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RESEARCH ARTICLE

QUATERNARY DEPOSITS, CYCLIC SEDIMENTATION AND ASSOCIATED SEDIMENTRY SRUCTURES OF HOMONID LOCALITY HATHNORA DISTRICT SEHORE M.P.INDIA.

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Abstract

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The Narmada river orginated at Amarkantak plateau of Satpura Ranges in Rewa at an elevation of about 1057 m (220 40' -810 45'), it flows westerly course across the middle of Indian subcontinent before entering Gulf of Cambay in the Arabian sea in Gujarat state.

The Quaternary landscape of Narmada basin covers an area of about 17950 sq. km starting from west of Jabalpur (23^{0}07^{0}79 05 30) to east of Harda (22^0 29'; 76^0 58') , and Gurdeshwar and Bharouche section in Gujarat state for a distance of about 1320 km. It is found to be ideal locus of Quaternary sedimentation in Central India as witness by multi-cyclic sequence of Quaternary terraces in the valley

The Narmada River course is 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 Narmada valley has maximum length of about 1300 kms and has maximum width of about 32 kms.

The Narmada Rift valley formed a linear trench in the middle of Indian subcontinent was an ideal loci 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 on unstable platform, where the, block faulting and linear displacement and dislocation, uplifting and isolated domal up- lift, Neogene rifting and is conspicuos feature of Quaternary sedimentation. The 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.

A lot of data has been generated on Narmada Valley Quaternary deposits during last 150 years; the different workers have studied the subject separately in the line of their specializations Roy, A.K. (1971),

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It is seen that there has been very little coordinated approach towards understanding and building up the complet Quaternary Geology sequence of sedimentlogical history of the valley.

In the present work an attempt has been made for the first time to study sedimentary structures of quaternary deposits, cyclic sedimentationand environment of deposition of Narmada valley with a objective to build- up and conceive the model of Quaternary sedimentation & tectonics of the Hominid locality Hathnora in Narmada valley. About 32 sections and 9 bore hole logs were studied round Hathnora to study the different sedimentary features to understand the dynamics of sedimentation.

The Narmada Valley in the Hathnora area is occupied by thick Quaternary sediments. These sediments are classified based on sedimentary depositional environments, sedimentological characters and correlation with depositional / erosional terraces. The lowermost units (Boulder bed) is or glacio-fluvial origin (Khan *el al* 1991), whereas the rest of fluvial origin. The top four formations Sohagpur, Shahganj, Hoshangabad and Janwasa are classified based on morphostratigraphic state (NT_o-NT_3), degree of oxidation, calcification and compaction. Janwasa formation comprises of sediments of active channel deposition and is the older Sohagpur, Shahganj, Hoshangabad formation are related to older flood plains deposits of paleo-do-main of Narmada and are grouped under older alluvium. Boulder conglomerate of fluvio-glacial origin 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 top 90 m of the Narmada alluvium was deposited in a single aggradations episode with minor pauses when dissection of the alluvium formed two terraces (NT_3-NT_2). The sediments of this aggradations episode constitute three lithostratigraphy units viz. Boulder conglomerate, Sohagpur and Shahganj 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). These deposits display various sedimentry structuresin these deposits with different intensity and frequency in vertial quaternary coloumn gradded bedding,cross bedding, cut &fill features, ripple marks and cross bedding scour features, climbing ripple , cross lamination. The fossiliferous basal boulder conglomerate is being of middle Pleistocene age (Khan 1992) in the Hathnora section it displays cross bedding, cross lamination, gradded lamination scour features and cut and fill features.

The statistical parameters,heavy mineral study,paleosole, quartz grrain analysis indicate three mejor breaks in vertical stratigrphic column between 00.00 to 260 m below the ground level indicate that the sediments consist of three domains viz. glacial, fluvio-glacial and fluvial. Khan(2015) Khan (2014-15).The study of these concealed sediments, their sedimentary environments and sedimentation and correlation both in vertical and horizontal columns indicates that the lower most units, Boulder bed (20 to 260 m. below ground level) is of glacial origin, where as the fossiliferous bed Boulder conglomerate (260 to 278m. above m.s.l.) is of fluvio-glacial and top four formations in increasing antiquity Sohagpur, Shahganj, Hoshangabad

and Janwasa (278 to 350m. above m.s.l.) are of fluvial origin and represent the complete sequence of Quaternary sedimentation which comprise of three distinct groups of deposits viz. glacial, fluvio-glacial and fluvial in Central India.Khan (1984)
In Sardrpur –Hathnora—Shahganj -Hoshangabad section critical and crucial study of exposed terrace sections of fluvial domain of Narmada revealed that sediments which constitute various lithouints are characterized by association of distinct and diagnostic rock fabrics clay and silt matrix. The units further constitutes a thick sequence of quaternary strata comprises of thick of boulder, cobble, pebbles of quartzite, gneiss, granite, schist, phyllite, slate, basalt limestone sandstone augate chert and chalcedony in different proportion assemblage. These rock clastics range in size from >64 and < 256 mm and constitute horizontally bedded disposed units of variable thickness depicting various sedimentary structures. Each unit is characterized by specific size association of rock fabric/sediments, and rock composition sedimentary structures and other diagnostic sediment characters, categorizing distinct regime of deposition of that specific unit of specific energy level. The successive repetition of units of allied characters is quite frequent in terrace sections. The repetition of each unit marks the completion of single cycle and represents particular phase of energy condition of the channel under which the sediments were deposited. On the basis of study of about 27 scarp sections around Hathnora Sardarpur, Nathanhkeri, Shahgunj, Hoshangabad in the different fluvial terraces (NT1 to NT3) of Narmada nine types of cycles are identified (Khan (1984), Khan et.al (1985) and Khan et al 1981). These cycles have been classified as main cycles and sub-cycles which suggest cyclic sedimentation in Narmada valley.

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Introduction:-

The Narmada river orginated at Amarkantak plateau of Satpura Ranges in Rewa at an elevation of about 1057 m (220 40' -810 45'), it flows westerly course across the middle of Indian subcontinent before entering Gulf of Cambay in the Arabian sea in Gujarat state.

The Narmada River course is 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 Narmada valley has maximum length of about 1300 kms and has maximum width of about 32 kms.

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 on unstable platform where the, block faulting and linear displacement and dislocation, uplifting and isolated domal up- lift, Neogene rifting and is conspicuos feature of Quaternary sedimentation. The 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.Khan et.al 1990-91 & 1991-92)

The Quaternary events of the Narmada portys three prominent terraces and two sub terraces which are designated NT1 to NT3 and sub terraces NT2-A is NT2-B, NT2 B, besides NT2-C, NT3-A & NT3-B in increasing order of antiquity. The terraces are described in detail separately. These are both erosional and depositional terraces and confined at an elevation of, between 280m to 310-400. The NT1 is being the youngest terrace and NT3- B it is being the oldest terrace identified in the valley.

The Quaternary landscape of Narmada basin covers an area of about 17950 sq. km starting from west of Jabalpur ($23^0 07^0$79 05 30) to east of Harda (22^0 29'; 76^0 58') , and Gureshwar and Bharouche section in Gujarat state for a distance of about 1320 km. It is found to be ideal locus of Quaternary sedimentation in Central India as witness by multi-cyclic sequence of Quaternary terraces in the valley (Plate No _1)

Present work:-

The Narmada valley forms a ENE-WSW lineament and Quaternary deposits in it are confined to trough like basin, with profound asymmetry in northern and southern valley walls. The Narmada valley in Peninsular India negotiates along a prominent lineament with profound geomorphological and geological asymmetry between the northern and southern valley walls, giving it a tectonic significance. The Quaternary deposits of the Narmada valley represent the thickest deposits in peninsular India representing different domain of sediments deposited in glacial, fluvioglacial environment. The various aspects of Quaternary deposits and their quarries are well described in faulted and sinking platform under structural riparian rift trench however digonestics and concealed strata remained silent and unrevealed as such hidden miseries of Narmada valley needs attention.

A lot of data has been generated on Narmada Valley Quaternary deposits during last 150 years. The different workers have studied the subject separately in the line of their specializations Roy, A.K. (1971), but there has been very little coordinated approach towards understanding and building up the Quaternary sedimentlogical history of the valley.

In the present work an attempt has been made for the first time to study sedimentary structures of quaternary deposits of Narmada with a objective to build- up and conceive the dynamics of Quaternary sedimentation & tectonics of the Hominid locality Hathnora in Narmada valley. About 27 sections were studied besides bore logs around Hathnora to study the different sedimentary features, cyclic sedimentation, and rock pathology to understand the dynamics of sedimentation. (Plate No _1)

Hominid locality Hathnora Indian homo erectus and evalution (22°-52 'N-77° 52'):-

The skull cap of Narmada man Homo erectus (Narmada man) was found in near village Hathnora (22 ° 52" N; 77 ° 52" E) in Sehore district Madhaya Pradesh India, in fossiliferous boulder conglomerate (Sonakia, 1984), at an elevation of about 268 m above the m.s.l. and at the depth of about(83m) in Central Narmada Valley. These deposits are underlain by glacial deposits and overlain by fluvial deposits of palaeo-domain of Narmada. The Quaternary sequence of Hathnora is described by Khan & Sonakia (1992).

The Boulder conglomerate at Hominid locality Hathnora consist of stratified hard compact basal unit comprising of rook fragments of different shape and size of granite, quartzite, sandstone, augate, chalcedony, chart, basalt and calcareous nodules tightly cemented in the matrix of brown, red and grayish sand and silt. These rock clastics constitute various sub- litho units and are supported by grey and brownish, cross bedded sand. The sub-litho units consists of mostly pebble supported horizons which contains vertebrate fossils, stone implements, like chopper, scraper hand axes and core flakes mostly of quartzite, flint, chalcedony and quartzite.

The rock basin of Narmada is occupied by the Quaternary sediments of three domains viz. glacial, fluvio- glacial and fluvial which were deposited in distinct environments during Quaternary time. The glacial deposit comprised of thick pile of sediments occupied base of rock basin and was deposited by glacial activities in dry and cold climatic condition during early Pleistocene time. The Boulder conglomerate constitute fossiliferous horizon of Narmada, deposited in fluvio-glacial environments (interglacial). It is a marker horizon of Quaternary sedimentation in Narmada Valley and as well in Central India, its disposition and relation with other deposits in the valley, indicates a significant change in regional climate from cold dry to warm and humid, during which the sediment were re-worked from glacial front intermittently and deposited in the valley over a very long time. The skull cap of Home erectus (Narmada Man) and other fauna recorded along with calc- nodules within the boulder conglomerate; suggest that warm climatic phase prevailed long time.

In India Narmada basin considering the one of a main locus of Quaternary sedimentation, assuming the uniform accumulation rate of sediment in the basin in the line of Ma. et. al. (1978) Yobin Sun & Zhisheng, An (2005) and comparing the Narmada sequence of Quaternary deposit (325 m.) with those of Luochuan standard sequence of Chenjiawo and Congwangling sequence of China. The skull cap of Homo erectus (Narmada Man) recovered from the Boulder conglomerate of fluvio-glacial origin in middle part of Quaternary column from deeper level of quaternary sequence at the depth of (83 m.) above glacial deposits, in association of ash bed, as compared to Chenjiawo Hominid from inter bedded sequence of paleo sols loess and silty loess at the depth of (38 m.) and Congwangling (26 m.) from pale sole which are younger than Narmada deposits.

