Review Article Narmada Rift Valley & Quaternary Sedimentation

A A Khan, Maria Aziz

Abstract— The Narmada river originates at Amarkantak at an elevation of about 1057 m above m.s.l. it descends across the rugged and mountainous tract through deep and steep gorges in straight sinuous to meandering pattern over a distance of 1300 km across the middle of the Indian sub-continent to join the Gulf of Cambay in Arabian sea in Gujarat state. In the area of study in lower Narmada between Grudeshwar and Baruche is occupied by thick Quaternary deposits of about 800 m which represent various domain of sedimentation. Based on sedimentlogical characters, depositional environments, erosional processes and their relation with depositional activity revealed that it comprised of four domains of sediments viz glacial, fluvio-glacial fluvial and tidal flats. The lower most units (Boulder bed) are, of glacial origin, followed by the boulder conglomerate of glacio-fluvial and subsequently by fluvial of paleo- domain of Narmada and tidal flats. The top four formations Ankleshwar, Tilakwarda & Bharuch and Aliabat are designated as (NTo-NT3). Boulder conglomerate is assigned an independent formational status based on distinct lithology and fossil assemblage.

The area of study has repurcassions of impact of movements of the Indian Plate which is currently moving northeast at 5 cm/yr (2 in/yr), while the Eurasian Plate is moving northeast at only 2 cm/yr (0.8 in/yr). This is causing the Eurasian Plate to deform, and the Indian Plate to compress leading to tectonic activity along major fault zones. In tectonically active areas sedimentary basins undergo phases of both crustal extension and contraction leading to basin inversion and hence display features typical of subsidence and uplift. Geomorphic attributes and deformation in late Quaternary sediments are the indicators of active tectonic activity in any sedimentary basin. The geomorphic evolution in such reactivated basins is primarily due to complex interaction between sedimentation processes and tectonics. The peninsular India has been undergoing high compressive stresses due to the sea-floor spreading in the Indian Ocean and locking up of the Indian plate with the Eurasian plate to the north. Much of this N-S directed stresses have been accommodated by the under thrusting of the Indian plate below the Eurasian plate.

The Narmada Rift valley formed a linear trench in the middle of Indian subcontinent which was an ideal locus for accumulation of sediments. The Quaternary sedimentation incepting from glacial activity, followed by fluvio-glacial, lacustrine and fluvial phase within the rinsing and sinking environment, block faulting, linear displacement and dislocation, uplifting and isolated domal up- lift, Neogene rifting and Quaternary sedimentation and rift-bound Pliocene–Pleistocene rifting and volcanic activity specifically during glacial and fluvio-glacial phase are major component of the Quaternary period and tectonic processes of the Narmada Rift System which form the base of quaternary deposits.In Narmada Rift system taking as single ecological unit for Quaternary sedimentation & tectonics and presence of the Katni Formation in central sector with angiosperm flora suggests that sedimentation continued during Mio-Pliocene in localized lakes. The relative disposition of such lakes and subsequent deformation and structural dislocation on oscillating valley platform clubbed with rifting and faulting during Quaternary period has shifted the site of the lakes towards the present alluvium-covered area between Harda -Jabalpur, Garudeshwar and Bharouch as presumed: where as the present study of various aspects of Quaternary blanket in SONATA LINEAMENT ZONE reveled that quaternary sedimentation was a sequential and continuous process in rift valley system from Mio-Pliocene Pleistocene time, has deposited complete sequence of glacial, fluvio-glacial lacustrine fluvial and tidal deposits with changing environments and climate in time & space .

Index Terms— narmada, rift valley, sedimentation, repurcassions, eurasian plate, ecology, india, river.

1. INTRODUCTION

The Narmada river originates from the Amarkantak plateau of Satpura Ranges in Rewa at an elevation of about 1057 m (220 40′ -810 45′) flows westerly course for about 1300 kms length across the middle of Indian subcontinent before entering Gulf of Cambay in the Arabian sea near Baroda in Gujarat state. It enters the fertile alluvial plain and passes through the gorge of about 19 kms long consisting of Marble rocks near Jabalpur.It then takes westerly turn through the alluvial tract, situated between the Satpura and Vindhyan hills. The river course of Narmada conspicuously straight and is controlled by ENE_WSW to E_W lineament, is bounded by Vindhyan in the north and Satpura in the south. The valley has maximum width of about 32 kms.

