

CHAPTER 21

GEOLOGY

Doctoral Theses

01. ABDUL HAMEED

Paleopedogenesis in Overbank Sediments of the Lower and Middle Siwalik Sub Groups, Kangra Sub-Basin, NW Himalaya: A Response to Climatic Changes And Tectonics During Mid-Late Miocene.

Supervisors: Prof. Pankaj Srivastava and Jayant K. Tripathi

Th 26679

Abstract

This study presents high-resolution data on paleosols of the Siwalik Group from the Himalayan Foreland Basin (HFB) deposited during the Mid-Late Miocene. This helped to understand the complex interplay between chemical weathering, paleopedogenesis, climatic changes, and tectonic activity from 12.0 Ma to 5.4 Ma. During this study, a 2.25 km succession along the Katilu Khad, Kangra sub-basin was studied for 19 paleosol profiles in the Lower Siwalik and 61 paleosol profiles in the Middle Siwalik Sub-Groups for macro-, microscopic, clay mineralogical, bulk geochemistry, and stable isotope geochemistry. The field characteristics of the paleosols in overbank sediments of the HFB helped to identify and differentiate different types of paleosols. Micromorphology confirmed the dominance of well-developed paleosols in the Lower Siwalik in contrast to moderately-weakly developed paleosols in the Middle Siwalik. Pedofacies analysis showed the dominance of Type-A pedofacies in Lower Siwalik, but the dominance of Type-B pedofacies in Middle Siwalik. Clay mineralogy confirmed varying proportions of different clay minerals related to source rock and weathering conditions. Bulk geochemistry showed varying extent of chemical weathering in the paleosols. Stable isotope data of the pedogenic carbonate nodules values are consistent with C3 vegetation and an increase in rainfall after 8.0 Ma. These high-resolution paleopedological details of 2.25 km succession helped to reconstruct weathering conditions, paleopedogenic processes, climate, and tectonic events. It is summarized as (1) 12.1 Ma to 11.0 Ma warm-humid conditions and stable landscapes, (2) 11.0 Ma to 10.6 Ma dry conditions and major tectonic activity, (3) 10.6 Ma to 8.7 Ma subhumid to semiarid conditions and stable landscapes, (4) 8.7 Ma to 8.3 Ma increased humidity and increased exhumation rates, (5) 8.3 Ma to 6.0 Ma subhumid to humid conditions and stable landscapes, and (6) 6.0 Ma to 5.4 Ma subhumid phase and reactivation of MCT.

Contents

1. Introduction 2. Geology, Materials and Methods 3. Result and Analysis 4. Discussion 5. Conclusion. Reference

02. BAILWAL (Rahul)
Post-Rift Depositional History of Paleoproterozoic Bayana Basin, North Delhi Fold Belt, India.
 Supervisor: Prof. Partha Pratim chakraborty
Th 26680

Abstract

The present study deals with post-rift depositional history from the Paleoproterozoic riftogenic Bayana sub-basin, North Delhi Fold Belt. Five stratigraphic Formations belonging to the Alwar and Ajabgarh Groups namely Badalgarh, Bayana and Damdama Formations of the Alwar Group and Kushalgarh and Wier Formations of the Ajabgarh Group, in order of superposition, are studied herein to decode the nuances of Paleoproterozoic continental and shallow marine sedimentation. Whereas the Badalgarh Formation in the basal part and Kushalgarh -Wier Formations in the upper most part of studied stratigraphic interval record shallow marine sedimentation ranging from shelf to shoreface-foreshore, maximum up to beach. In contrast, the Bayana and Damdama Formations of the Alwar Group record continental sedimentation belonging to alluvial fan and braided fluvial setting. Irrespective of the stratigraphic level (i.e Badalgarh or Kushalgarh-Wier Formation), the Bayana shallow marine system always remained wave-dominated and storm infested; tidal influence observed only at patches in course of Badalgarh sedimentation. A near east-west paleo-shoreline orientation is inferred from the crestal trend of swash ripple present in Badalgarh foreshore-shoreface strata. Products of sediment and fluid gravity flows of varying rheology i.e debris flow, hyperconcentrated flow, turbidites (both high- and low-density), bipartite flow is documented from the fan succession. An exquisite array of microbial mat features related to mat growth, binding and trapping, mat metabolism, mat destruction and mat decay illustrated from Bayana shallow marine sandstones. Raman spectroscopy was carried out to establish biogenicity of mat structures. It is inferred that in absence of grazers and burrowers the Bayana coastline was infested with microbial mats and thereby controlled the siliciclastic sedimentation. An event of transgression in the coastline initiated argillaceous sedimentation of Ajabgarh Group. Occurrence of coarse-grained sandstone with mud chips and chevron cross-stratification immediately above sandy fluvial deposit suggests development of ravinement surface with transgression.