The Narmada skull cap of Homo erectus which is recovered from the vom of basal unit of boulder conglomerate at the depth of (83 m) i.e. (278 m. above m.s.l.) is estimated to be of upper segment of lower Pleistocene age. It is older than the Homo erectus of Chenjiawo, Congwangling of China which were recovered from paleo sole and loess deposit at the depth of (38 m) and (26 m). The Quaternary sequence of Narmada (325 m.) as compared to Louchuan (136 m.) sections of China on unified Quaternary platform is older and represents the complete and type sequence of Quaternary sedimentation in Central India Khan & Maria (2012). The occurrence of skull cap of early man at the depth of 83 m. in basal unit of boulder conglomerate of fluvio-glacial origin in Narmada Valley is one of the earliest and oldest Homo erectus in Asia. Khan & Maria (2012). (Plate No _1)

Quaternary Geology:-

The Narmada Valley in the Hathnora area is occupied by thick Quaternary sediments. These sediments are classified based on sedimentary depositional environments, sedimentological characters and correlation with depositional / erosional terraces. The lower most units (Boulder bed) is or glacio-fluvial origin (Khan *el al* 1991) whereas the rest of fluvial origin. The top four formations (Sohagpur, Shahganj, Hoshangabad and Janwasa) are identified based on morphostratigraphic state (NT_o-NT_3), degree of oxidation, calcification and compaction. Janwasa formation comprises of sediments of active channel deposition and is the older three (Sohagpur, Shahganj, Hoshangabad formation) are related to older flood plains deposits of paleo-do-main of Narmada and are grouped under older alluvium. Boulder conglomerate of fluvio-glacial origin 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 top 90 m of the Narmada alluvium was deposited in a single aggradations episode with minor pauses when dissection of the alluvium produced two terraces (NT_3-NT_2). The sediments of this aggradations episode constitute three lithostratigraphy units viz. Boulder conglomerate, Sohagpur and Shahganj 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)

Based on study of statistical parameters of sediment their deviation and breaks in vertical stratigrphic column between 00.00 to 260 m below the ground level indicate that the sediments consist of three domains viz. glacial, fluvio-glacial and fluvial.(Khan et.al in press) The study of these concealed sediments, their sedimentary environments and sedimentation and correlation both in vertical and horizontal columns indicates that the lower most units, Boulder bed (20 to 260 m. below ground level) is of glacial origin, where as the fossiliferous bed Boulder conglomerate (260 to 278m. above m.s.l.) is of fluvio-glacial and top four formations in increasing antiquity Sohagpur, Shahganj, Hoshangabad and Janwasa(278 to 350m. above m.s.l.) are of fluvial origin and represent the complete sequence of Quaternary sedimentation in Central India.

Boulder conglomerate of fluvio-glacial origin is assigned an independent formational status based on distinct lithology and fossil assemblage. The boulder conglomerate at Hominid locality Hathnora consist of stratified hard compact basal unit comprising of rook fragments of different shape and size of granite, quartzite, sandstone, agate, chalcedony, chart, basalt and calcareous nodules tightly cemented in the matrix of brown, red and grayish sand and silt. These rock clastics constitute various sub-litho units and are supported by grey and brownish, cross bedded sand. The sub-litho units consists of mostly pebble supported horizons which contains vertebrate fossils, stone implements, like chopper, scraper hand axes and core flakes mostly of quartzite, flint, chalcedony and quartzite.

The Quaternary sediments in Narmada valley comprise of three distinct groups of deposits viz. glacial, fluvio-glacial and fluvial; their age, litho constituents, environments of deposition. In Sardrpur –Hathnora—Shahganj - Hoshangabad section critical and crucial study of exposed terrace sections of fluvial domain of Narmada revealed that sediments which constitute various lithouints are characterized by association of distinct and diagnostic rock fabrics clay and silt matrix. The units further constitutes a thick sequence of quaternary strata comprises of thick of boulder, cobble, pebbles of quartzite, gneiss, granite, schist, phyllite, slate, basalt limestone sandstone augate chert and chalcedony in different proportion assemblage. These rock clastics range in size from >64 and < 256 mm and constitute horizontally bedded disposed units of variable thickness depicting various sedimentary structures. Each unit is characterized by specific size association of rock fabric/sediments, and rock composition sedimentary structures and other diagnostic sediment characters, categorizing distinct regime of deposition of that specific unit of specific energy level.

The successive repetition of units of allied characters is quite frequent in terrace sections. The repetition of each unit marks the completion of single cycle and represents particular phase of energy condition of the channel under which the sediments were deposited. On the basis of study of terraces about 27 sections around upstream Sardarpur, Nathanhkeri, Shahgunj, Hoshangabad Hathnora Bhariagaht in the different fluvial terraces (NT1 to NT3) of Narmada nine types of cycles are identified (Khan 1981). These cycles have been classified as main cycles and sub-cycles which suggest cyclic sedimentation of Quaternary of Narmada. (Plate No _1)

Table I:- Quaternary Deposits of Narmada Valley.

Age	Quaternary formations	Lithe constituents	Environments of Deposition	Associated sedimentary structures / features
1	**2**	**3**	**4**	**5**
Recent	Younger Alluvium Fluvial terraces / fluvial deposit of present domain of Narmada	Reworked sediments, mostly rock gravel consisting boulder, cobble, pebble of quartzite, gneiss, granite, schist, basics, slate, phyllite, limestone & shale in a matrix of coarse to fine sand	Channel & flood plain environments	Gradded structures, cross bedding, lamination, cross, lamination crevasse-splay. The scour and fill cross bedding structure small ripple cross bedding
Holocene	Fluvial terraces fluvial deposits / older alluvium & Sediment of paleo-domian of Narmada	Coarse gravel consisting of boulder, cobble, pebble, of quartzite gneiss granite, schist, phyllite, state, fossiliferous lime stone, shale & basic rocks in a matrin of coarse to fine sand.	Channel & flood plain environments.	Graded bedding, Cross bedding, Planar lamination Ripple lamination, Ripple cross lamination & cut and fill features (Fluvial terraces of Narmada NT-0 to NT-3).
Late Pleistocene	Fluvio- glacial deposits	Sub-angular to sub rounded boulder, cobble, pebble of quartzite, gneiss, granite schist with subordinate amount of limestone, slate, phyllite & basic rocks with coarse to fine sand & silt.	Fluvio glacial environments	Graded bedding, Cross bedding, Planar lamination Mega – ripple bedding Rippal lamination, Rippal cross lamination climbing ripple lamination & cut and fill features Fluvio-glacial deposts "FGT"
Pleistocene	Glacial deposit	A heterogeneous mix of sub-angular to angular boulder and cobble of predominately gneiss, granite, schist, & quartzite with subordinate an amount of slate phyllite and shale together with very fine sand, silt & clays.	Glacial environment	Glacial deposits “GT”. Section Not Exposed

Sedimentry structures:-

In Narmada valley the Vindhyan Group of rocks and Deccan Trap in the central sector of from the basement for the Quaternary deposits. The conglomerate bed that constituted the fossiliferous horizon of Narmada is sandwiched between older Alluvium and the glacio-fluvial bounder bed. This conglomerate bed is a very persistent marker horizon indicating a distinct phase of sedimentation. It is exposed in the bluff/scrap of Narmada around Sardar Nager, Hathnora, Surajgarh, Budhni, Hoshangabad, Khoksa, Tigharia, Demawar and Bhariya-Ghat at the base of terraces NT_2 (Khan, 1984).The measured thickness of the exposed boulder conglomerate varies from 1.5 to 6.5m whereas average thickness is 5m.The rock pathology of Boulder conglomerate in the Hominid locality Hathnora is studied and correlated with erosional cycles in watershed region of Narmada .

The Quaternary deposits of both paleo and present domain comprised of sediment of both coarser sediment (more than 256 mm) and finer sediments (less than 16 mm). The coarser sediments display graded bedding in of sequence consisting of alternate layer of sub-rounded to well rounded boulder cobble, pebble in the matrix of coarse to fine sand. The basal units are often marked by boulder layer overlying either scoured surface of bed rock or the end bed of underlying cycle of sediments. The thickness of individual bed unit is highly variable. The relative thickness of these beds range from 80 to 150 cm. 20 to 45 cm and 10 to 35 cm in respect of boulder, cobble and pebble is respectively. At places the thickness of boulder units exceeds 300 cm. The cyclic development of graded bedding in terraces NT2-A, NT2-B, NT3-C is most common, whereas in the younger terraces the cycles are often incomplete and truncated by overlying sediment. The graded bedding portrays upward fining sequence. The cross bedding in coarser clastics is observed at very few places. These are mostly planner type, and have typically tangential contacts with underlying sediment units or bed rock. The thickness of these cross beds ranges from 80 to 250 cm. whereas the mean thickness is 160 cm. The fore set indication varies between 20 and 250 and average value in general increase towards younger terraces in the valley.

The graded lamination in the finer sediment is typically seen associated in sandy horizons of middle and lower sequence of deposits terraces around. It mainly comprised different units of light to dark yellow coarse to fine sand containing appreciable amount of quartz, feldspar and basic granules, dark ash colour coarse to fine sand, light to dark maroon coarse to fine sand, silt and clay, and dark brown coarse to fine sand, sandy silt and clay. The basal units generally comprise coarse sand associated with granites of quartzite followed to medium to fine sand and end with very fine sand or silt and clay. The individual lamine are often marked by colour banding parting or with concentration of mica flakes. The thickness of the individual lamine is highly variable and varies between 2.5 mm and 15 mm. The cyclic development of graded lamination is most common in the study horizons in flood plain deposits and fluvial terraces of Narmada.

The cross bedding is the most prominent sedimentary structure in the middle and lower terraces NT1,NT2-A, NT2-B, & NT2-C, it is most relevant in the coarse to fine sand, coarse to fine micaceous sand, light yellow to dark yellow coarse to fine sand, light brown maroon coarse to fine sand, silt and clay fine sand and pebble. These cross beds are both planar and through type corresponding to microns and phi class Allen (1963) the former one is most common. The planar cross beds have tangential relation with underlying sediment units. The thickness of foreset usually ranges from 45 to 95 cm, although at places it exceeds to 120 cm. The mean thickness is 55 cm. In general the thickness of fore set increases towards younger terraces. (NT0-NT1). , Sardarpur, Telankhedri, Hathnora, Shahganj Hoshangabad Demawar, Bhilariaghat river section.The cross bedding fore set inclination ranges between 50 to 20, the mean fore set inclination for middle terraces is about 12 and for younger terraces 15.5. The value of this angle increases towards younger terraces. NT0, NT1.

The development of planar cross bedding is commonly ascribed to the movement of the sand bar in the valley, under the flat environment during the flood, similarly trough cross bedding is considered to be due to the development and filling of hollow during the migration of river. Petijhon, F.G. (1957)

The imprints of sedimentation, tectonics and dynamic fluvial domain are causative factor of these features which area are originated when traction and fall out operates simultaneously and bed load and suspension population are therefore, mixed even though occasionally graded. The development of a particular type of ripple drift cross lamination requires persistent balance of various factors; particularly the current velocity and the ratio of deposition from suspension to bed load. No natural mechanism other than tidal current appears to adequately provide this balance. The initial bed load from ripples and dunes which are identical in form and migrate laterally during the process of sedimentation. These bed forms originate in non-cohesive bed material in response to shearing action of the flow. As soon as the bed material starts moving under the action of both flow and gravity, ripples appear and with increasing stream power, dunes form. Migration of ripples and dunes give rise to cross lamination and cross bedding respectively. The shape characteristic of cross-lamination and cross-bedding is controlled by grain size of bed material, and amount of contribution from suspension to the deposited material, as well as hydrodynamics. The sedimentation of quaternary deposits incepting by glacial activity at rock basin followed by fluvio-glacial and terminating with fluvial activity, the last one is more dynamic has resulted these features under fluctuating energy condition. The sediment load is by suspension and partly by traction bed load. The thickness of co-set exhibiting cross-lamination for middle order terraces viz. NT2-A NT2-B, NT3 ranges from 45 to 65 cms and for younger terraces from 75 to 95 cms. In general the mean thickness increases towards lower terraces in Narmada valley. These features are observed around Hathnora, Shahgunj, Hosagngabad, Shivepur, and Bhilariaghat

The boulder conglomerate is of middle Pleistocene age equivalent to Siwalik boulder conglomerate (India), Trine bed of Java (Indonesia) and boulder conglomerate of Tapti (Khan, 1984).