The principal tributaries of Narmada River are Sher and Sakkar in Narsingpur, the Tawa and Ganjal in Hoshangabad, and Gaur in Jabalpur. They all originate from the Satpura hills to the south of the trunk channel. The only important tributary in the north is Hiran River, which emerge from the Vindhyan hills in Jabalpur district.

The river course of Narmada conspicuously straight and is controlled by ENE_WSW to E_W lineament, is bounded by Vindhyan in the north and Satpura in the south it is exposed the repeated post erisional and depositional activities and subjected to anisotropic

and asymmetric tectonic dislocation which has culminated diversified morphogenetic units and region which further undergone to process of tectonic evolution and chiseling of terrain by dynamic erosional and depositional activity resulting in and reshaping the terrain into various morphogenetic units and land form element, configuration of drainage, topography, physiographic , erosional platform, planation surfaces, denudation ridges, structural units linear valleys, strike hills, valley gapes, escarpments and river terraces. The cumulative dynamics of structural deformation, rinsing and sinking platform of Narmada has also manifested concealed cyclic mechanism of tectonics and geothermic activity hydrological activity, seismicity, neosiesmic events and in surface manifestation. In addition the valley gapes and valley trenches provided ideal sites for sedimentation for formation of quaternary platform, pediment, pediplain, peniplain and river terraces.

The Narmada flows along tectonically active NSF which forms a fault controlled basin of a huge thickness of Tertiary and Quaternary sediments. The thick blanket of Quaternary sediments occurs in the central part of valley in Jabalpur –Harda section and in Gurudeshwar – Bharouche section in lower of valley; where as in the other part in Harda – Mandleshwar section thin and isolated caps and strips of quaternary sediments are noticed on rock cut terraces and rock benches of country rocks. In Mandleshwar-Barwani, Dhadgaon- Tilakwarda the quaternary deposits are shallow to moderate in thickness and thin out to wards east. The isolated locus of accumulation and sedimentation along the entire length of 1300 kms of Narmada is controlled by the tectonics and structural frame work and sinking and uplift of fault bounded blocks and lineaments. It is well illustrated by neoseismic signatures and imprints on quaternary deposits and landscapes in the valley. The critical analysis of landscape profile evolution of drainage, quaternary terraces, river morphology and analysis of bore hole data of basement configuration of rock and quaternary deposits revealed that Jabalpur-Harda section valley segment suffered mega dislocation and sink to level of about 1150 m as compared to the adjoining blocks and created and has formed open rock basin and platform of quaternary sedimentation. This section display complete record of quaternary deposits of glacial, fluvio- glacial and fluvial sediments in increasing antiquity from the base. The study of bore data of ETO, CGWB, and GSI indicates and average thickness of quaternary deposits of about 435 m. The quaternary deposits bear well preserved imprints of neotectonisam indicating that the Sonata lineament zone seismically is active and has direct bearing on quaternary landscape of rift valley. The Harda – Mandleshwar section predominenently portrays the sequence of cyclic and noncyclical rock cut terraces and rock cut platform and benches which are time equivalent to the quaternary terraces of central and lower Narmada valley Khan et.al (2014). The Gurudeshwar-Bharouche embodies the thickest quaternary deposits which represents complete sequence from the base glacial fluvio-galcial fluvial, lacustrine and mud deposits. This segment is about 90 km in length and forms the southern margin of the N–S extending Gujarat alluvial plains. The bore hole data of ONGC, CGWB, GSI of deep geology in the basin have revealed occurrence of Deccan Trap at depths of 6000 m followed by an Achaean basement (Roy, 1990). The quaternary landscape has been chiseled in to step sequence of terraces (NT1 –NT3) which are both paired and none paired in nature and are time equivalent to the terraces of central sector of Narmada.

2. INDIAN PLATE & QUATERNARY TECTONICS

The Indian Plate is currently moving northeast at 5 cm/yr (2 in/yr), while the Eurasian Plate is moving northeast at only 2 cm/yr (0.8 in/yr). This is causing the Eurasian Plate to deform, and the Indian Plate to compress leading to tectonic activity along major fault zones.

