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Neo-Thinking on Ganges–Brahmaputra Basin Geomorphology

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ISSN 2194-315X ISSN 2194-3168 (electronic)
Springer Geography
ISBN 978-3-319-26442-4 ISBN 978-3-319-26443-1 (eBook)
DOI 10.1007/978-3-319-26443-1

Library of Congress Control Number: 2015955883

Printed on acid-free paper

This Springer imprint is published by SpringerNature
The registered company is Springer International Publishing AG Switzerland

Our oblation
To our teacher
Professor Sandip Kumar Chaudhury

Foreword

Only having a common interest can make more than one person walk together; for the editors of this volume it was love for the physical geography of the Ganga–Brahmaputra Basin where they live. Even being personally unknown to each other, we came closer to organize valuable contributions of different scholars who were also in love with the landscape, ecology, and environment of the region concerned. Being likeminded we felt the problems of scholars who devoted themselves to studying the interaction between landforms and the geomorphic processes that shaped them and the grief of people having no scholarly volume containing all these informations regarding the Ganga–Brahmaputra Basin within only two cover pages. And we tried to materialise it with the existence of this volume.

The initiative came from Aznarul Islam, the only person who is personally known to all three editors and perhaps to every contributing scholar as well. During mid-2014, mail inviting scholarly works on the concerned topic was circulated and the responses gathered up to mid-2015 totalled more than 50. It was a great task to select 11 and we did it out of all of these. We acknowledge spontaneous responses from competent scholars all over India. We are also grateful to Springer for its association with us in giving its most reputed pages for these valuable research works. We hope the volume will be a worthy asset to students and researchers in the field.

July 2015

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Sandipan Ghosh
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Preface

Neo-Thinking on Geomorphology of the Ganges–Brahmaputra Basin is not in a true sense the geomorphology of the Ganges–Brahmaputra Basin but the study of sample forms and processes and events operating in this huge basin through the newer lorgnette.

Chapter 1 deals with the cause–effect relationship between controlling the variable climate and adjustable variables of the alluvial stratigraphy (Charlton 2008) of the Damodar River Basin of West Bengal, a subsystem of the Ganges–Brahmaputra system as tools for inference about the controlling variables of climate of the past geological epoch. Chapter 2 set its specs over typical forms of badlands of Bankura district of West Bengal and the processes responsible for their origin.

Fundamental theoretical bases are the backbone of the study of geomorphology as with all natural sciences. Chapters 3–5 are newer contributions to the theoretical base of fluvial geomorphology. River channel shapes are measured and formulated from different angles. Channel asymmetry is one such measure which was formulated and studied as a self-sufficient topic in fluvial geomorphology by Knighton (1981). But no knowledge in the world within the limited wisdom of mankind is final and so a newer avenue of knowledge opens that is nearer to the ultimate truth. Chapter 3 opens a newer pane to analyse the cross-sectional asymmetry of river channel. Different channel dimensions along with geomatics create hybrid tools in the study of fluvial geomorphic study. Chapter 4 categorizes alluvial channel reaches using these hybrid tools. Epitomizing His creatures is an instinct in human beings and scientists do it for better understanding His forms and processes. Chapter 5 tries to set His unmatchable unique forms into some gathering of geometric shapes which may knock on the newer door of geomorphic, hydraulics, and hydrologic studies.

The most influential external controlling variable interfering with fluvial forms and processes is humans. Through arrogant and callous attitudes towards land use, humans deform and disturb His pure, orderly, esthetic fluvial forms and processes which in turn conflict with human activities. Chapters 6 and 7 are concerned with the interaction between humans and rivers. In Chap. 6 longitudinal disconnection on road–stream crossings endorses significant changes on in-stream fluvial processes, for example, in-stream bar dynamics, thalweg wandering, and channel avulsion. These in turn impose threats to the bridge stability associated with severe bank erosion. Flood makes deltas possible. Therefore deltas and floods are inseparable no matter what. But when humans perceive it as a hazard, it does matter. Why and how a natural phenomenon became a hazard is a matter of serious concern for today's scientists. But Chap. 7 saw the phenomenon and its causes through the newer lorgnette of victims.