The pathological abundance and distribution of various rock reveals that the span of deposition of boulder conglomerate represent the specific and diagnostic phase of sedimentation that the rock constituents are co- relatable to selected rock units as per their disposition and lithological and tectonic conformity in watershed region which were subjected to extensive erosion in the eventual phase of change of climatic changes during sedimentation. The Quaternary terraces of fluvial domain comprised of three terraces designated as NTo to NT3in increasing antiquity the terrace NT2 is further divided in to three units as NT2-A, NT2-B, NT2-C in increasing antiquity with reference to active flood plain of river. These terraces predominantly consist of quartzite gneiss granite augate chert phyllites slate basics sandstone lime stone laterite and others..It is witnessed and agreed from table the abundance of various litho constituents and their frequency is with the regional conformity of geology of watershed area where the quartzite occurs and associated in all the formation. It indicates that the quartzite forms the prominent topography in the headword ends of Narmada and remained accessible to erosion throughout the history of Quaternary sedimentation. Its higher concentration in lower and younger terraces of Narmada indicates that during the formation of NT0-NT1 there was the extensive erosion of quartzite both from younger formation as well also from the oldest and stratigraphically lowest sequence which could be available to erosion only tow the quartzite bearing formation which are younger in age but have occupied structurally higher position; whereas the quartzite fragments of younger terraces from quartzite formation which have both tectonically lower and higher disposition and are older and younger in age (Khan et al, 1981) The older terrace viz. NT2A, NT2-B, NT2-C & NT3 comprise appreciable amount of boulder, cobble, pebble of white quartzite. The rock fragments constitute an average about 7.80 per cent of total terrace gravels. The relative contribution of these rock clastics show higher concentration towards the middle and higher terraces in the valley. It appears that the white quartzite exposed in the headward ends of Narmada were overlain, by thin but quite persistent veneer of quartzite containing high grade silica.

The rock fragments comprising gneiss, granite and schist are present in all the terraces but their higher concentration is restricted in the older terraces NT2-A , NT2-B, NT2-C of NT3 which were mostly derived from the quartzite bearing formation which are younger in age and have occupied structurally higher position; whereas the quartzite fragments of younger terraces from quartzite formation which have both tectonically lower and higher disposition and are older and younger in age (Khan et al, 1981).The rock fragments comprising gneiss, granite and schist are present in all the terraces but their higher concentration is restricted in the older terraces NT2-A, NT2-B, NT2-C & NT3. It is perhaps due to widespread occurrences, and prominent relief formed by these rocks in the watershed of Narmada and were subjected extensive erosion during the early stages of the inception of post-glacial drainage, subsequent to the melting of glaciers towards middle pleistocene these rock units became the less prominent suppliers of sediment load to the channel as evident by their contribution, which is greatly reduced towards younger terraces NTO- NT1, NT2A, NT2-B, NT2-C & NT3.The phyllites and slate very in percentage from 7.00 to 13.00 and share about 6.19% of total terrace sediment in the valley. These rocks are resident and moderately vulnerable to erosion. The persistent frequency of theses rock constituents except in NT2-C & NT3 reveals uniform and longer availability of these rocks to erosion during sedimentation The higher percentage of these rock fragments in NT2-C & NT3 towards older terraces indicate the higher vulnerability of these rocks perhaps due to change in climatic changes which reactivated erosional cycle and was the consecutive factor of supply of heavy load of sediments which were transported and brought by numerous subsequent streams draining the slate and phyllitic country during the later phases of sedimentation. The basic are younger in age, however, it is of great significance. Its affinity to younger terraces is suggestive of its late availability to erosion due to lower tectonic disposition and also by deep cutting and late up-warping towards the late Holocene time.

It is witnessed by study that the concentration of boulders and cobble ranging in size from 64 mm to >256 mm (15.50 to31.50 percent) is characteristically restricted mainly to the older terraces viz. NT2-A, NT2-B, NT2 & NT3 which contributes 33% boulder of its total sediments being highest in the valley. The affinity of boulder and large cobble (14.00 to 21.50 percent) small cobble (9.50 to 18.00) with the older terrace indicates high load carrying capacity of the paleo channel of Narmada during the early stages of sedimentation. The highest confinement of boulder with the third terrace NT3 (31.50 percent) is perhaps indication of reactivation in the energy system and load caliber of the channel during this particular phase of sedimentation.

The distribution of frequency of cobble towards the younger terrace is suggestive of steady depletion in the load caliber of the Narmada during the late history of river sedimentation in Quaternary time (Khan 1988).

The appreciable association of boulder 21.50 percent in the lowest terrace NT1 appears to be due to reworking of sediments from the older terrace in the valley.

The present river is nearly graded in nature and is misfit in its own valley as is evident from the occurrences of numerous channel braids point bars, sand bar, braided point bar, channel bar in the present day course of river. These landforms comprises of heterogeneous assemblage of rock boulder, cobbles, pebbles of diverse size and shape of different rock in matrix of coarse to fine sand are mostly reworked sediments

In Sardrpur–Hathnora-Hoshangabad section critical and crucial study of exposed terrace sections of fluvial domain of Narmada revealed that sediments which constitute various lithouints are characterized by association of distinct and diagnostic rock fabrics clay and silt matrix. The units further constitutes a thick sequence of quaternary strata comprises of thick of boulder, cobble, pebbles of quartzite, gneiss, granite, schist, phyllite, slate, basalt limestone sandstone augate chert and chalcedony in different proportion assemblage. These rock clastics range in size from >64 and < 256 mm and constitute horizontally bedded disposed units of variable thickness depicting various sedimentary structures. Each unit is characterized by specific size association of rock fabric/sediments, and rock composition sedimentary structures and other diagnostic sediment characters, categorizing distinct regime of deposition of that specific unit of specific energy level. The successive repetition of units of allied characters is quite frequent in terrace sections. The repetition of each unit marks the completion of single cycle and represents particular phase of energy condition of the channel under which the sediments were deposited. On the basis of study of terraceabot 37 sections around upstream Sardarpur, Nathanhkeri, Shahgunj, Hoshangabad Hathnora Bhariagaht in the different fluvial terraces (NT1 to NT3) of Narmada nine types of cycles are identified (Khan 1981 and Khan et al 1981). These cycles have been classified as main cycles and sub-cycles which suggest cyclic sedimentation of Quaternary of Narmada. The different cycles as identified are as follows

Main Cycles: Boulder Cobble Pebble Horizons.
a. Boulder Horizons with Sand.
b. Cobble Horizons with Sand.
c. Pebble Horizons with Sand.

Sub-cycles: Boulder, cobble, pebble horizon with sand.
a. Boulder, cobble, pebble horizon with sand.
b. Boulder, pebble, cobble horizon with sand.
c. Cobble, boulder, pebble horizon with sand.
d. Cobble, pebble, boulder horizon with sand.
e. Pebble, cobble, boulder horizon with sand.
f. Pebble, boulder, cobble horizon with sand.

Micro -cycles: Predominantly Very coarse, medium sand with pebble with occasional cobble and Boulder
a. Predominantly Very coarse, medium sand with pebble.
b. Predominantly Medium with fine sand with pebble,
c. Predominantly Fine sand with pebble, cobble.
d. Predominantly Very coarse, medium sand, pebble with occasional Cobble,
e. Predominantly Very coarse, medium sand pebble with occasional Boulder.
f. Predominantly Fine sand with Pebble with occasional cobble and Boulder.

Micro sub -cycles: Predominantly Very coarse to fine sand with pebble
a. Predominantly very coarse to fine sand with occasional pebble.
b. Predominantly medium to fine sand with occasional and scanty pebble,
c. Predominantly fine sand silt with occasional and scanty pebble,
d. Predominantly fine sand silt with occasional and scanty pebble.
e. Predominantly fine sand silt and clay with rock granules.
f. Predominantly fine sand silt with clay.

The study of occurrence of these cycles and their and frequency reveals that the main cycles a, b, c, chiefly consist of boulder cobble and pebble predominant in older terraces NT-3and NT2-B, NT2-C. These cycles are repetitive and represent longer time span in stratigraphic columns the average measured thickness in these terraces are 4.5 3.5 and 5.00 m respectively. The individual cycle consist of several both primary and secondary micro phases represented by different size clastic, energy level of channel and consequential sequence of sediment in the section. The cumulative analysis of these cycles indicates that the sediments of these terraces were deposited under high energy condition during the initial phases of sedimentation in the valley.

The frequency of these cycles in NT2-A decreases and at the same time the relative thickness of these cycles also decreases to the order of 3.5, 3.00 and 3.5 m respectively. The repetitive time interval became shorter and size of sediment become selective which indicates that during the middle phase of sedimentation energy of channel towards the inception of cycle was declined and there after it became static for longer time.

The abundance these cycles in NT1 and NTo further decreases but these frequency increases.The average measuring thickness of these cycles declined towards to the order of 3.00, 2.50. 2.00 m suggest constant decrease of energy level of channel towards the later phases of sedimentation.

The overall disposition of these cycles in the stratigraphic column in different terraces in Narmada indicate that the sediment in the initial phases were deposited under high energy condition and channel system was highly and agitating nature. The energy condition towards the middle phase of sedimentation was declined but became static for longer time and thereafter steadily declined till the formation of NTo in the valley. The sub cycles are associated with these cycles and their frequency and occurrences depict oscillation in energy condition in between the mega event related with the climatic changes in watershed region and it also reveals that both laminar and turbulent flow was mainly responsible for transportation of sediments from the source area. It also indicates that the stream load was constituted mainly of bed load, suspension, and graded suspension load. They were dislodged, transported and deposited in the environments of highly oscillating energy condition during the sedimentation in Quaternary time (Khan 1984). The stream kinetics and frequential change in the energy condition was mainly control by micro pulses of uplift, stream gradient and the climatic changes. Further synthesis of data relating to the size distribution of rock clastics, relative thickness, of sediments, sedimentary pattern, degree of sorting, imbrications pattern, plunge of larger axes of the pebbles, disposition of various horizons and relative cyclic interval, it is deduced that

1. There was frequential change in the operational competence and capacity of stream load and discharge throughout the history of river sedimentation.
2. The current velocity of stream was highly fluctuating from turbulent to sluggish and was mainly controlled by micro-climatic changes in the headward ends of channel.
3. The current velocity of stream was predominantly violent and torrential during the early stages of sedimentation, perhaps due to tectonic dislocation of consequential the release of impounded energy of in the stream due to high gradient.
   (Plate No _6 to 8)

The Quaternary sediments comprised of boulder cobble and pebblesas studied for cyclic sedimentation were further studied for their shape and size in the same n representative section and stratigraphic column from the different domain of terraces in Narmada valley in the area around Hathnora. The bulk samples were separated for the coarser clastic and finer clastics (>64 and < 256 mm). The coarser clastics above 16 mm were separately analyzed for study of lithological abundance of sediments of different domain. The objective of study to assess and evaluate lithological abundance of different rock gravel in quateranry deposits and to understand the frequency of occurrence of different lithology of rock constituents and their distribution in stratigraphic columns, their relation to erosional pattern in watershed region and provenances. The shape analysis of these rock gravel (>64 and < 256 mm) was undertaken as a part of sedimentological study as the shape is one of the most fundamental properties of sediments and is of prime importance in deciphering the geological history of sedimentary deposits. Sofar no detailed account of shape characteristic of rock fabric of Quaternay terraces (>64 and < 256 mm) seems to be available except Dubey & Khan (1974) and Sinha & Khan (1976) and Khan (1988) who have attempted to study the shape characters of rock fabric of terraces of Ganga in selected section Sinha et al (1979) and Khan (1981), described the various classes of rock clastic of fluvial terraces of Narmada and correlated shape with the lithology. The rock gravel / rock fabric comprising of boulder, cobbles, pebbles from such of terraces NT0, NT1, NT2-A, NT2-B, NT2-C have been studied for various shape classes and to compute various textural parameters like mean size, flatness and axial ratio. The various axis a, b, c, were measured with the help of varneer caliper and axial ratios were computed to identify the various shape classes of rock pebbles.