In tectonically active areas sedimentary basins undergo phases of both crustal extension and contraction leading to basin inversion and hence display features typical of subsidence and uplift. Geomorphic attributes and deformation in late Quaternary sediments are the indicators of active tectonic activity in any sedimentary basin. The geomorphic evolution in such reactivated basins is primarily due to complex interaction between sedimentation processes and tectonics. The peninsular India has been undergoing high compressive stresses due to the sea-floor spreading in the Indian Ocean and locking up of the Indian plate with the Eurasian plate to the north. Much of this N-S directed stresses

have been accommodated by the under thrusting of the Indian plate below the Eurasian plate. A part of these compressive stresses are accumulated along the Narmada-Son Fault (NSF), a major E-W trending crustal discontinuity in the central part of the Indian plate.

The Quaternary tectonic activity recorded in the Narmada valley, possibly, has wider ramifications when viewed in the larger perspective of the Indian plate. This suggests a renewed phase of extreme compression of the Indian plate, which led to tectonic inversion along the NSF in the lower Narmada valley. Significant increase in compressive stresses accumulating on an intracrustal fault like the NSF can transform a previously subsiding basin into an uplifting one. The NSF has been characterized by a compressive stress regime throughout the Quaternary and variations in the degree of compression relative to the rates of plate movement are responsible for the late Pleistocene subsidence and the Holocene tectonic inversion in the lower Narmada valley. Chamya, L.S; (1997, 2000))

The Narmada Rift valley is conspicuous ENE-WSW to E-W trending prominent composite structural system across Indian sub-continent. It consists of various blocks which are dislocated and faulted along various faults and lineaments in space and time. The Narmada Rift System consists of various sub- basins like Hiran, Sher Shakkar, Dudhi, Tawa, which are minor basins are integrated and in built part of main rift system. These sub basins possess imprints of rinsing sinking and rifting events. These imprints are recorded in terms of manifestation and signature on landscape, drainage, of land form elements and as paleo- meandering signature, river terraces, cut of meanders, paleo channels, scars, rock cut terraces, entrenchment and linear and curvilinear scars. These sub basins have developed transverse to the main axis of Narmada rifting and had deep cut across the quaternary blanket. The evolution of Narmada graben is differential and asymmetrical with sinking valley floor.

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3. QUATERNARY SEDIMENTATION

The Narmada Rift valley formed a linear trench in the middle of Indian subcontinent was an ideal locus for accumulation of sediments .The rift trench is intruded by the dolerite and other mafic and siliceous dykes and sills along lineaments in different phases of tectonic deformation. The Quaternary sedimentation incepting from glacial activity, followed by fluvio-glacial, lacustrine and fluvial phase within the rinsing and sinking environment, block faulting and segmental displacement, dislocation, uplifting and isolated domal up- lift, Neogene rifting and Quaternary sedimentation and rift-bound Pliocene–Pleistocene rifting specifically during glacial and

fluvio-glacial phase are major component of the Quaternary period and tectonic processes of the Narmada Rift System which form the base of quaternary deposits. The Quaternary sedimentation was triggered by tectonic activities / up lift and climatic changes. The provenance for these sediments is the weathering products of eroding pre- Cambrian, meta-sediments, sedimentary and volcanic rocks along the watershed upland, rift escarpments and shoulders; faulted and uplifted blocks, volcanic fissure zones, and plateaus within and outside the rift. The Narmada Rift System, bounded by adjacent plateaus rising 300–700 m above the rift floor, consists of number symmetrical and symmetrical faulted blocks, escarpment, rock cut terraces, rock floors and segments of micro half grabben. Although rift-related basins started to form during the late Oligocene to early Miocene times, the Narmada Rifts were fully defined by middle to late Miocene time.

The Narmada rift system basin platform provided a unique setting for dynamic ecosystems that were characterized by Rift-related subsidence and coeval sedimentation also created an ideal locus of Quaternary sedimentation and environment for the accumulation of sediments volcanic fabrics sediments, burial, digenesis, and preservation of organic remains. Because rifts formed after widespread Quaternary sedimentation occurred and voluminous sediments in the rift basins were accumulated by glacial activity consequential upon the lowering of temperature and climatic changes in the region.

The Miocene -Pliocene–Pleistocene lake deposit of Katni on the eastern rift shoulder was created by faulting, topographic control, or isostatic depression similar to that of other Rift system.

