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Profiling of late Tertiary–early Quaternary surface in the lower reaches of Narmada valley using microtremors

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ABSTRACT

In this paper, we propose the first approximation for thickness of Quaternary sediment and late Quaternary–early Tertiary topography for the part of lower reaches of Narmada valley in a systematic way using the shallow seismic method, that records both horizontal and vertical components of the microtremor (ambient noise) caused by natural processes. The measurements of microtremors were carried out at 31 sites spaced at a grid interval of 5 km s using Lennartz seismometer (5 s period) and City shark-II data acquisition system. The signals recorded were analysed for horizontal to the vertical (H/V) spectral ratio using GEOPSY software. For the present study, we concentrate on frequency range between 0.2 Hz and 10 Hz. The thickness of unconsolidated sediments at various sites is calculated based on non-linear regression equations proposed by Ibs-von Seht and Wohlenberg (1999) and Parolai et al. (2002). The estimated thickness is used to plot digital elevation model and cross profiles correlating with geomorphology and geology of the study area.

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1. Introduction

The frequency of seismic noise shows both temporal and regional variations depending on the influence of source and site. In case of thick unconsolidated sediment overlying the bedrock, the seismic waves give high mechanical contrast, where the upper unconsolidated sediment amplifies the seismic motion. The frequency of resonating waves in the unconsolidated upper layer is related to the velocity as well as the thickness of the sediment. Such site amplification can be estimated using an ambient noise method introduced by Kanai (1957). Several studies have shown that ambient seismic noise records reveal the fundamental resonant frequency of surface sediments (Ohta et al., 1978; Celebi et al., 1987; Lermo et al., 1988; Field et al., 1990; Hough et al., 1991; Konno and Ohmachi, 1998). To infer the site amplification characteristics from ambient noise, one however needs to remove source effect. Nakamura (1989) proposed a method to remove the source effect and estimate site response by dividing the horizontal component noise spectrum by the vertical component (H/V). Several modifications, shortcomings and applications of this method were studied thereafter (Ohta et al., 1978; Celebi et al., 1987; Lermo et al., 1988; Hough et al., 1991; Field and Jacob, 1993; Lermo and Chavez-Garcia, 1993, 1994; Konno and Ohmachi, 1998; Zhao et al., 2007). Several researchers have applied microtremor H/V spectrum for site investigation and measuring thickness of the top soil cover over the bedrock in Europe, China, Japan (Tertiary–Quaternary interphase: Yamanaka et al., 1994; Ibs-von Seht and Wohlenberg, 1999; Delgado et al., 2000; Parolai et al., 2002; Garcia-Jerez et al., 2006; Zhao et al., 2007) and mapping of regolith thickness over Archaeans (Dinesh et al., 2010). In both cases there is high mechanical contrast, however, in the former case the variation of Quaternary–Tertiary interphase in the basin is predictable, whereas regolith cover would have wide variation locally. Studies by Ibs-Von Seht and Wohlenberg (1999) and Parolai et al. (2002) proposed equations relating the fundamental resonant frequency to the thickness of soft sediment cover (Quaternary sediments) from the observed well data and theoretical calculations. Ibs-Von Seht and Wohlenberg (1999) investigated western Lower Rhine Embayment in Germany comprising a variable thickness of sediment belonging to Tertiary and Quaternary age. On the other hand, Parolai et al. (2002) investigated Cologne area in Germany comprising sediments of Quaternary and Tertiary age covering Devonian bedrock. In the recent work of Dinesh et al. (2010), they have derived an equation for the Archaean meta-sediments and the overlying sediment cover at Bangalore City, India.

The present investigation is the first attempt to map the thickness of the Quaternary sediments in the lower reaches of Narmada

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High Resolution Facies Record on Late Holocene Flood Plain Sediments from Lower Reaches of Narmada Valley, Western India

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Abstract: A high resolution quantitative granulometric record for site Uchediya [21°43'2.22" N, 73° 6'26.22" E; 10 m a. s. l.] gives understanding towards accretion history of the late Holocene flood plain in the lower reaches of Narmada River. Two sediment facies (sandy and muddy) and seven subfacies (sandy subfacies: $St_{MS+FS+CS}$, Sm_{FS+MS}, Sl_{FS+VFS}, and St_{MS+CS}; muddy subfacies: $Fm_{SILT+VFS+FS}$, $Fm_{SILT+VFS+FS}$ (O) and $Fm_{SILT+VFS+FS}$ (T)) are identified based on cluster analysis supplemented with sedimentary structures observed in field and other laboratory data. Changes in hydrodynamics are further deduced based on various sedimentological parameters and their ratios leading to arrive at a depositional model.