The study revealed that there appears to be direct relation between the size of fabric and sphericity and roundness. The boulder and cobbles of most resistant rocks, such as quartzite show a tendency of increase in sphericity and roundness as size increases. The pebble suites of Narmada also show similar relationship (Khan 1981) due to their isotropic physical characters and easy feasibility. The rock fragments comprising gneiss and granite exhibit unsystematic variation irrespective of their size in this regard. The mean diameter show higher frequency for quartzite, gneisses and granite in older and for quartzite in younger terraces. The flatness exhibit specific tilt, towards phyllite slate. It seems to have inverse relation with the sphercity and roundness and does not exhibit any systematic variation and their average value is restricted to the range of 0.15 to 0.25. It is perhaps due to their amenability to rapid break down during the transport. Such effect appears to be least pronounced near the source area, but get stronger expression away from it.

The rock clastics of younger terraces in general show higher order of sphericity and roundness. It appears to be due to repeated cyclic reworking of sediments towards later phases in the history of river sedimentation of different terraces both after Zing's (1935) and modified by Krumbein (1941). Sneed and Folk (1958) have shown in adequacy of Zings chart and instead have introduced ten form classes. The sphericity and roundness have been estimated visually with the help of standard chart given by the mean size was calculated by measuring a, b, c, axes of rock pebbles and flatness was calculated by the formula

Graded Bedding:-

In the graded bedding in coarser clastics comprised of sequence of alternate beds of sub-rounded to well rounded boulder cobble, pebble in the matrix of coarser to fine sand. The basal units are often marked by boulder layer overlying either scoured surface of bed rock or the end bed of underlying cycle of sediments. The thickness of individual bed unit is highly variable. The relative thickness of these beds range from 80 to 150 cm. 20 to 45 cm and 10 to 35 cm in respect of boulder, cobble and pebble is respectively. At places the thickness of boulder units exceeds 300 cm. The cyclic development of graded bedding in the middle order terraces NT2-A, NT2-B, NT3-C is most common, whereas in the younger terraces the cycles are often incomplete and truncated by overlying sediment the graded bidding portsrays upwand fining sequence. It is seen in Bhelaria Ghat, Shivpur and Shipra river section. (Plate No _2)

Cross Bedding:-

The cross bedding in coarser clastics is observed at very few places. These are mostly planner type, and have typically tangential contacts with underlying sediment units or bed rock.The thickness of these cross beds ranges from 80 to 250 cm. whereas the mean thickness is 160 cm. The fore set indication varies between 20 and 250 and average value in general increase towards younger terraces in the valley.
(Plate No _2 &3)

Graded Lamination:-

The graded lamination is typically seen associated in sandy horizons of middle and lower sequence of deposits terraces around Denawar, Bhilar. It mainly comprised different units of light to dark yellow coarse to fine sand containing appreciable amount of quartz, feldspar and basic granules, dark ash colour coarse to fine miraculous sand, light to dark maroon coarse to fine sand, silt and clay, and dark brown coarse to fine sand, sandy silt and clay. The basal units generally comprise coarse sand associated with granites of quartzite followed to medium to fine sand and end with very fine sand or silt and clay. The individual lamine are often marked by colour banding parting or with concentration of mica flakes. The thickness of the individual lamine is highly variable and varies between 2.5 mm and 15 mm. The cyclic development of graded lamination is most common in the study horizons of in flood plain deposits and fluvial terraces of Narmada. (Plate No _6 to 8)

Cross Bedding:-

The cross bedding is the most prominent sedimentary structure in the middle and lower terraces NT2-A, NT2-B, NT2-C & NT3 it is most relevant in the coarse to fine sand, coarse to fine micaceous sand, light yellow to dark yellow coarse to fine sand, light brown maroon coarse to fine sand, silt and clay fine sand and pebble. These cross beds are both planar and through type corresponding to microns and phi class Allen (1963) the former one is most common. The planar cross beds have tangential relation with underlying sediment units. The thickness of fore usually ranges from 45 to 95 cm, although at places it exceeds to 120 cm. The mean thickness is 55 cm. In general the thickness of fore set increases towards younger terraces. (NT0-NT1).

The cross bedding fore set inclination ranges between 50 to 20, the mean fore set inclination for middle terraces is about 12 and for younger terraces 15.5. The value of this angle increases towards younger terraces. NTO, NT1.

The development of planar cross bedding is commonly ascribed to the movement of the sand bar in the valley, under the flat environment during the flood, similarly trough cross bedding is considered to be due to the development and filling of hollow during the migration of river (Plate No _2 to 5)

Cross Lamination:-
The Cross lamination are very similar to cross bedding with the difference that cross laminated sets typically less than 10 cm in thickness. These structures have been variously called ripple cross lamination, ripple lamination (Mckee, 1965) and ripple drift cross lamination, (Jopling and Walker, 1958). All these terms have genetic connotation. Here non-genetic terms cross lamination is used. These are both planar and trough type (Jopling and Walker, 1968), cross stratification of Allen, 1963), and trough cross lamination (NU Cross stratification of Allen, (1963), the former one is most common and the later is occasionally seen. These features are mostly confined to the finer sediments comprising predominantly coarse to fine micaceous sand, light to dark maroon coarse to fine sand, silt, dark brown fine sand, silt clay, and light yellow coarse to fine sand. The cross lamination and cross bedding although differ in size but their genetic process of formation is almost same. Roger G. Walker (1969),

In the dynamic fluvial domain these features are originated when traction and fall out operates simultaneously and bed load and suspension population are therefore, mixed even though occasionally graded. The development of a particular type of ripple drift cross lamination requires persistent balance of various factors; particularly the current velocity and the ratio of deposition from suspension to bed load. No natural mechanism other than tidal current appears to adequately provide this balance.

The initial bed load from ripples and dunes which are identical in form and migrate laterally during the process of sedimentation. These bed forms originate in non-cohesive bed material in response to shearing action of the flow. As soon as the bed material starts moving under the action of both flow and gravity, ripples appear and with increasing stream power, dunes form. Migration of ripples and dunes give rise to cross lamination and cross bedding respectively. The shape characteristic of cross-lamination and cross-bedding is controlled by grain size of bed material, and amount of contribution from suspension to the deposited material, as well as hydrodynamics. The thickness of co-set exhibiting cross-lamination for middle order terraces viz. NT1-B, NT3 ranges from 45 to 65 cms and for younger terraces from 75 to 95 cms. In general the mean thickness increases towards lower terraces in Narmada valley.These features are observed around Hathnora, Shahgunj, Hosagngabad, Shivepur, and Bhilariaghat (Plate No _8 to 9)

Planar Lamination:-
The planar lamination is typically seen in coarse to fine micaceous sand, light to dark maroon coarse to fine sand, light to dark brown fine sand, silt and clay and light yellow coarse to fine sand and silt. These matrix constitute thin lamine of variable thickness ranging from 5 mm to 35 mm. At places the thickness of coarse micaceous sandy units exceeds 50 mm. These units are horizontally disposed or make small angle with the other bedding planes. These are separated by either colour parting or concentration of mica flakes. The well-preserved planar lamination is seen in the fluvial terrace deposits of NT2-A, NT2-B & NT3 in central part of valley. These features are observed around Hathnora, Shahgunj, Hosagngabad, Shivepur, and Bhilariaghat, Sardarpur and in river section up stream of Narsighpur. (Plate No _6 & 7)

Ripple Marks:-
The fluvial sediment of younger terraces display ripple marks which are both symmetrical and asymmetrical type, the later being the most common. These features are mostly associated with active flood plain and NT0-NT1 of Narmada and Tawa river section around the confluence area near Hoshangabad. The wave length varies from 15 to 30 cms. The mean length is 22.5 cms. The amplitude is up to 4 cm and ripple index ranges from 5 to 15. In general these are minor sedimentary structures and are found to be associated mostly with lower terraces and present day flood plain of the river.

The other sedimentary features of minor scale observed in the fluvial terraces are current lineation, cut and fill features, bedding planes and typical trapped elongated, lenses of fine micaceous sand embedded in light maroon and brown coarse to fine sand, sandy silt and clay. These are mostly exposed in the terrace section. The width of these lenses ranges from 15 to 30 mm and mean width is 16.5 mm. The length varies from 5 to 10 cms. The larger axes of these lenses make obtuse angle with the present day channel course of Narmada these appear to have formed due to filling up the gaps and cavities by the channel during the swing in the late history of sedimentation in the valley. (Plate No _1 & 2)

Rib and Furrow Structures:

The fluvial domain of sediment display ill preserved rib and furrow structure at very few places. These are small transverse markings which occur in sets confined to relatively long narrow grooves separated from one another by very narrow continuing ridges. These grooves are essentially parallel to one another to the direction of current flow. The ridges generally consists of light to dark brown coarse to fine sand silt with sub-ordinate amount of clay forming the small relief between longitudinal grooves. The average width of these grooves ranges from 25 to 35 cms and length from 25 to 50 cms. These features are observed at very few places generally associated with the ripple marks cross bedded and laminated units of sandy horizons of terraces. These features are observed around Hathnora, Bhilariaghat, and Sardarpur and in river section down stream of Hoshangabad.

Sedimentary Structures of Active Flood Plain:-

The point bar, sand bar and levee deposits associated with the present day active domain of Narmada around Hoshangabad consist of various sedimentary structures, which were developed in response to existing hydrodynamic condition of channel. These sedimentary structures include various types of features viz. surface marking and pene-cortemporaneous deformation features

Bedding structures:-

Following types of large scale cross bedding have been observed:

Scour and Fill Cross Bedding:-

This structure has been noticed in the area ground confluence of Narmada & Tawa at Hoshangabad, where Narmada broaden out its course and comprises of relatively very large point bar, sand bar and channel braids. The scour and fill structures are series of minor asymmetrical troughs with their longer axes parallel to the current direction, these trough are filled by horizontal lamine, up current dipping lamine, down current dipping lamine, through back filling is most common Renik &, Singh (1977) reports them from Ganga River Sediments. It is believed, that secour and fill cross-bedding is produced due to pulsation in the velocity during the flood. A sudden increase in velocity at any point leads to development of an irregular scoured surface, which is filled in by the sediments in response to the decrease in the current velocity of stream. The decrease in the velocity leads to sudden dumping of the sediments on the scoured surface, so that rarely laminations are visible. Later, deposition takes place under stabilized condition and lamination are prominent. In the next pulsation of the increased velocity the surface is again scoured and the whole process is repeated. The cyclic repetition of the process of the frequential change of system is related with repetitive upwards fining sequence of fluvial deposit. (Plate No _2 & 3)

Channel-Fill Cross-Bedding:-

This structure is observed in the flood palin and natural lavee cut across by crevasse-splay which is observed and recorded around Sardarpur and Bhilariaghat. Its dimension and genesis has been discussed in detail by Singh (1972 b). During floods, channel cutting across the levee are formed, which are filled mainly by suspension load during receding floods. In succeeding flood periods, the same channel partly eroded and refilled producing a succession of through shaped cross bedded units. The layers of cross-bedding are made up of sandy-silty material and often plants remain and fresh water molluses are concentrated in the pockets.