Moreover, regional correlation based on the chemistry and geochronology of interbedded tephra has made it possible to establish accurate stratigraphic relations that are useful for pale- environment reconstruction and evolutionary studies of fossil remains in the Narmada rift valley Khan et.al. (2012). Regional tephra correlation is being used increasingly to link sites together, and has already established that similar tephra layers are known from other parts of rift valley, as well as from other basin and peninsular India Achariya,(1993), Khan (1992) Khan et.al. (2012) Tiwari (1996). The quaternary deposits and tephra are interbedded with the fossiliferous sediments derivied from both from close and distant provenencse while the ash has been deposited and accumulated during sedimentation in the valley. The provinces of sediment mostly from crystalline basement volcanic, sedimentary, meta basic and sedimentry rocks, aided in the cementation and preservation of organic remains by providing secondary minerals released during alteration in a burial environment.However, evidence of the effects of tectonics o fauna and flora are distinct and its signatures o dislocation and concealing of fossiliferous horizons are uncontrolled ad ill defined and the ecosystem in the rift system during the Pliocene–Pleistocene periods is not clear.The boulder conglomerate which yielded the skull cap of Homo eructs in Narmada rift from Hathnora remained only discovery of hominid fossil in last two and half decade due inconsistency concealed nature of fosilifrous horizon in Narmada valley as such researcher and scientist failed to add any further knowledge to hominid discovery any further.

In the Narmada valley the River terraces in central and lower Narmada (NT1 to NT3) which represents sediments of Sohagpur, Sahganj, Hoshangabad and Bharuch and Tilakarda formation respectively date back to the Late Pleistocene. The sedimentation commenced with the deposition of the marine basal clays during the last interglacial high sea level at f125 ka, which is presumed to be about + 7 m as revealed by the studies Regression of this sea led to the initiation of fluvial sedimentation. The fluvial sediments were deposited in to two phases of sedimentation with a sharp break marked by tectonic changes and related climatic changes. The sequence of these to formation is exposed in the cliff section which represents different sediment facies typical of fluvial environments .The sequence of sediments display imprints of compressive tectonic regimes of sedimentation. The southern margin of lower Narmada is marked by Narmada–Son Fault the transformation of this geofracture in Tertiary to reverse fault in Quaternary is implicit in the seismic studies of the area (Roy, 1990). Additional evidence for prevalence of compressive stress regime in the lower Narmada basin is provided by numerous reverse faults in the Neogene sediments exposed immediately to the south of Narmada–Son Fault (Agarwal, 1986). These evidences suggest that the sediments of both the formation were formed in a compressive tectonic environment. There are evidences of subsidence of basin which has been documented on landscape of basin which are

authenticated by other studies exist from adjacent area of synsedimentary subsidence on alluvial plain sedimentation.

In the Lower Narmada valley the Mid–Late Holocene Quaternary valley deposits is the product of a Holocene high sea-level-induced deposition in a deeply incised valley trench trough highly influenced NSF fault. A significant slowing down of tectonic uplift facilitated the encroachment of the sea into the valley and the creation of a depositional wedge, which extended up to the deep in land foothills. The 5–10-m exposed thickness of the valley-fill sediments reveals tide dominated estuarine deposition in the lower reaches and fluvial deposition upstream of the tide reach.

The presence of the Katni Formation with angiospermic flora suggests that sedimentation continued during Mio-Pliocene in localized lakes. During Quaternary period, the site of the lakes shifted towards the present alluvium-covered area between Harda and Jabalpur due to Late Quaternery movements, the lake burst open and water rushed towards west through the present Narmada river channel. Presence of thick boulder bed in Harda inlier area, such as at Chandgarh and NE of Barwaha supports this assumption. These boulder beds carry boulders of Deccan basalts, apart from boulders of other intra -trappean formations.

Quaternary studies in Tapti-Purna valley region have indicated presence of a depression along Yaval-Adavad-Akot-Bawanbir area, through which an arm of the Arabian Sea (?) extended causing salinity in this region. The depression was filled up by sedimentation. Neotectonic activities resulted in further deepening of this basin and as a result alluvium at places reached below present mean sea level. Similar situation has also been observed locally in the Narmada Valley region.