Contents

1. Introduction 2. Methology 3. Facies Association and Paleo-Environmental Interpretation Sub- Chapter 3A: Shallow Marine System: Badalgarh Formation 3B: alluvial fan System: Bayana Formation 3C: Gravelly-Sandy Feeder System (Umraind fluvial system): Damdama formation 3D: sandy Feeder system (Kanwar Fluvial System): Damdama Formation 3E: Transitional Zone: Alwar-Ajabgarh Group 3F: Shallow Marine systems: Ajabgarh Group 4. Paleogeographic Shift in Sequence Stratigraphy framework 5. Sediment Geochemistry and Provenance analysis 6. Discussion 7. Conclusion. Annexures, Reference and Publication.

03. NEGI (Priyanka)
Nature and Origin of Anorthosites and Gabbroic Cumulates From the Barabar Hill Religion of Chotanagpur Granitic Gneiss Complex, Eastern India.
 Supervisor: Dr. Ashima Saikia
Th 26678

Abstract

Anorthositic rocks have attracted attention as markers of Archean-Paleoproterozoic plate tectonic regimes and also for their possible role as the primordial crust of our planet. Here we investigate the Barabar Hill Anorthosite Complex from the Chotanagpur Granite Gneiss Complex of Eastern India. In the study area, anorthosite plutons are found along with gabbro-norites. In this contribution, geochemical and geochronological analyses of anorthosites and gabbros are used to constrain the characteristics of the parental magma and the initiation time of Barabar Hill Anorthosite magmatism. Plagioclase (>90 vol %, An₆₀₋₉₆) with minor mafic minerals (amphibole, mica) exhibiting adcumulate texture comprises the anorthosite rock, while orthopyroxene (>40 vol %, Wo₃₉₋₄₀ En₄₆₋₅₀ Fe₁₀₋₂₁), plagioclase (40-50 vol %, An₅₀₋₇₀) and clinopyroxene (>20 vol %, En₃₆₋₄₃ Fs₁₂₋₁₅ Wo₄₃₋₄₇) make up the associated gabbro-norite with mesocumulate texture. Anorthosite show enrichment of LILE with respect to the HFSE and display enrichment in LREE ((La/Yb) N = 2.78-15.29) with positive Eu anomaly (Eu/Eu* = 1.29-3.45) and variable MREE. A flat to depleted trend for HREE ((Sm/Yb) N = 1.02-2.95) is observed for anorthosites. Associated gabbro-norites show enrichment of LREE ((La/Yb) N=1.99-4.93), depleted HREE ((Sm/Yb) N = 0.88-3.24) with negative to positive Eu anomaly (Eu/Eu* = 0.78-2.95). LA-ICPMS U-Pb analyses of magmatic zircon grains yield weighted mean ²⁰⁷Pb/²⁰⁶Pb age 1762.0 ± 3.8 Ma. for anorthosites. Findings show that the parental melt for anorthosite was generated at deeper levels, which then ascended adiabatically to shallower depths. At last, it caused the melt to become plagioclase saturated, resulting in crystallisation and gravity flotation of plagioclase cumulates. Plagioclase accumulations become less dense than the crust above and rise as crystal mush plutons which coalesced to become the massif type of anorthosites reported from the Barabar Hills Region of Chotanagpur Granite Gneiss Complex, which coincides with the amalgamation of Columbia supercontinent.

Contents

1. Introduction 2. Field description regional geology and field observations of the study area 3. Petrography 4. Mineral Chemistry 5. Bulk Rock Chemistry. References.