Keywords: Lower reaches of Narmada valley, Late Holocene, Sedimentology, Sediment facies, Hydrology.

RATIONALE, STUDY AREA AND BACKGROUND

Continental response to a climate change is best achieved through multi-faceted studies on various landforms in the river flood plains. The changes in both landforms and the sediment characteristics have long been used as an indication for climate change (Reid and Frostick, 1997; Nanson and Tooth, 1999; Knox, 2000; Macklin et al. 2002; Macklin and Lewin, 2003). Lower reaches of Narmada River (LrNR) expose a very conspicuous pair of landforms namely, the palaeobank extending from town Rajpardi in east towards the mouth of river Narmada in west, for almost 33 km (Bedi and Vaidyanadhan, 1982) and the late Holocene flood plain (chronology bracket from Raj and Yadava, 2009: ~1950 ± 90 to 1280 ± 70 yrs BP) that developed adjacent to palaeobank (Fig.1). The present study focuses on the late Holocene flood plain, along the present Narmada River. This river flows (on an average) 8 m below this late Holocene flood plain throughout most of the year except during monsoon flood periods, when the flood water submerges the Holocene surface and adjacent palaeobank becomes active. The majority of the surface is used for agriculture, whereas villages are located high above over palaeobank.

The LrNR has been investigated through various perspectives namely, general geomorphology (Wainwright, 1964; Allchin and Hegde, 1969; Gadekar et al. 1981; Bedi and Vaidyanadhan, 1982; Sant and Karanth, 1988; Ganapathi and Pandey, 1991; Sant and Karanth, 1993; Sant, 1999); Quaternary stratigraphy (Chamyal and Merh, 1992; Bhandari et al. 2005); volcanic ash (Raj, 2008); alluvial fans (Chamyal et al. 1994; Chamyal et al. 1997); neotectonics (Chamyal et al. 2002; Raj et al. 2003; Raj, 2007; Raj and Yadava, 2009) and radiocarbon chronology (Raj and Yadava, 2009: ~1950±90 to 1280±70 Years BP; cal BP 1924 to cal BP 1172 for intercalated silty sandy and clay sequence near Uchediya village along bank of river Kaveri). However the late Holocene sedimentary sequence in this area lacks a systematic sedimentological analysis.

In the present paper we discuss high resolution granulometric data as well as various statistical parameters calculated from these records, supplemented with inputs from field (nature of facies contacts and sedimentary structures) and other laboratory data (foraminifera record) from a representative site Uchediya [21°43'2.22" N, 73° 6'26.22" E; 10 m a.s.l.] west of Kaveri River along the bank of River Narmada. The quantitative record is further used to identify sediment facies, depositional environment, hydrological characters and changes that occurred through sediments aggradation.

GEOMORPHOLOGY

The course of River Narmada downstream of the dam at

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Late Holocene Storm Records from Lower Reaches of Narmada Valley, Western India

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Abstract: Storms from the Arabian Sea are the most significant meteorological feature in western India that brings extreme rainy days together with catastrophic flooding. The present study reports two such palaeo-storm horizons at 1.16 m and 3.2 m above the present day water level in the Narmada channel, 56 km inland based on sedimentology and foraminiferal records. Both the horizons show similar sediment facies and foraminiferal assemblage. The present findings instigate to look for new such sites and build palaeo-storm records for western India.

Keywords: Palaeo-storm, Late Holocene, Foraminifera, Flood plain, Western India.

INTRODUCTION

Foraminifers are the most widely studied microfossils for their short life cycles and immediate response to change in environment, calling them as an ideal bio-indicator for both modern to past environmental changes (Schafer, 2000; Hallock et al. 2003; Frontalini and Coccioni, 2008). Studies on modern foraminiferal faunal distribution have been used for documenting Holocene eustatic sea level changes (Gehrels, 1999; Horton et al. 1999; Edwards and Horton, 2000; Gebhardt et al. 2004; Massey et al. 2006; Woodroffe, 2009), bathymetric related zonation pattern (Culver, 1988) and the role of tectonics (Hayward et al. 2010). Studies on microfossils distribution in Narmada estuary along Quaternary marine sequence (Ambheta: 21°402 493 N; 72°352 423 E: 20 km inland) documents monsoonal upwelling (Ghosh et al., 2008). Further similar records from present active river channels (Narmada river and Tapti river) were used to document palaeo-macro-tidal estuarine environments (Ghosh et al. 2009).