The Quaternary tectonic activity recorded in the lower Narmada valley, possibly, has wider ramifications when viewed in the larger perspective of the Indian plate. This suggests a renewed phase of extreme compression of the Indian plate, which led to tectonic inversion along the NSF in the lower Narmada valley. Significant increase in compressive stresses accumulating on an intracrustal fault like the NSF can transform a previously subsiding basin into an uplifting one. The NSF has been characterized by a compressive stress regime throughout the Quaternary and variations in the degree of compression relative to the rates of plate movement are responsible for the late Pleistocene subsidence and the Holocene tectonic inversion in the lower Narmada valley.The repurcessions of movement of Indian plate in regional prospective accross SONATA LINEAMENT ZONE to Himalaya are well preserved and recorded both on hardrock lanscape and quaternary land scape and in behaviour of Peninsular rivers and Himalayan river Khan (1882)., Khan (1983), Khan et.al. (1881) (Khan et.al (1981) The Himalayan foot hill region where the major river debouches in Indo Gangetic plain manifest relict of impact of movement of Indian plate Khan et.at (1980), Sehgal et.al. (1980) In Indo Gangetic plain the manifestation are recorded in Ganga Yamuna Kosi Ghagra and Sarda Khan et.al (1982) , Khan et.al (1981), Betwa & Tons rivers. In Central India Son Narmada Tapti manifast the impact of land scape, reconfiguration of drainge, mass wasting activity reorganisation of topography, manifetation of geothermal activity, and neoseismic events rock cut terraces and anomolous behaviour of channel systems. Khan (2007).

The complete account of Quaternary lithostratigraphy has been up dated in the Narmada valley (Khan 1984, Khan & Benarjee 1984, Khan & Rahate 1990-91-90 Khan & Sonakia 1992, Khan & et al 1991, Rahate & Khan 1985, Khan et al. 1991, Khan 1991, Khan et al. 1992, Yadav & Khan 1996. The Narmada valley embodied almost whole of the Quaternary deposits time span from the lower Pleistocene to Holocene (Khan & Sonakia 1992).Khan & Sonakia (1991) sedimentology , Khan (in Press) Quartz grain morphology sediment column, Khan (in Press) Quartz grain morphology of pale- sole, , Khan (in Press) Heavy mineral assemblage Khan (in Press) tephrastratigraphy, , Khan et.al (1991) Khan & Maria (1912) magnetostratigraphy, and bio-stratigraphy and correlation of sediment columns intra valley wise , inter valley wise and on unified Quaternary Platform Khan et.al (2012) focusing on hominid localities of China these deposits have given the new insight on the age of the Narmada Homo erectus. Discoveries of volcanic ash beds and palaeomagnetic reversal in these deposits for the first time for peninsular India are breakthroughs in fixing the chronologic position of the human skull. Fresh data on the age of the Narmada Homo erectus are also available by additional finds of fossil mammals and a detailed taxonomic study along with a thorough review of some families of mammals. The Homo erectus skull

was discovered embedded in a conglomerate bed within the Quaternary alluvial deposits of the Narmada Valley. In Narmada Valley several biostratigraphic classifications have been suggested for Quaternary deposits. The conglomerate bed designated as Hathnora Formation which has a 19 m thickness at its type section and a 50 m compiled thickness and its exposure is limited with in the mendring loop of Narmada. The section exposed is mostly by lateral cutting in the selected segment by lateral cutting, the major part of conglomerate bed is conealled under younger deposits. The Hathnora Formation which represnts boulder conglomerate is sandwiched between Boulder bed of glacial origin at the base showing Matuyama reversed polarity chron3 (0.73 Ma) and the younger one of fluvial origin with tephra layer equivalent to Toba ash4, 5 of 74,000 yrs BP. Some upper layers of these Narmada Valley alluvial deposits have also been proved to be older than 25,000 yrs BP by 14C dating which represents youngest deposits of present domain of Narmada. Table NO QTG _2 & 3

In Narmada Rift system taking as single ecological unit for Quaternary sedimentation & tectonics and presence of the Katni Formation in central sector with angiosperm flora suggests that sedimentation continued during Mio-Pliocene in localized lakes. The relative disposition of such lakes and subsequent deformation and structural dislocation on oscillating valley platform clubbed with rifting and faulting during Quaternary period has shifted the site of the lakes towards the present alluvium-covered area between Harda -Jabalpur, Garudeshwar and Bharouch as presumed where as the present study of various aspects of Quaternary blanket in SONATA LINEAMENT ZONE reveled that quaternary sedimentation was a sequential and continuous process in rift valley system (Table No -3) from Mio-Pliocene Pleistocene time, has deposited complete sequence of glacial, fluvio-glacial lacustrine fluvial and tidal deposits with changing environments and climate in time & space . The present disposition of quaternary blankets in Son Narmada basin is due to post deposition Quaternary tectonics which is solely responsible for sedimentation, dislocation, faulting and shifting of different blocks and distorting ecology in rift system. The occurrence of Boulder bed and Boulder Conglomerate in Son Narmada Tapti and Purna with similar rock assemblages and suites of rock fabrics, heavy mineral assemblages, and quartz grain morphology in critical and crucial sections across the SONATA LINEAMENT ZONE strongly support tearing and rifting of quaternary blanket during late Pleistocene time. The presence of thick boulder bed in Harda inliers area, such as at Chandgarh and north east of Barwaha,