04. SARKAR (Arkaprabha)
Sediment Dynamics Within the Critical Zone of Pranmati Catchment NW Himalaya.
 Supervisor: Dr. Vimal Singh
Th 27037

Abstract

The Critical Zone of the Earth is one of the most crucial components of the planet in terms of sustaining life. This thin outer skin of the planet, extending from the top of the vegetation canopy to the bottom of the circulating groundwater, is an interface of complex interactions between the lithosphere, hydrosphere, atmosphere and biosphere. However, most of the process pathways have been altered and disrupted by anthropogenic activities in the present day, thus, misbalancing the system. In order to understand and mitigate the problem, it is important to understand the natural process pathways at the grass-root level. Critical Zone research is based on the idea of collaborative research between experts from various scientific disciplines. The Critical Zone has two major components – soil and water. Soil hosts the interactions between the various spheres while the water travels through all the spheres, binding the system together. These processes operating at various

timescales gets recorded within the soil and the water of the Critical Zone. Therefore, one approach of studying the Critical Zone is to interpret these records to understand the process pathways of the system. In this thesis, I have quantified the sediment routing processes within a small catchment located in a tectonically active terrain. I have chosen Pranmati River basin, a 93 km² catchment in the central Uttarakhand (north-west Himalayas) as my study area. I have calculated the *rates of soil production* from the underlying bedrock, *the rates of soil erosion*, and *spatially averaged catchment denudation rates* within the catchment using ¹⁰Be (terrestrial and meteoric) nuclide. I have analysed the relation of these rates with various controlling factors such as topography, land cover, etc. and derived empirical relationships between the parameters. I have identified potential zones of sediment supply and storage within the hillslope system. I have also investigated the role of stochastic events in sediment mobilisation. My study shows that the average soil production on the divergent surfaces within the catchment is 12 m Ma⁻¹. The rates of soil erosion are strongly controlled by topography and the geomorphic transport laws work differently in the hilltop region and mid slope region. The soil gets transported and accumulates in convergent zones at a mean rate of 21 m Ma⁻¹. The smaller catchments in the Himalayas are denuding at slow rates (10 m Ma⁻¹), storing most of the sediments within the hillslope. Denudation in these catchments are controlled more by local factors than regional tectonics unlike larger catchments like Ganga, Yamuna, etc. The sediment stored within the system is evacuated by stochastic high magnitude events (e.g., flash floods). Based on my findings, I have classified the hillslope profile into four sections based on morphology, processes operating in the region, sediment connectivity, and storage characteristics. I have given a cyclic model of evolution of sediment storage zone on a hillslope involving growth by positive feedback and resetting by extreme events. Based on the study, I have also formulated a quantified sediment routing model for the Pranmati catchment. This study demonstrates that the factors controlling the sediment cycle in lower order stream catchments are different than the higher order stream catchments.

Contents

1. Introduction 2. Study Area 3. Basin Characterisation 4. Estimation of Soil Production rates 5. Estimation of Soil Erosion rates 6. Estimation of Spatially averaged denudation rates of catchments 7. Sediment Connectivity and Storage 8. Role of Stochastic High Magnitude Events: Case Study of a Flash Flood 9. Discussion and Conclusion. References, Appendix.

05. SHARMA (Aditi)
Depositional Model, Sedimentation Age and Provenance of the Mahakoshal Group, Central India: Clues from the Sleemanabad and Parsoi Formations.
 Supervisor: Dr. Partha Pratim Chakraborty
Th 26675

Abstract

As an integral part of the Central Indian Tectonic Zone (CITZ), the Mahakoshal Group of rocks register the early history for the crustal-scale shear zone as well as the docking history between the northern Indian craton (NIC) and southern Indian craton (SIC). Described as 'Supracrustals', 'Belt', and 'Supracrustal Belt', studies in the Mahakoshals traditionally remained confined to a broad description of lithology, stratigraphy, pattern of deformation and degree of metamorphism. Attempts were also made to constrain the geological age of this poly-deformed, metamorphosed succession by geochronological dating of basement rock and intrusions within this