Our recent sedimentological studies on Uchediya Sequence in lower reaches of river Narmada (21°43'2.22" N, 73° 6'26.22" E; 10 m a. s. l; 56 km inland from coast; Sukumaran et al. 2012) reveals two dominant sediment facies namely, sandy (68%) and muddy facies (32%). Sedimentology and field studies discover that muddy facies occur at three distinct levels namely, Level 1 (L1), 1.6 m to 1.62 m; Level 2 (L2), 3.5 m to 4.26 m; and Level 3 (L3), 6.00 m to 8.02 m from the present day water line. Of the three layers, the two muddy facies, L1 and L2 shows distinct and sharp lower and upper bounding surfaces whereas upper most unit, L3, show a gradual transition along lower bounding surface. Landform studies reveal that the Uchediya sequence along Narmada river belongs to historical period and is younger to the landform that features dated sequence close to Uchediya village (1200 -1900 years; Raj and Yadava, 2009). Our present study is therefore, focused on two muddy facies belonging to L1 and L2 levels developed along Uchediya sequence. Microfaunal studies undertaken gives significant understanding towards depositional environment. The methodology adopted for microfaunal studies, identification of various species, their count and their environmental significance is discussed. The present work further highlights repeated palaeo-storm events in the lower reaches of Narmada valley through Arabian Sea and looks forward toward need of finding of such historical evidence of palaeo-storm along the west coast.

STUDY AREA

The Uchediya sequence [21°43'2.22" N, 73° 6'26.22" E; 10 m a. s. l], under present study falls in the present left bank of Narmada channel about 56 km inland from the coastline (Fig.1). A systematic survey carried out over a late Holocene flood plain reveals continuity of lithounits for about 2.4 km. Sedimentologically the sequence is classified into three distinct sedimentary facies based on both nature

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Morphostratigraphy and Palaeoclimate Appraisal of the Leh Valley, Ladakh Himalayas, India

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Abstract: In the present paper we study morphology, occurrence and mutual interrelationship of erosional (amphitheaters) and depositional landforms belonging to glacial (moraines), fluvio-glacial (glacial out wash), mass wasting (alluvial fans), aeolian (obstacle dune and sand sheets) and lacustrine (palaeo-lake sediments) processes within the Leh valley. These landforms are the geomorphic expression of past deglaciation grouped into five Formative Stages of Landform (FSL 1 to FSL 5) development in the Leh valley. The broad age bracket for the formative stages are based on the empirical relationship of the landforms, available chronology and their correlation with comparable climate phases. The retreat of glaciers in the Leh valley, along the southern slopes of Ladakh hill range and their retention over the northern slopes and Karakoram is further explained.

Keywords: Leh Valley, Ladakh Himalayas, Geomorphology, Climate change, Snow Accumulation Zone, Westerlies.

INTRODUCTION

The Leh valley is developed as an arcuate depression along the interface of undeformed Ladakh batholith to its north and folded, thrusted Zanskar meta-sedimentaries to its south (Fig. 1). It forms an integral part of the Ladakh Himalayas, the western central sector of the Himalayan mountain range that accumulates the largest body of ice outside the Polar Ice Cap in the mid-latitudes. The Leh valley preserves plethora of paraglacial landforms viz. moraines, dunes, sand-sheets, alluvial fans, and palaeo-lakes. It gives an opportunity to study the inter-relationship within these paraglacial landforms and understanding of denudational processes in the valley.

The Leh valley lies in the rain shadow of the Great Himalayas (towards south) with Karakoram range (towards north) and Tibetan plateau (towards east) serve as an orographic barrier that controls the continental wind system and consequently, the climate of the region. It receives scanty and infrequent rainfall /snowfall under the influence of both Southwest Indian Monsoon and Westerlies (Owen and Benn, 2005; Fowler and Archer, 2006; Bhutiyani, et al. 2007). The wind interface locates itself along the Karakoram and its variation is controlled by the mid-troposphere thermal anomaly (Vernekar and Ji, 1999). Historical records from weather monitoring station at Leh indicate that the average summer temperature goes up to 20°C by July, while the average winter temperature dips down to -13°C by January. It receives rainfall twice a year during June to September (Southwest Monsoon: average precipitation is 41 mm) and October to May (Westerlies: average precipitation is 53 mm); whereas above 5000 m. a. s. l. the precipitation is in the form of snowfall. Glacier melted water is a major contributor to the Indus drainage system than the rainfall. High altitude and reduced amount of rainfall in the valley portions of the Ladakh Himalaya elucidate prolonged cold and arid climate assigning a status of High Altitude Cold Desert.