boulder bed in confluence are of Tapti and waghur around Khadgaon in Tapti valley Khan et.al (1984) supports this assumption.

The Quaternary sedimentation incepting from glacial activity, followed by fluvio-glacial, lacustrine and fluvial phase within the rinsing and sinking environment, block faulting and segmental and linear displacement, dislocation, uplifting and isolated domal up- lift, Neogene rifting and Quaternary sedimentation, rift-bound Pliocene–Pleistocene rifting and volcanic activity specifically during glacial and fluvio-glacial phase are major component of the Quaternary period and tectonic processes of the Narmada Rift System.

The Narmada rift system provided a unique setting for dynamic ecosystems that were characterized by rift up lift and subsidence which has created ideal locus of Quaternary sedimentation and environment for the accumulation of sediments, volcanic fabrics sediments, burial, digenesis, and preservation of organic remains. The rifts formed after widespread Quaternary sedimentation occurred and voluminous sediments in the rift basins accumulated by glacial activity consequential upon the lowering of temperature and climatic changes in water shed region. The Miocene -Pliocene–Pleistocene lake deposit of Katni on the eastern rift shoulder was created by faulting, topographic control or isostatic depression within the rift system.

4. SUCCESSION OF QUATERNARY SEDIMENTS

The area of study is occupied by Quaternary blanket of about 800 m which represent different domain of sedimentation. Based on sedimentlogical characters, depositional environments, and erosional processes and their correlation with depositional erosional activity revealed that it comprised of four distinct domains of sediments viz glacial, fluvio-glacial fluvial / lacutrine and tidal flats. The lower most units (Boulder bed) is of glacial origin, the boulder conglomerate which seprates glacial and fluvial deposit is persistent horizon and is of of glacio-fluvial (Khan el. al 1991) fluvial terraces are of paleo- domain

of Narmada and tidal flats over top the fluvial deposits and confined along the coast line on the margin of gulf of Cambay.The top three formations Ankleshwar, Tilakwarda , Bharuch, and Aliabat are designated as (NTo-NT3) represent thick and multiple sequences of Quaternary sediments.

The stratigraphic succession of Quaternary sediments in lower Narmada valley comprise of four distinct groups of deposits viz. glacial, fluvio- glacial and fluvial ad tidal flats ; their age, litho constituents, environments of deposition and associated geomorphic elements are given in table (Table No 2).

5. GLACIAL/FLUVIO-GLACIAL DEPOSIT

The glacial and fluvio-glacial deposits of Narmada unconformable overly the Vindhyan and Deccan Trap rocks. The sediments consist of a heterogeneous assemblage of sub-angular to angular, sub-rounded, unsorted, unstratified rock fragments ranging from boulders to small pebbles, predominantly of quartzite, gneiss, sandstone, basalt, jasper, chart, gneiss, sandstone, basalt, chart, altered feldspar, ferruginous nodules, in a matrix of very coarse to very fine-sand, silt and clay. These clastics are highly angular, generally poorly sorted and, imbricated in fine matrix. The fine sediments comprise of reddish grayish and greenish sand with appreciable amount of mica flaks, altered feldspar, brick-red and buff silt, greenish-brown silt and clay, and greenish, reddish and dark maroon hard and plastic clay. These fine sediments contain fairly good amount of ferruginous material, quartz, mica flakes and altered feldspar grain. Though these sediments are similar in composition to the other deposits of Narmada but exhibit entirely different sedimentary pattern, sediment characters and mineral composition. These rock clastics are largely angular, very poorly sorted and demonstrate isotropic pattern in the valley. The sediments of glacial domain of Narmada were deposited in glacial environments during Pleistocene time. These deposits are concealed under boulder conglomerate in the valley.