Not only surface water but also subsurface water plays an influential role in earth surface forms and processes. That is why Chaps. 8 and 9 are concerned with groundwater. Applying established methods devised by Thornthwaite and Mather, the water balance of a microregion of this basin is studied in Chap. 8. Chapter 9 opens another newer pane raising the question of whether a dug-well water level can be treated as a groundwater level.

Applied geomorphology perhaps reaches the ultimate as it deals with the use of geomorphological knowledge with the goal of human wellbeing. Chapters 10 and 11 shed a newer spectrum of light on the mining of energy and water and its consequences.

Neo-Thinking on Geomorphology of the Ganges–Brahmaputra Basin has a diverse concern within the sphere of geomorphology ranging from insight into the fundamentals of river science, geology, forms and processes, groundwater, and ecology. Therefore the volume is a useful tool for geologists, geographers, hydrologists, landscape-ecologists, environmentalists, engineers, planners, and policy makers as well.

Balai Chandra Das
Sandipan Ghosh
Aznarul Islam
Md Ismail

References

Charlton R (2008) Fundamentals of fluvial geomorphology, Rutledge, New York, pp 4–7
Knighton AD (1981) Asymmetry of river channel cross-sections: Part I. Quantitative indices. Earth Surf Proc Land 6:581–588

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About the Editors

Balai Chandra Das born in 1970, he began teaching geography at Acharya Prafulla Chandra College, New Barrackpore, North 24 Parganas. Thereafter he joined WBES and served Darjeeling Government College and Krishnagar Govt. College of West Bengal gathering 20 years of teaching experience in the schools at the under-graduate and post-graduate levels. After earning his bachelor's degree (1992) and master's degree (1994) in geography from the University of Burdwan he was awarded his PhD degree in geography from the University of Calcutta. Dr. Das has published about 20 research articles in national and international journals, proceedings, and edited volumes. He has reviewed manuscripts for the *International Earth Science Journal*. At present he is passing his hours with students and rivers and lakes.

Sandipan Ghosh is an Applied Geographer with post-graduate and M.Phil. degrees in geography from The University of Burdwan. He has published more than 25 international and national research papers in various renowned geography and geoscience journals. He has authored a book entitled *Flood Hydrology and Risk Assessment: Flood Study in a Dam-Controlled River of India.* He is one of editors of the *Asian Journal of Spatial Science* (published by the Geographical Society, Dibrugarh University). Alongside he has performed as a reviewer of many international geoscience journals of Taylor & Francis, Springer, and the International Water Association (IWM). Mr. Ghosh is a lifetime member of The International Association of Hydrological Sciences (IAHS), Eastern Geographical Society (EGS), and Indian Geographical Foundation (IGF).

His principal research fields are various dimensions of fluvial geomorphology, flood geomorphology, Quaternary geology, and laterite study. Currently he has worked on the gully geomorphology and soil erosion on the lateritic terrain of West Bengal and the Quaternary geology and active tectonics of the Lower Damodar Basin, West Bengal. At present he is an Assistant Professor at the Department of Geography, Chandrapur College, Bardhaman.

Aznarul Islam is an Applied Fluvial Geomorphologist with his M.Sc. degree in geography from Kalyani University, West Bengal and MPhil in geography from the University of Burdwan, West Bengal. He is currently engaged as an Assistant Professor (WBES) in the Department of Geography, Barasat Government College, West Bengal. Previously he was engaged in teaching and research at the Department of Geography, Aliah University, Kolkata. Mr. Islam has already published 22 research papers in different journals, proceedings, and edited volumes of national and international repute. He has presented papers in more than 15 national and international seminars and conferences. In addition he has also delivered several invited lectures and special lectures in different national and regional programmes. He has reviewed manuscripts for the *International Earth Science Journal*. Mr. Islam is a life member of the Indian Geographical Foundation (IGF), Kolkata, and National Association of Geographers, India (NAGI), New Delhi. To date he has successfully supervised seven dissertations on various topics of geomorphology at the Master's level. His principal area of research includes channel shifting and riverbank erosion. Currently he is deeply engaged in the analysis of channel shifting and bank erosion of the River Bhagirathi, West Bengal, and its impact on society and the economy.