Numerous glaciological, palaeo-climatological and chronological studies indicate that glaciers in lower Himalayas (Thompson et al. 2006; Owen, 2009; Seong et al. 2009), southern Ladakh range (Owen et al. 2006) the Zanskar range (Burbank and Fort, 1985; Osmaston, 1994; Mitchell et al. 1999) and Tibetan plateau (Thompson et al. 2006; Heyman et al. 2009) shows sign of overall recession over Himalayas, while the glaciers over Karakoram sector (Hewitt, 2005) and western Tibet (Damm, 2006) show signs of advancement in recent times. Most studies carried out

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Linkage of Paraglacial Processes from Last Glacial to Recent Inferred from Spituk Sequence, Leh Valley, Ladakh Himalaya

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Abstract: The paraglacial sequence in the Leh valley, Ladakh Himalaya preserves imprints of various processes active during deglaciation in the late phase of Last Glacial. In present work, a high resolution sedimentological record generated for Spituk is presented identifying aeolian episodes, mudflow events from Ladakh Range and debris flows extending from Zanskar Range across present Indus River. Two temporal phases of water ponding within Spituk Sequence are also identified. The seismites recorded at various stratigraphic depths and their association with the sediment facies signifies gravity induced process besides possible seismic activity as an added phenomena. Linkage between paraglacial processes since Last Glacial to Recent is tracked and evaluated.

Keywords: Paraglacial, Soft-sediment deformation structures, Leh, Spituk, Ladakh Himalaya.

INTRODUCTION

The sedimentary sequences in the Leh valley, Ladakh Himalaya provide a window to study the paraglacial processes that were active during deglaciation ever since Last Glacial. The term 'Paraglacial', coined by Ryder (1971a, b), and later, Church and Ryder (1972) describes non-glacial processes (mass movement and fluvial) that are directly conditioned under glacial environment. The term is also extended to cluster of non-glacial landforms that capture the response of high altitude mountains to changing environmental conditions in terms of denudational history (Ballantyne, 2002a, b). In the present paper, we discuss aggradation of Spituk sequence under the influence of three paraglacial processes namely, mass movement (mudflows, debris flow and sheet wash); fluvio-glacial (glacial wash); aeolian (dunes and sand sheets) and local isolated lakes within the Leh valley. The Leh valley has been investigated by various workers on several aspects namely, moraines (Drew, 1873; Dainelli, 1922; Fort, 1978, 1983; Burbank and Fort, 1985; Fort et al. 1989; Osmaston, 1994); glacial influence over transverse valleys (Jamieson et al. 2004); influence of glacial and fluvial processes over high mountain landscape (Hobley et al. 2010); lacustrine deposits (Burgisser et al. 1982; Fort et al. 1989; Bagati and Thakur, 1993; Sangode and Bagati 1995; Bagati et al. 1996; Kotlia et al. 1998; Shukla et al. 2002; Phartiyal et al. 2005; Phartiyal and Sharma, 2009) and on chronology using magnetic method (Fort et al. 1989), radiocarbon method (Bagati et al. 1996; Phartiyal et al. 2005) and surface dating of moraines using ^{10}Be isotope (Brown et al. 2002; Owen et al. 2006).

The present paper focuses on the detailed study of the known sedimentary sequence exposed at Spituk (34°07' 50.25" N; 77° 31' 28.30" E; 3213 m). The radiocarbon dates along the sequence (~40 ka: Phartiyal et al. 2005) places the sequence in a time frame of Late phase of Last Glacial (LLG). The study records sedimentary facies, nature of transition, and sedimentary structures at high resolution so as to resolve paraglacial processes that operated during the aggradation of Spituk sequence. The present findings are significant for they establish the linkage of paraglacial processes operative during LLG to Recent time. Further the paper brings out a comprehensive understanding on recent catastrophe that occurred in Leh (Juyal, 2010) where a cloud burst triggered mud flows swept over the Leh town destroying civil infrastructure and buried several persons within the flow.

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Thank You....