and biosphere. Availability of state-of-the-art geochronology facility allowed dating of these basins in last two decades and established a dominantly late-Paleoproterozoic to Mesoproterozoic time frame for most of these basins, barring only a few. The Kurnool and Marwar basin successions are amongst the few that represents the Neoproterozoic time frame. Since the Neoproterozoic represents the most volatile time period in the Earth history in terms of Supercontinent amalgamation and fragmentation, recurrent glaciations, advent and exuberance of multicellular life and large-scale oxygenation (Neoproterozoic Oxygenation Event; NOE) of atmosphere and hydrosphere; the Neoproterozoic basin successions have become

the attraction of sedimentologists in recent times. In this backdrop, the present study attempted a multi-proxy study in the Kurnool Group of rocks, represented by a ~ 500 m thick mixed siliciclastic-carbonate succession. Two arenaceous (Banganapalle sandstone and Panium sandstone), one argillaceous (Owk shale) and one carbonate (Narji limestone) Formations in the basin succession allowed i) documentation of nuances in continental and shallow marine sedimentation motif in the Neoproterozoic clastic and carbonate shoreline, ii) track sediment provenance for the basin including its temporal variation, if any, iii) understand spatio-temporal variation in basin sedimentation motif in response to relative sea level variation, and iv) track signature for presence of any global-scale event (glaciations!), if present, from stable carbon isotope signature of carbonate succession.

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08 SALIM AKHTAR

Melt Source Characterisation of Cumulate Gabbros and Basalts of South Andaman Island Ophiolite Suite of India.

Supervisor: Dr. Ashima Saikia

Th 26038

Abstract

Ophiolites are remnants of the oceanic crust which got incorporated onto the continental margin either due to continent-continent collision or arc-continent collisions, ridge-trench interactions, and/or subduction accretion events. The Andaman Ophiolite of south-eastern India is located on the outer arc of the Andaman-Java subduction zone. It is represented by thrust slices formed in the Mesozoic Neo-Tethyan Ocean. Lithologically, it consists of dismembered mafic (gabbro, basalt, basaltic andesite) and ultramafic (dunite, harzburgite, lherzolite etc.) rocks and associated oceanic pelagic sediments. The present work focuses on the the mafic volcanic rocks (pillow and massive basaltic rocks) and mafic cumulate rocks (gabbro). In the last few decades, several authors have scientifically contributed on the origin of the Andaman ophiolite, however, fundamental geochemical findings are still required to bridge the petrochemical understanding of this ophiolite suite in the south-eastern margin of India plate. My research work is based on the field sample collection, outcrop identification, petrography, mineral chemistry and geochemical modelling of the south Andaman ophiolite. Field surveys were carried out in and around south Andaman Island and sampling of mafic volcanics (basalt) and mafic cumulates (gabbro) were done in large number to establish their melt evolution characteristics, partial melting of source and geodynamic evolution. Field occurrences of basalts are of two types massive and pillow type. Basalts consists of plagioclase, clinopyroxene, Fe-Ti oxide and Cr-spinel. Based on fractional crystallization modelling using PELE (modified version of MELTS software) at 2 Kb to 4 Kb (FMQ-1 to FMQ+1 respectively) the crystallization sequence determined as Plagioclase ± Cr-Spinel → clinopyroxene + plagioclase ± Fe-Ti oxide. The nature of magma is subalkaline (tholeiitic to transitional) in nature. Temperature (T) and pressures (P) of clinopyroxene crystallisation in massive basalts from South Andaman Island Ophiolite have been estimated using Putirka (2008b) clinopyroxene-only thermometer (Eq. 32d, R2 0.36, SEE ± 87°C for hydrous) and barometer (Eq. 32b, R2 0.91, SEE ± 2.6 kbar). The results of the calculation shows that the clinopyroxene phenocryst have experienced low crystallization pressures of 3 - 8 kbar, corresponding to a depth (d) range of 15 - 29 km, using the expression d (km) = 3.02 × P (kbar) + 5

(Scarrow and Cox, 1995). The estimated average temperature of clinopyroxene crystallisation is 1201 °C with a maximum-minimum range of 1223-1168 °C.

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1. Introduction and Scope of the Thesis 2. Geological Background 3. Petrographic and mineral chemical attributes 4. Geochemistry 5. Petrogenetic Pathway of Basalts and Gabbros 6. Conclusions. Publication.

09 SHAKIR ALI

Process Based Insight into the Groundwater Contamination and Fluoride Pollution in Parts of Delhi.

Supervisor: Prof Shashank Shekhar

Th 26039

Abstract

Fluoride (F^-) in the groundwater of India is a serious problem. A systematic review, meta-analysis, risk assessment and statistical correlations of F^- concentration with other parameters, elucidated their mobilization pathways into the groundwater system. The non-carcinogenic human health risk assessment due to the consumption of F^- enriched groundwater in Delhi revealed that the children are at a higher risk and the problem is mainly restricted to the Older Alluvial Plains (OAP) of Delhi An integrated research involving major ions chemistry; hydrochemical modelling; sediment geochemistry; together with stable isotopes and radiocarbon dating was accomplished. It has emerged out that the F^- pollution in groundwater of the OAP is mainly restricted to the $SO4\ 2^-$ - Cl^- type facies. The bivariate plot between $HCO3^-$/Na+ vs Ca2+/Na+ and Mg2+/Na+ vs Ca2+/Na+ indicates silicate weathering to be responsible for the elevated F^- in majority of the groundwater samples. In addition, the bivariate plot between corrected [(Ca2++ Mg2+) - ($HCO3^-$+ SO4 2−)] and corrected [Na+ - Cl−] reveal the dominance of cations exchange processes. Besides, the geochemical modelling revealed amenability of F^- bearing minerals to weathering, thereby increasing the possibility of enrichment of F^- concentration in the groundwater. Weathering of the silicates is source of most of the major ions, except $SO4\ 2^-$, which has been attributed to the anthropogenic sources.

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1. Introduction 2. Geology and Hydrogeology 3. Materials and Methods 4. A Review of the global and local fluoride contamination, Meta analysis and the risk assessment 5. Non-Carcinogenic health risk assessment of fluoride in the groundwater of Delhi, India 6. Major ions Chemistry and Fluoride pollution in groundwater of the older alluvial Plains of Delhi, India. 7. Isotopic Signature based Understanding of the hydro-chemical Processes in the order Alluvial Plains(OAP) of Delhi, India 8.River Bank Filtration along Yamuna flood plain: An augmenting drinking water needs of Delhi. Conclusions, References and Annexure.