6. FLUVIO-GLACIAL DEPOSITS (BOULDER CONGLOMERATE)

The conglomerate bed which constituted the fossiliferous horizon of Narmada is sandwiched between older fluvial sediment of paleo -domain and the glacio-fluvial boulder bed. This conglomerate bed is a very persistent horizon indicating a distinct phase of sedimentation in the valley. It is exposed in the bluff/scrap of Narmada around at the base of terraces NT2 (Khan, 1984). The measured exposed thickness of the boulder conglomerate in western sector of Narmada is about 16.5 m and average thickness is 12.00 m.

The boulder conglomerate predominantly consists of sub-rounded to well rounded boulder, cobble and pebble of quartzite, gneiss, sandstone, basalt, agate, jasper, chart, chalcedony tightly cemented in a matrix of sand and silt. The finer sediments include different grade of sand and silt, brown and maroon in color often laminated and cross laminated. The skull cap of early man Homo erectus is recovered from boulder conglomerate (Sonakia, 1984)

It consists of three sub-litho units; each sub-unit characterized by distinct rock fragment shape, size, lithological abundance and allied sediment characters. The sub-units are composed of variable assemblage of quartzite, gneiss, basalt, sandstone, agate, jasper, chalcedony, chart, sand and silt (Khan1992) These sub-litho units display facies variation in the valley and upper units grades into gritty sandstone upstream of Tilakwarda.. The rock clastics of boulder conglomerate are tightly cemented in deep brown and maroon sand, silt and clay. The finer clastics display sedimentary feature like lamination, cross-bedding load structure, small ripples and, cut and fill feature. The cross-bedded units are often truncated by a pebbly layer at the top. The average measured thickness of these sub-units is about 2m.

The boulder conglomerate is of middle Pleistocene age equivalent to Siwalik boulder conglomerate (India), Trini bed of Java (Indonesia) and boulder conglomerate of Tapti (Khan.1982) These deposits have yielded skull cap of early man, Homo erectus Narmadensis along with other mammalian fossils Sonakia, (1984). (Khan 1991) has identified and recorded Ash bed of Quaternary age associated with these deposits around Timrawan upstream of Hathnora is of Aeolian nature and perhaps indicates volcanic activity during middle Pleistocene time

7. FLUVIAL DEPOSIT (PALEO DOMAIN OF NARMADA)

The Fluvial deposit of conformably overlies the boulder conglomerate and represents the flood-plain

fancies of palaeo -domain of Narmada. The sediments facies predominantly consist of clay silt and sand, calc nodules and calc matrix. The sediments are horizontal disposed and exhibit upward fining sequence typical of fluviatile deposits. The Fluvial deposit of paleo-domain of Narmada can be divided into three formations based on lithology, sediment assemblage, shape and size of rock clastics, relative disposition and diagnostic sedimentary characteristics. These formations are, viz. where as the older three Ankleshwar, Tilakwarda Bharouch formation Aliabat are related to older flood plains deposits of paleo-do-main of Narmada respectively. These formations represent the sediments of the palaeodomain of Narmada deposited in channel and flood plain environments during Upper Pleistocene times Khan & Sonakia (1992).

The younger alluvium is represented by sediments of active flood plain, point bar and sand bar facies of present domain of Narmada and consist of unconsolidated imprecated, stratified, polymodal sorted rock-gravel supported by very coarse to very fine-sand and is named as Aliabat formation.

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9. CONCLUSIONS

The area of study has repurcassions of impact of movements of the Indian Plate which is currently moving northeast at 5 cm/yr (2 in/yr), while the Eurasian Plate is moving northeast at only 2 cm/yr (0.8 in/yr). This is causing the Eurasian Plate to deform, and the Indian Plate to compress leading to tectonic activity along major fault zones. In tectonically active areas sedimentary basins undergo phases of both crustal extension and contraction leading to basin inversion and hence display features typical of subsidence and uplift. Geomorphic attributes and deformation in late Quaternary sediments are the indicators of active tectonic activity in any sedimentary basin. The geomorphic evolution in such reactivated basins is