rock succession. The unwinding of the depositional history of the basin prior to its tectonic deformation and metamorphism was long awaited in Indian geological literature. Crossing this boundary, the present work attempts i) unwinding of sedimentation pattern in the Sleemanabad and Parsoi Formations of the Mahakoshal Group, ii) determination of depositional age from interbedded pyroclastics, iii) tracking of detrital provenance, iv) understanding basin hydrosphere redox condition from Banded Iron Formation (BIF) present within the basin succession, and iv) to provide the clue for the tectonic setting of the basin. Process-based sedimentological analysis in the Sleemanabad Formation, based on three north-south transects spanning over 250 km in the east-west transect of the basin, documented a large-scale variation in the depositional motif; whereas the Singrauli-Chitrangi section in the east and Sidhi south section in the middle of the basin allowed documentation of early Sleemanabad sedimentation history, the Katni- Sleemanabad section exposes the uppermost part of the Formation. Starting with oceanic volcanics in the Singrauli-Chitrangi section the Sleemanabad Formation registers occurrences of carbonates of shallow coastal lagoons, meta-arenites of shallow marine shoreface, phyllite (shale)- meta-siltstone heterolithics of shelf origin ranging from above to below storm wave base and BIF. The depositional realm is different in the Sidhi south section, where overlying the gneissic basement the Sleemanabad succession initiates with a fluvial succession that in downdip direction gives way to shallow-marine shoreface deposit and further to phyllite (shale)- metaiv siltstone heterolithics of shelf origin, often ferruginous in character. In contrast, the Katni-Sleemanabad section, which exposes the upper part of the Formation, illustrates the development of a carbonate platform that opened towards the east. Stromatolites, thrombolites, algal laminites and intraclastic conglomerates of desiccation origin constitute the carbonate succession and together record a progradational succession. A riftogenic origin is proposed for the Sleemanabad Formation that initiated and opened in an oceanic condition in the east and with time widened to the west. The Sidhi section is identified as a possible horst in the rift system. The incursion of the storm in the Sleemanabad coastline forced shallowing of the redox boundary in the basin and provoked precipitation of BIF from the ocean water column. Documentation of pillowed volcanics of intraoceanic origin and BIF in this Formation in the eastern part of the basin (Singrauli-Chitrangi section) allowed the inference that the Mahakoshal rift led to an open ocean basin in its east. From its open ocean character, it is argued that the Mahakoshal basin initiated and evolved as a back-arc rift, instead of an intracontinental rift. In contrast, the Parsoi Formation records more basin-scale depositional pattern. From the study of a number of sections spanning over the entire east-west span of the basin, a half-graben depositional model is proposed. Whereas a delta system developed in the footwall part of the half-graben in the west/northwest, shoreface sediments represent the hanging wall in the southeast of the basin. Despite intense deformation, a fortuitous section at the Parma nala allowed documentation of different anatomical parts of the delta including the fluvial feeder system and the mass flow products in the delta front. In fact, mass flows of the delta with varying rheology including chaotic debris flow, reverse graded grain flow, and normal graded high-and low-density turbidity current are documented in different sections with proximaldistal relation. Mass flow conglomerates are also documented in the westernmost Katni-Sleemanabad section; mass flow conglomerates present at the Parma nala section though interpreted as near contemporaneous based on their relative stratigraphic position, are also identified as non-cogenetic based on detrital zircon geochronology data. Eastward, the mass flow beds get thinner, isolated and finer in grain size. Mms to Cm thick thin isolated silty mass flows encased within thick phyllite succession at the Singrauli- Chitrangi section may represent the pro-deltaic part with occasional reach out of plumes in course of high energy events at the proximal part of the delta.

In this backdrop, the shoreface succession exposed at the isolated hill section at the south-eastern part of the basin is identified as the product of a low-gradient hanging wall.

Contents

2. Introduction 2. Methodology 3. Facies Associations 4. Geochemistry: Phyllite (Shale), Banded Iron Formation (BIF) and Volcanics 5. U-pb Zircon Geochronology: Clues for Basin age and sediment Provenance 6. Discussion Conclusion, References, Publication.

06. SHARMA (Jeev Jatan)

Metamorphic Evolution of the Pangong Metamorphic Complex (PMC): Insights into Kinetic Controls of Staurolite-Sillimanite Growth.