Mega Ripple Bedding:-

The Mega – ripple bedding is recorded in the point bar sequence of Narmada at Hoshangabad, Bhilariaghat, and Shivepur. This type of bedding is also seen in the lower sequence of point bar in the other localities in Narmada viz. at Sardaopur, Jaitpur Gotegaon section. (Plate No _4)

Small Ripple cross bedding:-

The bedding is made up of sets of fore set lamine, which do not show any climbing or upward building tendency. The cross – bed units are 1-3 cms thick and invariably trough shaped. In Narmada, Dudhi and Ganjal river sections small ripple cross bedding is mostly recorded in point bar deposits. On an average this bedding makes 65-85% of point bar sequence in the deposit of fluvial domain of Narmada. The active flood plain and coalescing channel and flood plain sediments of Tawa in the confluence area of Tawa and Narmada embraces luxurious assemblage of this features. In river section in the flood sediment in the unit section measuring about of about 2 m small ripple cross-bedding are quite common. It is often seen that this unit occurs intricately inter- bedded with the horizontal bedding in the point bar sequence. (Plate No _5)

Climbind Ripple Lamination:
The climbing ripple lamination bedding is formed during forward migration and simultaneous upward growth of the ripples. In sections, cut parallel to the direction of flow, fore set lamine show a tendency of climbing. Mckee (1965), Jopling and Richardson r (1966) provide good discussion on the classification and the gneiss of climbing ripple lamination.

Small ripple cross bedding and climbing ripple lamination are closely related. If little sand is available in suspension, the former is formed; with increase in supply of suspension load, climbing-ripple lamination with only lee-side lamine are formed C type I of Joping and Walker (1968); with the further increase in suspension load, climbing ripple lamination with well preserved lee- and – stows – side are developed (type II of Jopling and Walker 1968). In cease in suspension load also causes increase in the angle of climb of the lamine.

In Narmada climbing – ripple lamination are commonly seen associated in upper point bar sequence constituting average 75 cm. thick units. Some times they occur closely associated with small ripple cross – bedding. On an average climbing ripple lamination accounts for 25% of total bedding features in point bar sequence in Narmada & Tawa. In association with small ripple cross bedding it constitute over 66% of the point bar sequence.

Antidune Cross Bedding:-
Antidune are ripple like features formed in upper flow regime under the condition of rapid flow (Gilbert, Simons 1965). If antidunes have been active at some place and enough sediment is available they leave behind characteristic cross bedding, made up of thin lenticels inclined at low angles both up stream and down stream (Middleton 1965; Wunderlich 1972; Reinec and Singh 1973). Within the lenticels; lamination is very faint because of the extremely high rate of deposition during the movement of antidunes. In Narmada the antidune cross bedding are recorded in upper part of the point bar sequence around in the confluence area of Narmada and Tawa ground Hoshangabad. (Plate No _3 & 4)

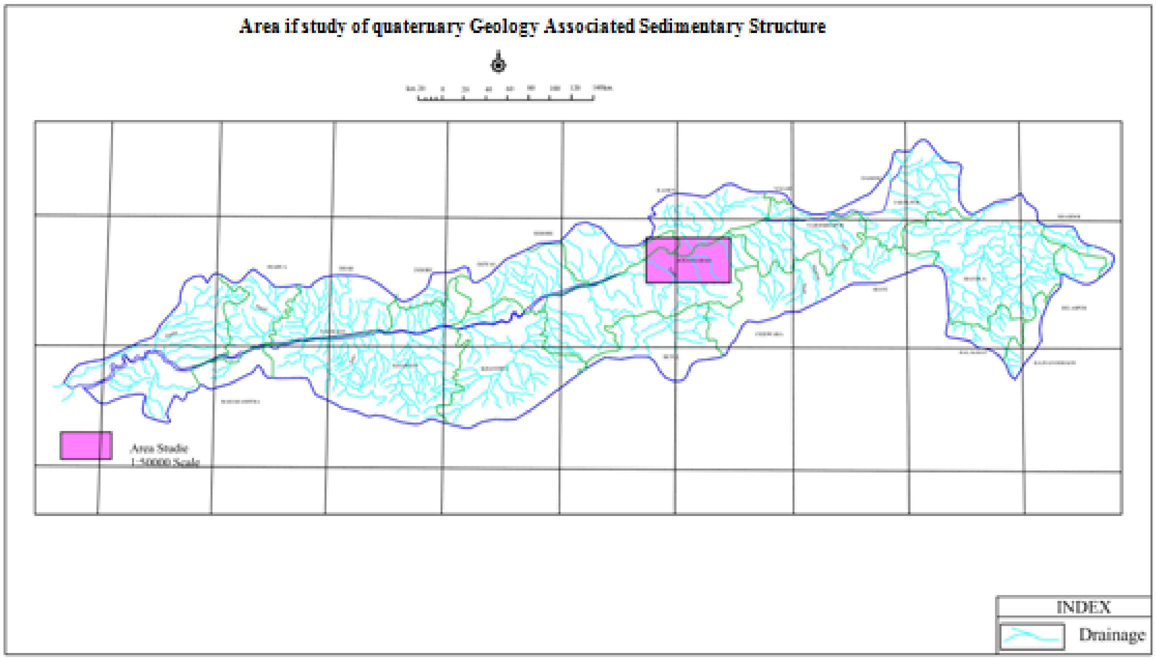
Other features:-

Erosional Channels:-
Small erosional channels (about 1.5 m in cross section) filled with sediments conforming to their general shape are seen in natural levee deposits. These channels are filled up by sand, silt and plant debris. The filling of such channels conforms to the general shape in the lower part. Upwards sediments show horizontal bedding and ultimately grade into over lying sediments. (Plate No _5)

Mud Pebbles:-
The mud pebbles are seen in point bar sequence in Narmada Hiran and Shakkar river section. These pebbles are mostly discoidal bodies up to 5 cm length.. The mud pebbles ranging in size 25-35 cm length and 5-15 cms height are quite common and often occur concentrated in the central part of point bar sequences. (Plate No _2)

Mud Layers:-
In the point-bar deposit of Narmada river around Shivepur Nasrullahgunj few mm to 1-2 cm thick mud layers are present. These layers appear to have been deposited under high velocity conditions. These mud layers mostly show faint thin lamination and possess minute streaks of fine sand and silt. (Plate No _2 & 3)