Md Ismail is a geographer associated with the Department of Geography, Aliah University and his field of specialization is agricultural geography and population geography. He also taught contemporary issues, statistics, environmental geography, biogeography, and social geography. He did his post-graduate work and received his MPhil from Aligarh Muslim University. He has published one edited book entitled *Life and Living Through Newer Spectrum of Geography* and more than 20 research papers in various international and national journals, as well as seminars and proceedings and has written chapters in edited volumes. Md Ismail has attended over 12 international and national seminars, conferences, and workshops.

Chapter 1
Quaternary Alluvial Stratigraphy and Palaeoclimatic Reconstruction in the Damodar River Basin of West Bengal

Sandipan Ghosh and Aznarul Islam

Abstract The Quaternary (starting from ~2.6 million years ago) climate changes have progressively triggered abrupt changes in the fluvial system and the resultant signatures are captured in the fluvial archives which are used as climate proxies to detect the palaeoclimate. In this chapter, the stratigraphic exposures, sediment characteristics, and dating information have been utilised to reconstruct the palaeoclimate in the alluvial valley of the Damodar River, West Bengal. This study has identified four distinct Quaternary geological units of the lower Damodar River Basin (DRB)—Lalgarh, Sijua, Chuchura, and Hooghly—morphostratigraphic units which belong to the northwestern part of the Bengal Basin. Analysing the architectures of different lithofacies, approximately six to seven climate changes (semi-arid to warm–humid) occurred in the study area from ~14 and 6 kiloannum (ka). Alongside these climate changes (from Late Pleistocene to Late Holocene) were directly linked the variability of the southwest monsoon (SWM) in two forms: (1) the semi-arid climate (i.e. the onset of low-strength SWM, associated with caliches, pond, and backswamp deposits of waning low-energy floods), and (2) the warm–humid climate (i.e., the onset of high-strength SWM, bearing imprints of sandy bedforms, valley fills, slack water deposits (SWD) of extreme floods, and ferruginous nodules).

Keywords Morphostratigraphical unit · Fluvial archives · Climate proxies · Palaeoclimate · Quaternary · Damodar river

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B.C. Das et al. (eds.), *Neo-Thinking on Ganges-Brahmaputra Basin Geomorphology*, Springer Geography, DOI 10.1007/978-3-319-26443-1_1

1.1 Introduction

Climate change refers to a significant shift from the longer term average weather conditions at a place or a region due to natural or anthropogenic causes (Singhvi and Kale 2009). The quest to understand climate change has become more intense in recent times largely on account of anticipated global warming scenarios, which may affect the climate patterns and hence, the biodiversity, food production, and lifestyles of people. But modern scientific research on climate change severally highlights an issue regarding the past climate, that is, palaeoclimate, which validates that our ancient climates were continually changed several times and these are not new phenomena to our planet. To address this issue recourse is taken to reconstruct the past climates of various regions and use the information on the past changes to provide the necessary baseline data of climatic variability. In this case, many researchers select the major river basins of India (as the study unit) to reconstruct the palaeoclimate because these river basins are considered an important repository of Quaternary climate changes (Rajaguru et al. 1993; Kale et al. 2004, 2010; Sridhar 2008; Singhvi and Kale 2009; Sinha and Sarkar 2009). Fluvial systems of drainage basins have been found to be most sensitive elements of the earth's surface and any shift in climate and environmental conditions instigates a rapid response from the fluvial systems (Sridhar 2008; Ghosh and Guchhait 2014). Therefore, it is reasonable to assume that major rivers of West Bengal might have responded to the climate changes of the Pleistocene and Holocene epochs almost in the same way that can be analysed by sedimentology and palaeoclimatology. The Damodar River of India has great potentiality for palaeoclimatic research, because of its existence since the formation of the Bengal Basin (since the Miocene) and it is much older than the Bhagirathi–Hooghly River of West Bengal. The principal aim of this study is to unearth the alluvial history of Quaternary morphostratigraphic units and to correlate Quaternary climate changes with the alterations of fluvial regimes and pedogenesis in the Damodar River floodplain. So to reach that aim, the following major objectives of research are set forth.