primarily due to complex interaction between sedimentation processes and tectonics. The peninsular India has been undergoing high compressive stresses due to the sea-floor spreading in the Indian Ocean and locking up of the Indian plate with the Eurasian plate to the north. Much of this N-S directed stresses have been accommodated by the under thrusting of the Indian plate below the Eurasian plate. The Narmada Rift valley formed a linear trench in the middle of Indian subcontinent which was an ideal locus for accumulation of sediments. The Quaternary sedimentation incepting from glacial activity, followed by fluvio-glacial, lacustrine and fluvial phase within the rinsing and sinking environment, block faulting, linear displacement and dislocation, uplifting and isolated domal up-lift, Neogene rifting and Quaternary sedimentation and rift-bound Pliocene–Pleistocene rifting and volcanic activity specifically during glacial and fluvio-glacial phase are major component of the Quaternary period and tectonic processes of the Narmada Rift System which form the base of quaternary deposits.In Narmada Rift system taking as single ecological unit for Quaternary sedimentation & tectonics and presence of the Katni Formation in central sector with angiosperm flora suggests that sedimentation continued during Mio-Pliocene in localized lakes. The relative disposition of such lakes and subsequent deformation and structural dislocation on oscillating valley platform clubbed with rifting and faulting during Quaternary period has shifted the site of the lakes towards the present alluvium-covered area between Harda -Jabalpur, Garudeshwar and Bharouch as presumed: where as the present study of various aspects of Quaternary blanket in SONATA LINEAMENT ZONE reveled that quaternary sedimentation was a sequential and continuous process in rift valley system from Mio-Pliocene Pleistocene time, has deposited complete sequence of glacial, fluvio-glacial lacustrine fluvial and tidal deposits with changing environments and climate in time & space .

The area of lower Narmada valley between Gurudeshwar-Bharuch is occupied by thick Quaternary deposits of about 800 m which represent various domain of sedimentation. Based on statistical parameters sedimentlogical characters, depositional environments revealed that it comprised of four distinct domains of sediments viz glacial, fluvio-glacial fluvial and tidal flats. The lower most units (Boulder bed) is or glacial origin, the boulder conglomerate of glacio-fluvial (Khan el. al 1991) and fluvial terraces are of fluvial paleo- domain of Narmada and tidal flats. The top three formations of paleo- fluvial domain of Narmada is represented by Ankleshwar, Tilakwarda and Bharuch formation. The Boulder conglomerate is assigned an independent formational status based on distinct lithology and fossil assemblage. The sequence of Quaternary events and the history of sedimentation of Narmada indicate that the upper 180 of the Narmada alluvium was deposited in two distinct aggradations episode with a distinct and well defined break in sedimentation in rift system. The dissection of the quaternary blanket resulted two terraces (NT3-NT2), after break in sedimentation. The sediments of this aggradations episode constitute three lithostratigraphy units Ankleshwar, Tilakwarda and Bharuch & Alibat formation. The sediments of the alluvial phase are underlain by a boulder bed of glacio-fluvial origin. Thus, the fossiliferous boulder conglomerate, the basal unit of alluvium marks a disconformity between the lower glacial-boulder layer and upper fluvial sediments. The fossiliferous basal boulder conglomerate is being of middle Pleistocene age (Khan 1992)

The Quaternary blanket of Narmada in Garudeshwar –Bharuch section has formed three terraces, besides its presented-day flood-plains, in the valley. These are designed (NTO to NT3), NTO being the lowest terrace above the present-day course of the river, NT1 , NT2 both are of cyclic and non cyclic nature. The NT3 terrace occurs as elongated strip and isolated caps and lenses along the margin of valley flanks has divergent relative disposition. These land forms indicate vigorous and abrupt incision of valley floor due to relatively & repaid uplift of watershed area during Upper Pleistocene time. The (NT1 NT2) are the major depositional terrace and have both convergent & divergent mutual disposition with other terrace. These terraces further downstream have matched equivalents along the valley flank, whereas in the up stream section the matched equivalents are rare. The conspicuous divergent

relation of these terraces the valley reveals successive uplift of catchments area and consequential incision of valley floor and adjustment of base level of Narmada during Upper Pleistocene time. The other land form elements of fluvial domain associated are point bar, sand bar, braided channel, meander scroll and cut of meander and paleo- channel. These terraces NT1 to NT3 of western sector are time equivalent to the three terraces of central Narmada and represents three sequential Quaternary events in SNONATA LINEAMENT ZONE in Central India Khan (1982) (1984) (1992) Khan et.al (2014). The quaternary landscape has evoluved under compressive stress as witnessed by by configuration of drainage , land profile disposition of terraces and imprints of neotectonisam Khan (2016)