Plate No. 1


Area if study of quaternary Geology Associated Sedimentary Structure
Area Studie
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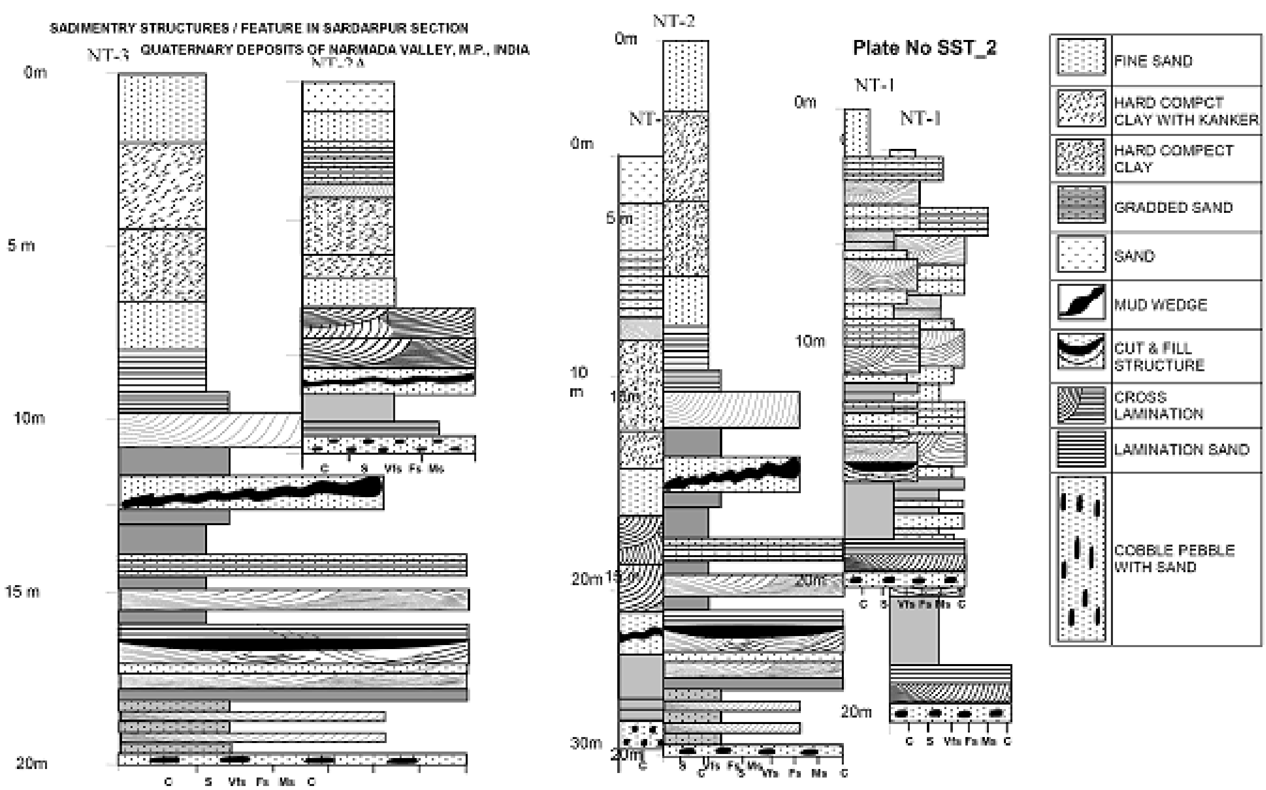
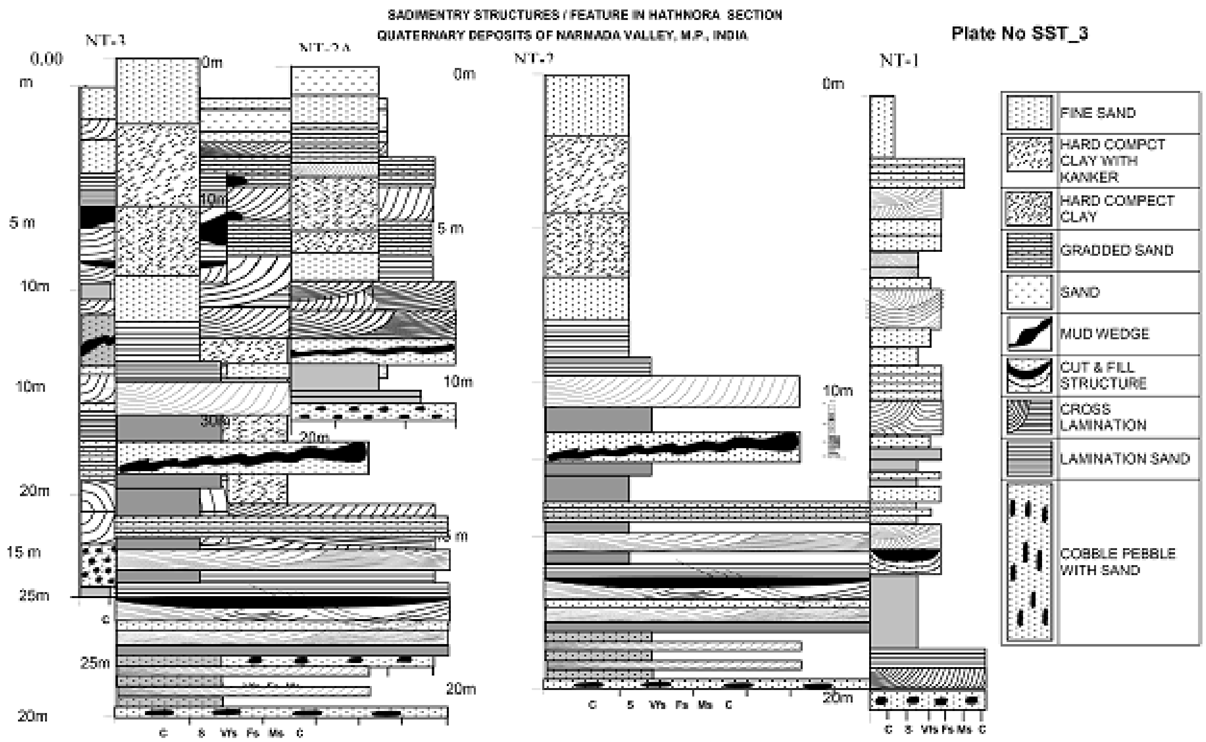
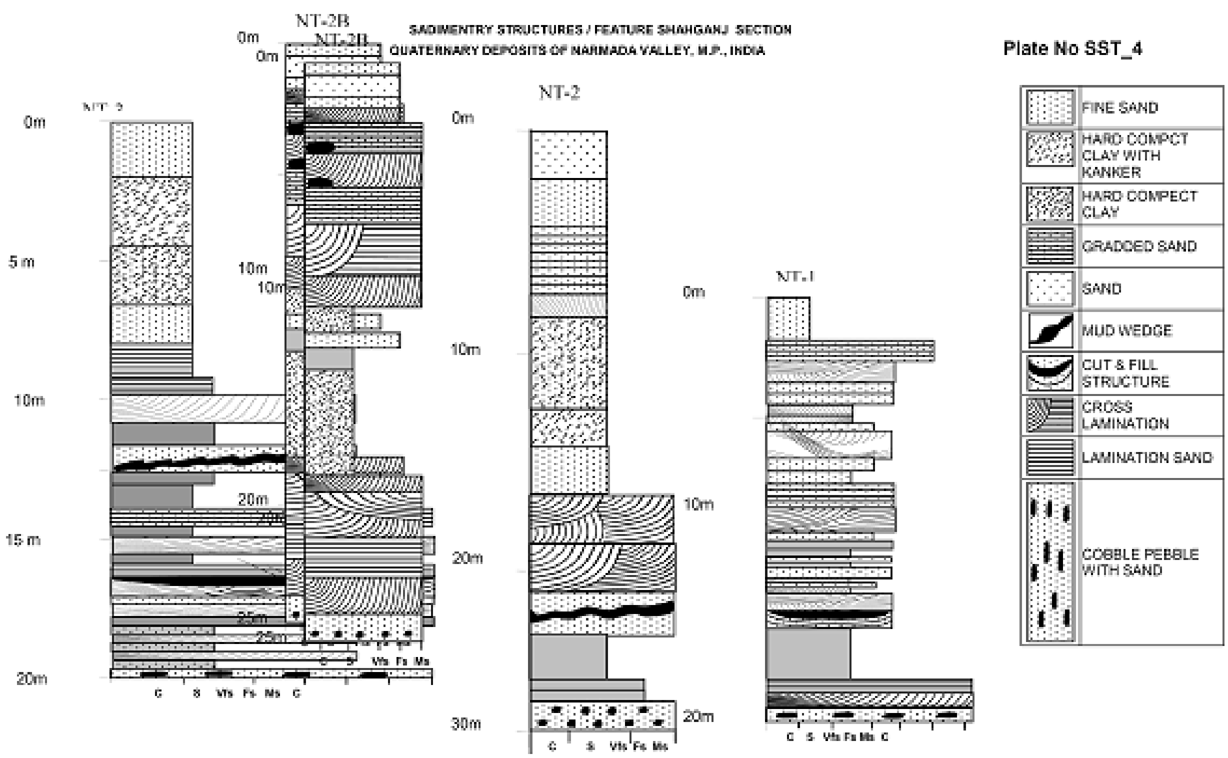
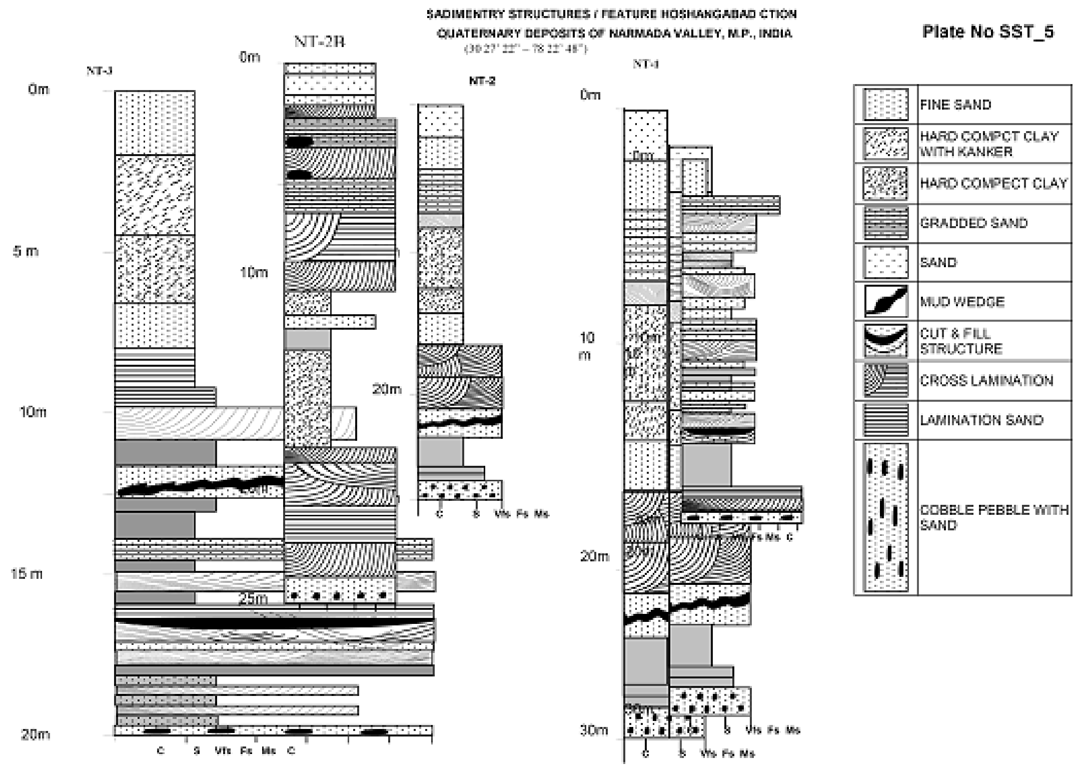
INDEX
Drainage


SADIMENTRY STRUCTURES / FEATURE IN SARDARPUR SECTION
QUATERNARY DEPOSITS OF NARMADA VALLEY, M.P., INDIA
NT-3
0m
5 m
10m
15 m
20m
C S Vfs Fs Ms C
NT-2
NT-1
Plate No SST_2
FINE SAND
HARD COMPCT CLAY WITH KANKER
HARD COMPECT CLAY
GRADDED SAND
SAND
MUD WEDGE
CUT & FILL STRUCTURE
CROSS LAMINATION
LAMINATION SAND
COBBLE PEBBLE WITH SAND

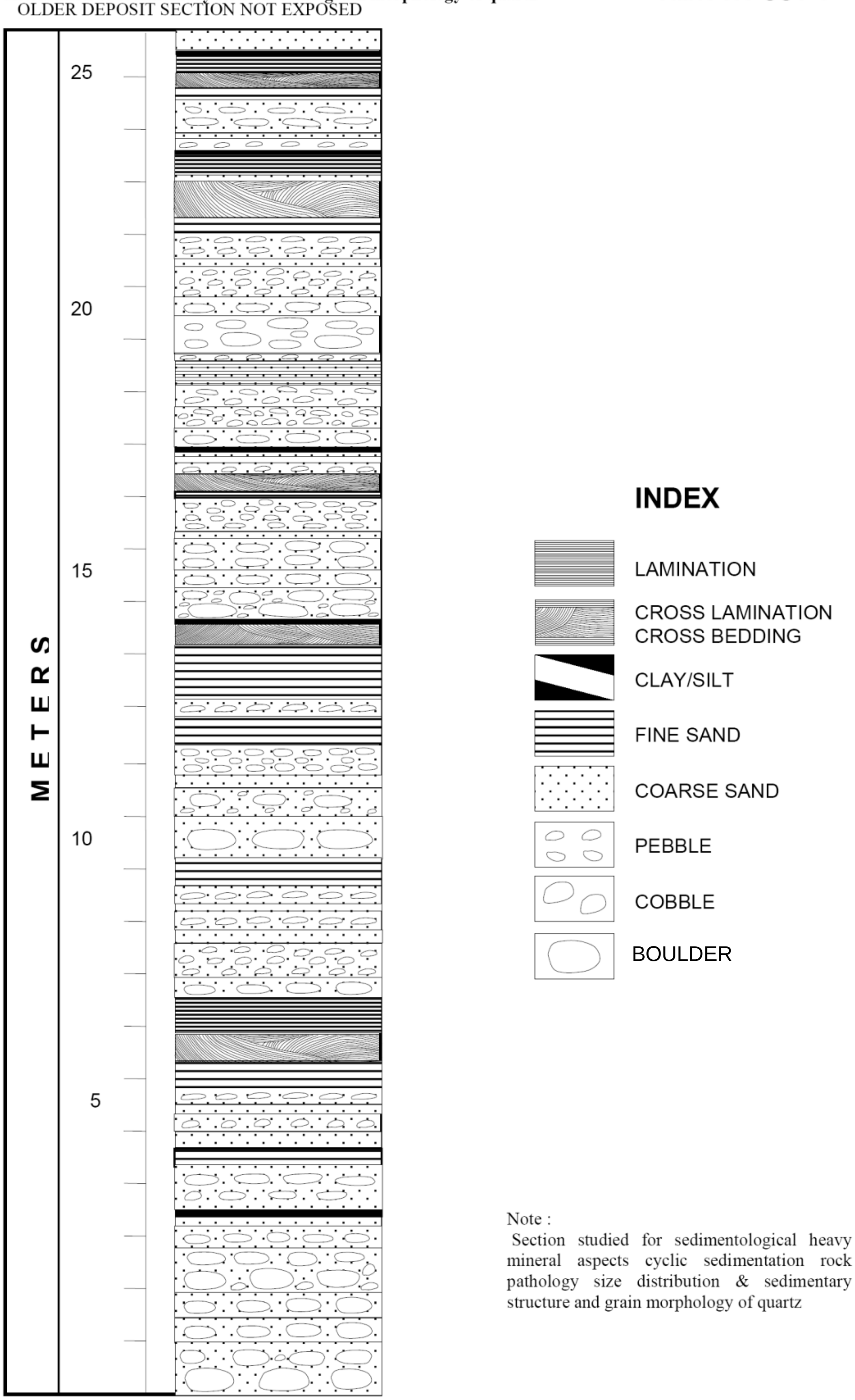

SADIMENTRY STRUCTURES / FEATURE IN HATHNORA SECTION
QUATERNARY DEPOSITS OF NARMADA VALLEY, M.P., INDIA
Plate No SST_3
NT-3
NT-2A
NT-2
NT-1
FINE SAND
HARD COMPCT CLAY WITH KANKER
HARD COMPECT CLAY
GRADDED SAND
SAND
MUD WEDGE
CUT & FILL STRUCTURE
CROSS LAMINATION
LAMINATION SAND
COBBLE PEBBLE WITH SAND


SADIMENTRY STRUCTURES / FEATURE SHAHGANJ SECTION
QUATERNARY DEPOSITS OF NARMADA VALLEY, M.P., INDIA
Plate No SST_4
NT-2B
NT-2
NT-1
FINE SAND
HARD COMPCT CLAY WITH KANKER
HARD COMPECT CLAY
GRADDED SAND
SAND
MUD WEDGE
CUT & FILL STRUCTURE
CROSS LAMINATION
LAMINATION SAND
COBBLE PEBBLE WITH SAND