(1) Recognizing different morphostratigraphic lithosections from Early Quaternary to Recent
(2) Characterizing the facies of each lithosection from the perspective of palaeogeomorphic origin
(3) Identifying the climate proxies and palaeoclimatic condition since the Early Quaternary

1.2 Study Area

The Damodar River Basin (DRB) is an important peninsular tributary basin of the Bhagirathi–Hooghly River system in West Bengal. Its funnel-shaped basin area is about 23,370 km^2, having latitudinal extension of 22°30′ to 23°40′N and

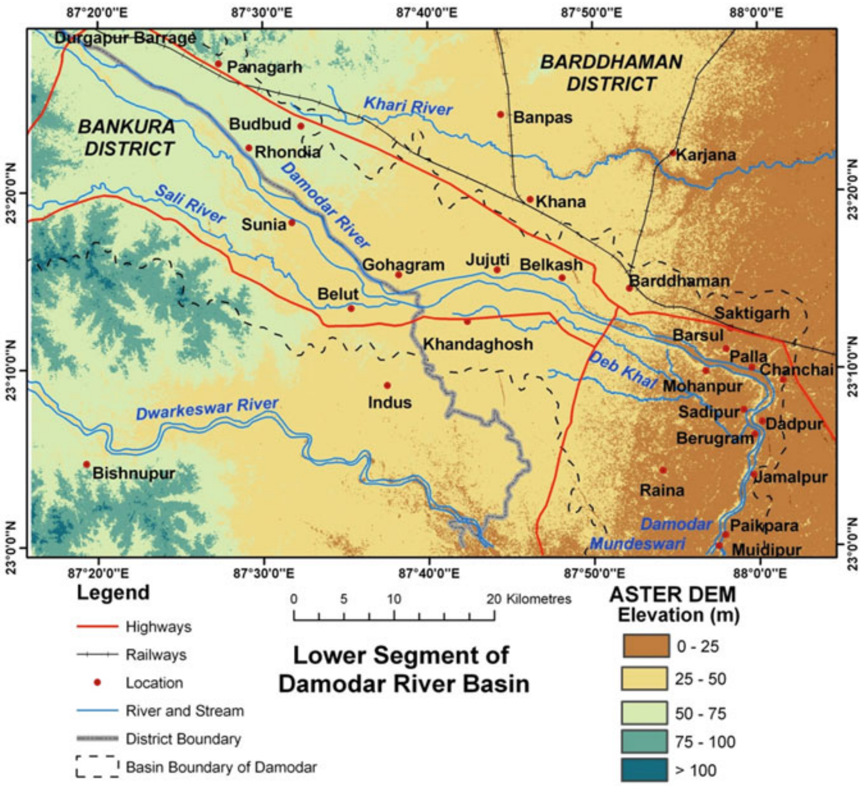

Fig. 1.1 Advanced space borne thermal emission and radiometer (ASTER) elevation map of study area, depicting the west–east slope, river system, and important locations in the lower Damodar River Basin

longitudinal extension of 84°45′ to 88°10′E (covering the states of Jharkhand and West Bengal). For detailed field investigation, the lower course of the Damodar (23°00′ to 23°22′N and 87°28′ to 88°01′E), in between Rhondia and Paikpara, was selected (Fig. 1.1). Topographically, the middle and lower parts of the DRB (specifically in Bardhaman district) can be categorized in five geomorphic units: (1) Ajay–Damodar–Barakar Interfluve (Gondwana part), (2) Kanksa–Ketugram Plain (*Rarh* Plain), (3) Bardhaman Plain, (4) Damodar–Bhagirathi Plain, and (5) Khandoghosh Plain. The lithostratigraphic study has been carried out on the left bank floodplain of the Damodar (from Belkash to Barsul, covering Bardhaman Plain) where ample Quaternary landforms, viz., alluvial terraces, avulsion, palaeochannels, mature point bars, uplifted older terraces, backswamp, levees, and so on are found. A separate laterite lithosection of *Rarh* Plain has been investigated in the region of Durgapur to Panagarh.