Supervisors: Dr. Ashima Saikia and Naresh Chandra Pant

Th 26676

Abstract

The Eastern Karakoram Metamorphic Complex is exposed primarily near Pangong Tso in the Ladakh province of India. The area has a complex history starting from subduction of Ladakh Arc under the Shyok Suture followed by the subsequent regional metamorphism by collision of Indian plate with the Eurasian block. We examined garnet sillimanite/fibrolite schists and garnet sillimanite schists along with lower grade metapelitic rocks from the Pangong Metamorphic Complex (PMC) and the Pangong Transpressional Zone (PTZ). Garnet grains (up to ~10mm sized) show complex zoning profiles with sharp breaks and complex inclusion patterns suggesting growth during multiple metamorphic events. To understand the multiple episodes of mineral development and metamorphic evolution, effective bulk participating during the inferred reactions is estimated by removing core of garnet porphyroblasts. Detailed petrographic and geothermobarometric study reveal a common peak amphibolite facies regional metamorphism in the area ~ 630°C and 5.7kbar followed by a younger event ~ 560°C and 4.6 kbar reported from sillimanite bearing metapelites of the area. The younger event can be interpreted as a distinct subduction event following a hiatus from the older event. Another probable explanation could be an anti-clockwise PT evolution path for the area, likely due to the subduction of Ladakh arc under Asian plate causing magmatic heating prior to crustal thickening of the EKMC. The sillimanite- staurolite bearing metapelite in the area were studied to understand the crystallographic controls on reactant breakdown in metamorphic rocks. In the present study, the periodic bond chain theory is used to explain lower reaction rates on the faces parallel to the trace of c-axis (hk0) than the faces across the trace of c-axis (hkl≠0) of staurolite. This apparent crystallographic control on staurolite breakdown further complicate the problem associated with modelling kinetics of metamorphic systems. Hence, a critical appraisal of crystallographic control is needed before modeling natural systems. The widespread occurrence of fibrolite before (lower T) prismatic sillimanite contradicts equilibrium thermodynamics and hence the past literature tries to reconcile this problem using reaction kinetics. This study reasons that fibrolite should be considered as the nucleation phase for prismatic sillimanite and tries to reconcile the fibrolite problem. In view of this understanding it is suggested that the current thermodynamic databases used in metamorphic petrology have an inherent overstep for sillimanite bearing fields and hence should not be used to quantify reaction oversteps for such systems.

Contents

1. Introduction 2. Geological Setting 3. Petrography and Mineral Chemistry 4. Thermodynamic Modelling of the metamorphic rocks 5. Kinetic Modelling of the Metamorphic rocks 6. Discussion and conclusions. References, Appendix.

07. ROY (Debojyoti Basu)
Morphotectonic Evolution of the Sutlej River Exit, NW Himalaya.
 Supervisor: Dr. Vimal Singh
Th 26677

Abstract

Himalayan rivers are lifelines for millions of people living on the Indo-Gangetic Plains since the beginning of the early civilizations. The demise of the Harappan civilization on the Punjab-Haryana plains has been linked to the disappearance/shifting/avulsion of one such river system that existed in the past, i.e. the Saraswati River system. Recent studies (Singhet.al..2017; Singh and Sinha, 2019) have shown the the Sutlej River contributed to this early river system and the shifting of the Sutlej river occurred at around 8 ka. The main cause of the shifting was ascribed to the climate. however, earlier studies fail to trace the upstream link of the Sutlej River. This is a major gap in the understanding of the shifting/avulsion of the Sutlej River. In this study, the Sutlej river exit is investigated for its morph tectonic evolution to understand the cause of its westward shifting. The methodology used in the study included geomorphic analysis, field investigation sedimentary facies analysis, sediment fingerprinting and geochronology. This study records the first evidence of paleo Sutlej River sediments on the surface which correlates to the subsurface sediments that have been dated by previous workers and fills the gap between Roper and the previous northernmost sampling location of Sirhind. Also, this analysis is the first documentation of the role of tectonic control on the avulsion of the Himalayan-fed paleo-sutlej River System which once flowed SSW into the Ghaggar-Hakra valley before its westward deflection, through a multi-staged avulsion process.

Contents

1. Introduction 2. Regional geology and Geomorphology 3. Geomorphic Investigations 4. Sedimentary Characterisation 5. Geochronology 6. Discussion. References.