SADIMENTRY STRUCTURES / FEATURE HOSHANGABAD CTION
QUATERNARY DEPOSITS OF NARMADA VALLEY, M.P., INDIA
Plate No SST_5
NT-3
NT-2B
NT-2
NT-1
0m
5 m
10m
15 m
20m
25m
30m
C S Vfs Fs Ms
FINE SAND
HARD COMPCT CLAY WITH KANKER
HARD COMPECT CLAY
GRADDED SAND
SAND
MUD WEDGE
CUT & FILL STRUCTURE
CROSS LAMINATION
LAMINATION SAND
COBBLE PEBBLE WITH SAND

SARDARPUR SECTION studied for sedimentological heavy mineral aspects cyclic sedimentation rock pathology size distribution & sedimentary structure and grain morphology of quartz

Table No SST-6

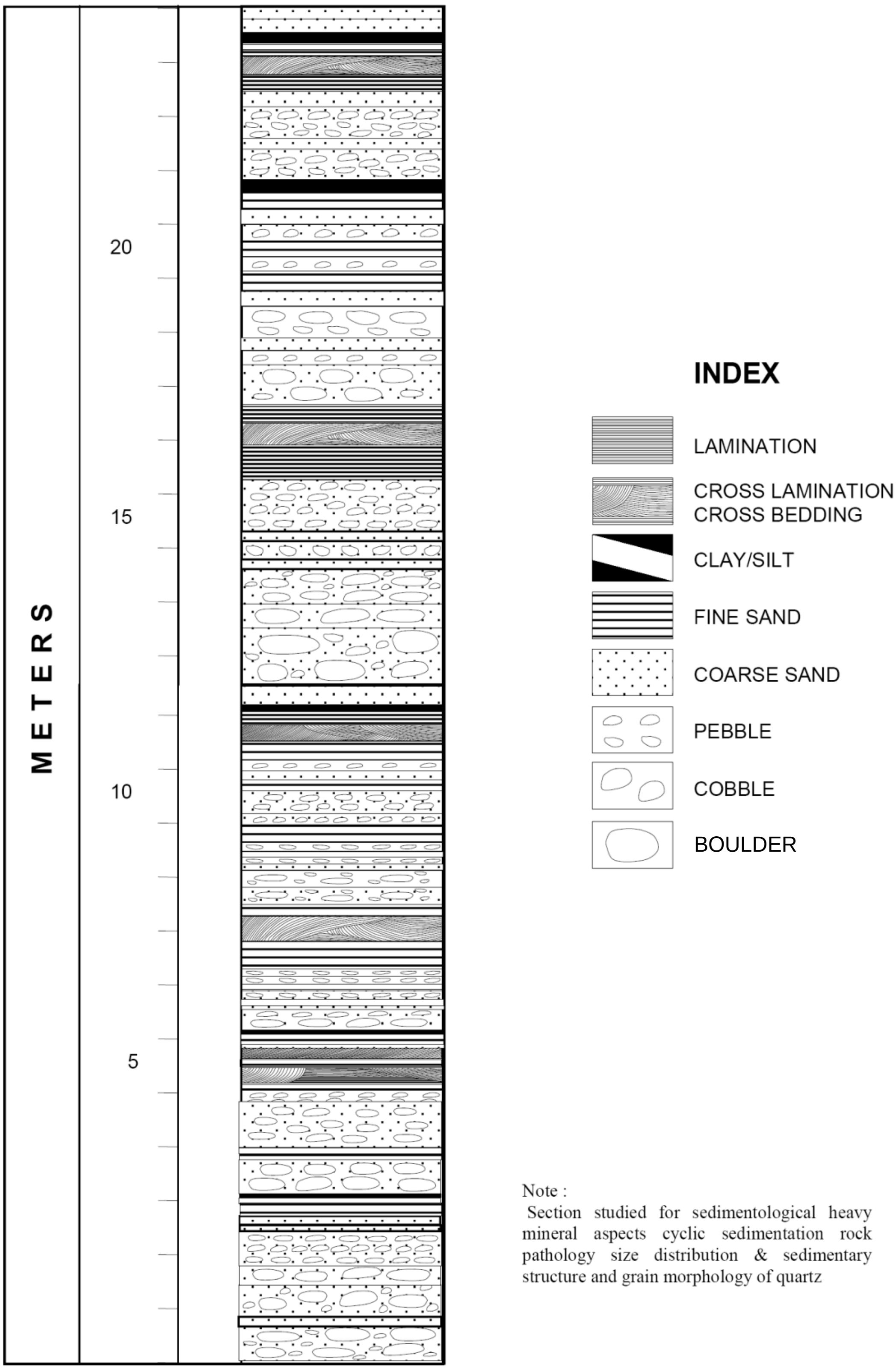


Note :
Section studied for sedimentological heavy mineral aspects cyclic sedimentation rock pathology size distribution & sedimentary structure and grain morphology of quartz

HATHNORA SECTION studied for sedimentological heavy mineral aspects cyclic sedimentation rock pathology size distribution & sedimentary structure and grain morphology of quartz

Table No SST-7

OLDER DEPOSIT SECTION NOT EXPOSED

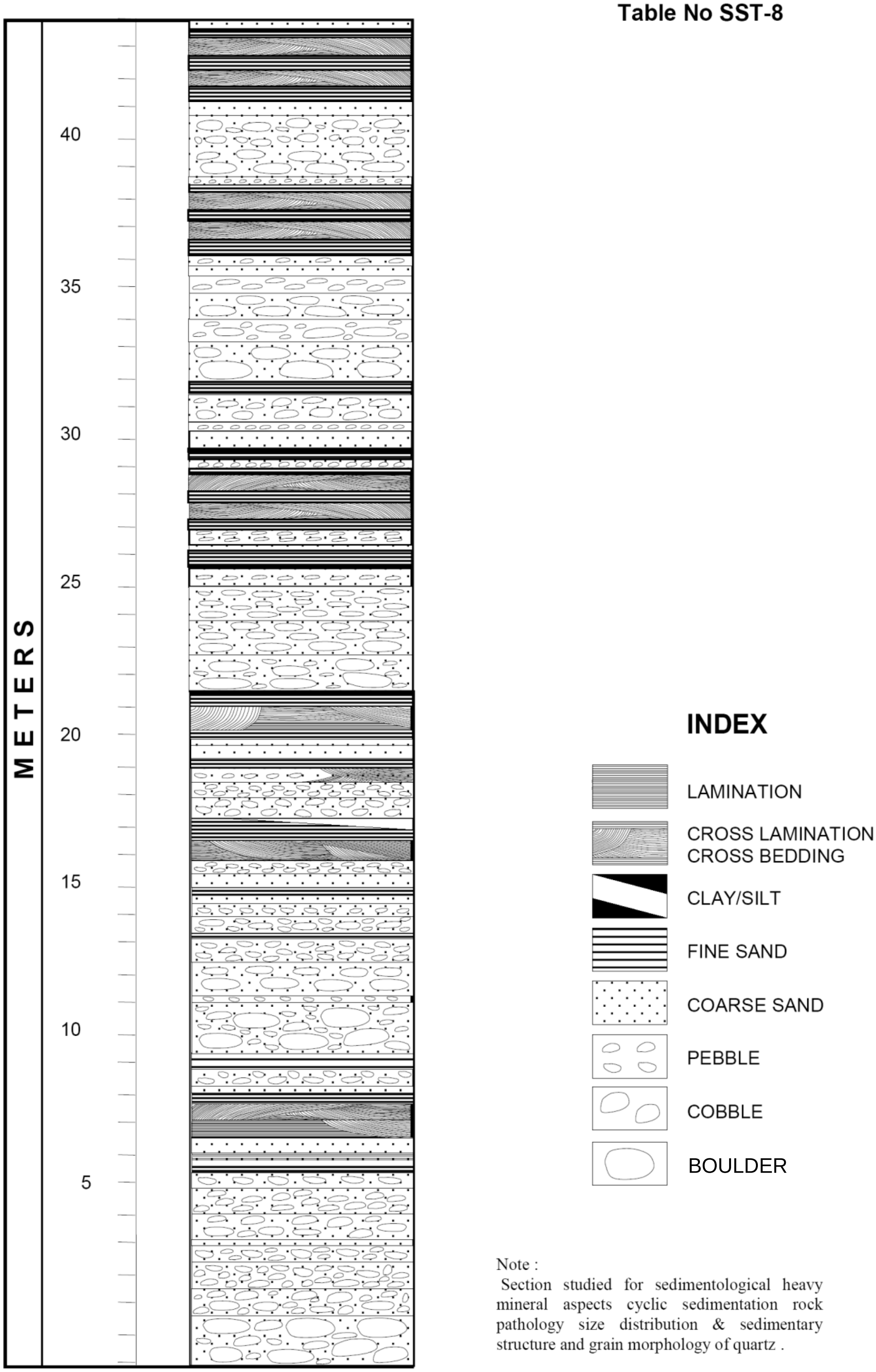


Note :
Section studied for sedimentological heavy mineral aspects cyclic sedimentation rock pathology size distribution & sedimentary structure and grain morphology of quartz

OLDER DEPOSIT SECTION NOT EXPOSED

SHAHGANJ SECTION studied for sedimentological heavy mineral aspects cyclic sedimentation rock pathology size distribution & sedimentary structure and grain morphology of quartz

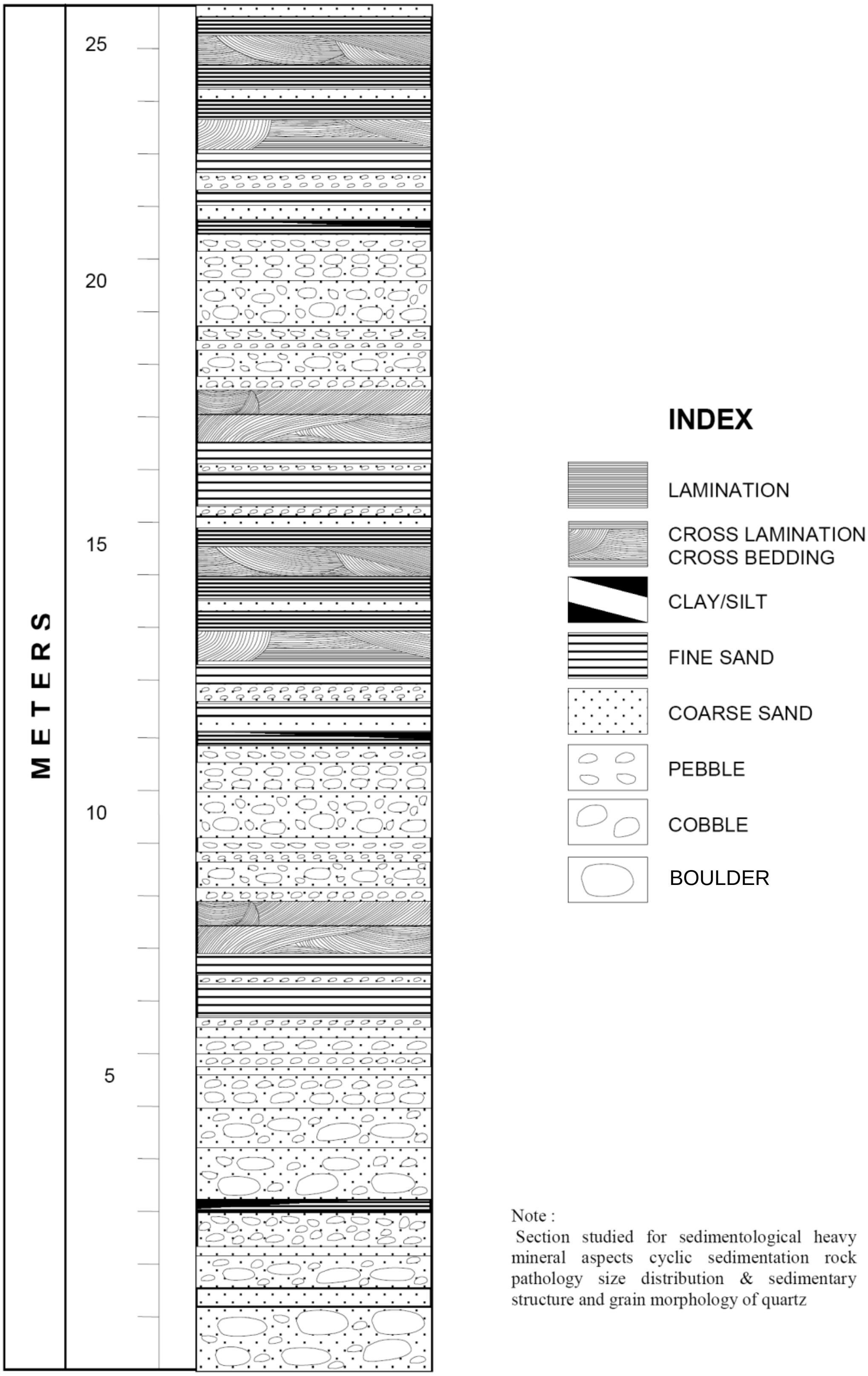
Table No SST-8



Note :
Section studied for sedimentological heavy mineral aspects cyclic sedimentation rock pathology size distribution & sedimentary structure and grain morphology of quartz .