Away from the basaltic outcrops in the Rajmahal Hills of Jharkhand (Early Cretaceous), many lava flows have been encountered in a number of deep wells within the western Bengal Basin which acts as the basement of Pliocene–Miocene sedimentation along the middle to lower Damodar River (Alam et al. 2003; Kuehl et al. 2005; Das Gupta and Mukherjee 2006; Bandyopadhyay 2007). The thickness of sediments overlying the Rajmahal basalt in the wells at Bardhaman and Galsi are, respectively, 2515 and 1273 m from the surface (Kumar et al. 2004). The Damodar River is one of the important peninsular rivers which contributed to fill up the western part of the Bengal Basin through alluvial fan to fan-deltaic sedimentation since the Neogene. From that period, Late Palaeogene, the sedimentation of the western shelf of the Bengal Basin was tectonically influenced due to the Chotanagpur Foothill Fault, Pingla Fault, Garhmayna–Khandaghosh Fault, and Damodar Fault (Singh et al. 1998). The growth of the Damodar floodplain is directly influenced by occasional reactivation of these basement faults, climate changes of the last glacial maxima (LGM), and the marine transgression–regression, forming variable morphostratigraphic units as the fan-delta formations. These fluvial archives provide us ample palaeogeographic information on the western shelf of the Bengal Basin since the Early Quaternary.

1.3 Materials and Methods

Over the last four decades, fluvial sedimentology has progressed towards understanding how fluvial systems develop and change over time as a response to tectonism, climate, and sea-level change (Jain and Tandon 2003). A river can exist close to a threshold condition where a small shift in flow or sediment character, possibly induced by climate, can produce a dramatic change in the style of fluvial deposits (Jain and Tandon 2003; Jain et al. 2004; Sinha et al. 2005; Babar et al. 2012; Babar and Snehal 2014). Floodplain stratigraphy (Bridge 2003; Nichols 2009) provides the timeframe that allows us to interpret sedimentary deposits in terms of dynamic evolving environments. The main focus of methodology is concentrated on the identification of physical, chemical, and biological conditions of Quaternary sediments that existed at the time of sedimentation and the postdepositional environment.

The term *facies* is used here to refer to the individual characteristics of each sedimentary unit or lithosection and through recognizing association of facies or lithofacies (Maill 2006, 2014) it is possible to establish the combination of fluvial processes that were dominant. The term *morphostratigraphic unit* is used here to recognize the similar stratigraphic association of unique lithofacies in a particular region with distinct fluvial depositional style, similar morphology of section, associated landforms, and geomorphic evolution. The main approach of this study is concentrated on the interpretation of lithofacies by which the sediments in terms of the physical, chemical, and ecological conditions at the time of deposition (or post-deposition) enable us to reconstruct our palaeoenvironments. Fundamentally the methodology is adopted from the great works of Kale and Rajaguru (1987), Joshi and Kale (1997), Singh et al. (1998), Rajaguru et al. (1994, 2011), Sinha et al.

(2005), Sridhar (2008) and Kale et al. (2010) etc. The stratigraphical studies were carried out at the selected sites of Attagarh (23°14′28″N, 87°58′25″E), Beldanga (23°23′28″N, 87°56′04″E), Birpur (23°17′09″N, 87°50′32″E), Krishnapur (23°15′37″N, 87°51′18″E), Kamnara (23°17′47″N, 87°51′03″E), Vita (23°17′28″N, 87°54′43″E), Nandra (23°14′55″N, 87°54′39″E), Amarun (23°21′37″N, 87°56′21″E), Nari (23°14′12″N, 87°53′48″E), Kandorsona (23°12′46″N, 87°56′18″E), Balamhat (23°13′34″N, 87°50′37″ E), Bam (23°13′15″N and 87°54′29″E), Kala Nabagram (23°10′42″N, 87°59′54″E), Pamra (23°12′37″ N, 87°54′43″E), Sadhanpur (23°14′51″N, 87°53′04″E), and Baikunthapur (23°17′19″N, 87°50′27″E) having 9.0 m subsurface lithologues. Alongside these, the lithosections of the *Rarh* Plain were investigated around the north of Durgapur City and along the Panagarh–Illambazar Road. The reliable database of deep boreholes was collected from the unpublished reports of the Geological Survey of India (GSI; Eastern Region, Kolkata). Near-surface sediment characters of lithofacies were analysed in the selected sections of levee, bank, backswamp, abandoned channel, and point bar. The facies architecture classification was done using the Miall model (1985, 2006, 2014) to identify the fluvial depositional character (Ghosh 2014). Miall's architectural elements of fluvial deposits, viz., Gcm, Gmg, Gm, Gt. Sp, Sm, Fm, and so on, were applied here to annotate the Quaternary lithofacies (Table 1.1). The graphic sedimentary logs (1:100 scale) were prepared following Tucker (1996) formats and the symbols with abbreviations (Nichols 2009) were used to recognize each facies. Additionally the chemical analysis of climate proxies (i.e. caliches and Fe-nodules) was done. Other secondary spatial information was collected from the Survey of India (SOI) topographical sheets of 73 M/15 and M/16 (1:50,000 scale; 1969–1974), district resource map of Bardhaman from GSI (2001), ASTER DEM data (2011) from United States Geological Survey (USGS; Earth Explorer), and Landsat TM image (2006) from USGS and Google Map.

1.4 Results and Discussion

1.4.1 Quaternary Morphostratigraphical Units of Damodar Floodplain

Geologically the floodplain of the study area belongs to the western part of the Bengal Basin and geomorphologically it is a mature fan-delta of the Damodar River sloping towards the east to southeast. The western part of the study area is associated with the typical lateritic *Rarh* Plain (Acharyya and Shah 2007). Understanding the regional stratigraphy, four major Quaternary to Recent morphostratigraphic units were identified and these reflect a different history of evolution related to palaeoclimate, neotectonic activity, and floodplain processes. These sedimentary units (the names of units are recognized by GSI) are described

Table 1.1 Details of fluvial facies used in the analysis (modified from Miall 1985, 2006, 2014)

Facies code	Sedimentary structure	Interpretation
Gmg	Matrix-supported massive gravels; inverse to normal grading	Pseudoplastic debris flow (low-strength, viscous)
Gcm	Clast-supported massive gravel; out-sized clasts	Pseudoplastic debris flow (inertial bedload, turbulent flow)
Gh	Clast-supported, crudely bedded gravel; imbrications	longitudinal bedforms, lag deposits, sieve deposits
Gt	Gravel stratified; trough cross-beds	Minor channel fills
Gm	Massive poorly sorted gravels	Point bar deposits
Sm	Sand, fine to coarse; massive or faint wavy lamination	Sediment-gravity flow deposits
Sp	Planar cross-bedded sand	Traction and intermittent suspension, forming ripples
St	Trough cross-bedded sand	Migration of dunes with lag deposits
Sh	Horizontally bedded sand	Transition from subcritical to supercritical flow, deposits of flash deposits
Ss	Scour-fill sand	Rapid deposition of poor sand, coarse bed load, basin fills
Fm	Mud, silt; massive, desiccation cracks	Overbank or waning flood deposits
Ft	Laminated sand, silt, and mud	Deposition from suspension and from weak traction currents
Fsm	Finely laminated silt and clay	Floodplain deposits, more distal relative to clastic sources such as nearby fluvial channels

below with important sediment characteristics and landform assemblages (Table 1.2 and Fig. 1.2).

1.4.1.1 Lalgarh Morphostratigraphical Unit

The lateritic or ferruginous lithosections around the Durgapur–Panagarh belt (a part of *Rarh* Plain) is actually the weathering product of ex situ lateritization of debris flow–fluvial deposits during the Neogene to Late Pleistocene. This ferruginous formation is quite comparable to the Lalgarh Morphostratigraphical Unit (LMU) which is analogous to secondary laterites of *Rarh* (Biswas 1987). LMU appears as a conglomerate reworked ferricrete and Gmg fluvial facies (i.e. inverse to normal matrix-supported gravels). The matrix or ground-mass is highly cemented by ferruginous cement (mainly limonite and goethite) which makes it very ind-uarted duricrust. Below the duricrust the pebble horizon is characterized by lag deposits (fan-delta formation) constituted of pisoids, quartz pebbles, and petrified