HOSHANGABAD SECTION studied for sedimentological heavy mineral aspects cyclic sedimentation rock pathology size distribution & sedimentary structure and grain morphology of quartz

Table No SST-9



Note :
Section studied for sedimentological heavy mineral aspects cyclic sedimentation rock pathology size distribution & sedimentary structure and grain morphology of quartz

OLDER DEPOSIT SECTION NOT EXPOSED

Summary & Conclusion:-

The Rift valley formed a linear trench in the middle of Indian subcontinent was an ideal loci 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 on unstable platform where the, block faulting and linear displacement and dislocation, uplifting and isolated domal up- lift, Neogene rifting and is conspicuos feature of Quaternary sedimentation. The 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 Narmada Valley area around Hathnora is occupied by thick Quaternary sediments. These sediments are classified based on sedimentary depositional environments, sedimentological characters and correlation with depositional / erosional terraces. The lowermost units (Boulder bed) is or glacio-fluvial origin (Khan *el al* 1991) whereas the rest of fluvial origin. The top four formations (Sohagpur, Shahganj, Hoshangabad and Janwasa) are classified based on morphostratigraphic state (NT_o-NT_3), degree of oxidation, calcification and compaction. The Janwasa formation comprises of sediments of active channel deposition and is the older three (Sohagpur, Shahganj, Hoshangabad formation) are related to older flood plains deposits of paleo-do-main of Narmada and are grouped under older alluvium. Boulder conglomerate of fluvio-glacial origin 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 70 m top 90 m of the Narmada alluvium was deposited in a single aggradations episode with minor pauses when dissection of the alluvium produced two terraces (NT_3-NT_2). The sediments of this aggradations episode constitute three lithostratigraphy units viz. Boulder conglomerate, Sohagpur and Shahganj 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) These deposits display various sedimentry structuresin with different intensity and frequency in vertial coloumns.The gradded bedding,cross bedding, cut &fill features, ripple marks and cross bedding scour features, climbing ripple , cross lamination. The fossiliferous basal boulder conglomerate is being of middle Pleistocene age (Khan 1992) in the Hathnora section display cross bedding, cross lamination, gradded lamination scour features and cut and fill features.

The Quaternary deposits of both paleo and present domain comprised of sediment of both coarser sediment (more than 256 mm) and finer sediments (less than 16 mm). The coarser sediments display graded bedding in of sequence consisting of alternate layer of sub-rounded to well rounded boulder cobble, pebble in the matrix of coarser to fine sand. The basal units are often marked by boulder layer overlying either scoured surface of bed rock or the end bed of underlying cycle of sediments. The thickness of individual bed unit is highly variable. The relative thickness of these beds range from 80 to 150 cm. 20 to 45 cm and 10 to 35 cm in respect of boulder, cobble and pebble is respectively. At places the thickness of boulder units exceeds 300 cm. The cyclic development of graded bedding in terraces NT2-A, NT2-B, NT3-C is most common, whereas in the younger terraces the cycles are often incomplete and truncated by overlying sediment. The graded bedding portrays upward fining sequence. The cross bedding in coarser clastics is observed at very few places. These are mostly planner type, and have typically tangential contacts with underlying sediment units or bed rock. The thickness of these cross beds ranges from 80 to 250 cm. whereas the mean thickness is 160 cm. The fore set indication varies between 20 and 250 and average value in general increase towards younger terraces in the valley.The graded lamination in the finer sediment is typically seen associated in sandy horizons of middle and lower sequence of deposits terraces .

The cross bedding is the most prominent sedimentary structure in the middle and lower terraces NT2-A, NT2-B, NT2-C & NT3 it is most relevant in the coarse to fine sand, coarse to fine micaceous sand, light yellow to dark yellow coarse to fine sand, light brown maroon coarse to fine sand, silt and clay fine sand and pebble. These cross beds are both planar and through type corresponding to microns and phi class Allen (1963) the former one is most common. The planar cross beds have tangential relation with underlying sediment units. The thickness of fore set usually ranges from 45 to 95 cm, although at places it exceeds to 120 cm. The mean thickness is 55 cm. In general the thickness of fore set increases towards younger terraces. (NT0-NT1). , Sardarpur, Telankhedri, Hathnora, Shahganj Hoshangabad Demawar, Narmada section.The cross bedding fore set inclination ranges between 50 to 20, the mean fore set inclination for middle terraces is about 12 and for younger terraces 15.5. The value of this angle increases towards younger terraces. NT0, NT1.

The development of planar cross bedding is commonly ascribed to the movement of the sand bar in the valley, under the flat environment during the flood, similarly trough cross bedding is considered to be due to the development and filling of hollow during the migration of river.

The Quaternry deposits of Narmada display different intensity and frequency of ocuurence and aboundence of sedimentry structures in different doamin, the glacial deposits show low frequency of occurrence, the fluvio-glacial moderate frequency whereas the fluvial domain the highest intensity in increasing antiquity. The fluvial domanin (NTo-NT3) ehxibit further increasing antiquity to wards the yonger deposits and ultimately the present flood plain display gradded nature of river. The association of rock gravel associated with snad of different grade and size, size distributiob of rock febrics, occurnce of different cycles, pethology of rock gravel of sediments of different domain and association of sedimentry strucures in increasing antiquity in stratigraphic coloumn depict relicts' hiden mystries of tectonisam of rift valley.

The imprints of sedimentation, tectonics and dynamic fluvial domain are causative factor of these features which area are originated when traction and fall out operates simultaneously and bed load and suspension population are therefore, mixed even though occasionally graded. The development of a particular type of ripple drift cross lamination requires persistent balance of various factors; particularly the current velocity and the ratio of deposition from suspension to bed load. No natural mechanism other than tidal current appears to adequately provide this balance. The initial bed load from ripples and dunes which are identical in form and migrate laterally during the process of sedimentation. These bed forms originate in non-cohesive bed material in response to shearing action of the flow. As soon as the bed material starts moving under the action of both flow and gravity, ripples appear and with increasing stream power, dunes form. Migration of ripples and dunes give rise to cross lamination and cross bedding respectively. The shape characteristic of cross-lamination and cross-bedding is controlled by grain size of bed material, and amount of contribution from suspension to the deposited material, as well as hydrodynamics. The sedimentation of quaternary deposits incepting by glacial activity at rock basin followed by fluvio-glacial and terminating with fluvial activity, the last one is more dynamic has resulted these features under fluctuating energy condition. The sediment load is by suspension and partly by traction bed load. The thickness of co-set exhibiting cross-lamination for middle order terraces viz. NT2-A NT2-B, NT3 ranges from 45 to 65 cms and for younger terraces from 75 to 95 cms. In general the mean thickness increases towards lower terraces in Narmada valley. These features are observed around Hathnora, Shahgunj, Hosagngabad, Shivepur, and Bhilariaghat.

The pethology of rock fabrics of terrace gravel and their abundance and distribution reveals that the span of deposition of boulder conglomerate represent the specific and diagnostic phase of sedimentation that the rock constituents are co- relatable to selected rock units as per their disposition and lithological and tectonic conformity in watershed region which were subjected to extensive erosion in the eventual phase of change of climatic changes during sedimentation. The Quaternary terraces of fluvial domain comprised of three terraces designated as NTo to NT3in increasing antiquity the terrace NT2 is further divided in to three units as NT2-A, NT2-B, NT2-C in increasing antiquity with reference to active flood plain of river.

In Sardrpur –Hathnora—Shahganj -Hoshangabad section critical and crucial study of exposed section of Quaternary deposits of Narmada revealed that sediments which constitute various lithouints are characterized by association of distinct and diagnostic rock fabrics clay and silt matrix. The units further constitutes a thick sequence of quaternary strata comprises of thick of boulder, cobble, pebbles of quartzite, gneiss, granite, schist, phyllite, slate, basalt limestone sandstone augate chert and chalcedony in different proportion assemblage. These rock clastics range in size from >64 and < 256 mm and constitute horizontally bedded disposed units of variable thickness depicting various sedimentary structures. Each unit is characterized by specific size association of rock fabric/sediments, and rock composition sedimentary structures and other diagnostic sediment characters, categorizing distinct regime of deposition of that specific unit of specific energy level. The successive repetition of units of allied characters is quite frequent in terrace sections. The repetition of each unit marks the completion of single cycle and represents particular phase of energy condition of the channel under which the sediments were deposited. On the basis of study of terraceabot 37 sections around upstream Sardarpur, Nathanhkeri, Shahgunj, Hoshangabad Hathnora Bhariagaht in the different fluvial terraces (NT1 to NT3) of Narmada indicate nine types of cycles as identified (Khan 1981 and Khan et al 1981). These cycles have been classified as main cycles and sub-cycles which suggest cyclic sedimentation realted with tectonisam and cyclic pulsation of rift trench platform of sedimentation.

It is witnessed from the study that the concentration of boulders and cobble ranging in size from 64 mm to >256 mm (15.50 to31.50 percent) is characteristically restricted mainly to the older terraces viz. NT2-A, NT2-B, NT2 & NT3 which contributes 33% boulder of its total sediments being highest in the valley. The affinity of boulder and large cobble (14.00 to 21.50 percent) small cobble (9.50 to 18.00) with the older terrace indicates high load carrying capacity of the paleo channel of Narmada during the early stages of sedimentation. The highest confinement of boulder with the third terrace NT3 (31.50 percent) is perhaps indication of reactivation in the energy system and load caliber of the channel during this particular phase of sedimentation.The present river is nearly graded in nature and is misfit in its own valley as is evident from the occurrences of numerous channel braids point bars, sand bar, braided point bar, channel bar in the present day course of river. These landforms comprises of heterogeneous assemblage of rock boulder, cobbles, pebbles of diverse size and shape of different rock in matrix of coarse to fine sand are mostly reworked sediments

The study of occurrence of these cycles and their and frequency reveals that the main cycles a, b, c, chiefly consist of boulder cobble and pebble predominant in older terraces NT-3and NT2-B, NT2-C.

Further synthesis of data relating to the size distribution of rock clastics, relative thickness, of sediments, sedimentary pattern, degree of sorting, imbrications pattern, plunge of larger axes of the pebbles, it is deduced that

There was frequential change in the operational competence and capacity of stream load and discharge throughout the history of river sedimentation.

The current velocity of stream was highly fluctuating from turbulent to sluggish and was mainly controlled by micro-climatic changes in the headward ends of channel.

The current velocity of stream was predominantly violent and torrential during the early stages of sedimentation, perhaps due to tectonic dislocation of consequential the release of impounded energy of in the stream due to high gradient.

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