Jour. Indian Association of Sedimentologists, Vol. 36, No. 1 & 2 (2019), pp.3-18
ISSN Online 2582 – 2020
ISSN Print 0970 – 3268

Facies variation in a half graben tectonic model: case study from Kolhan Basin, Jharkhand-Orissa

Rohini Das[1] and Subhashish Das[2]
Department of Geology and Geophysics, IIT Kharagpur, PIN: 721302, India
Rohini Das, Department of Geology and Geophysics, IIT Kharagpur, PIN: 721302, India.
E-mail romiyadas@gmail.com

Abstract: The pear shaped Kolhan Group in the studied sub-basins of Chaibasa–Noamundi and Chamakpur-Keonjhar is usually represented by a sequence of thin and discontinuous patches of basal conglomerates with sandstone and shale (±carbonate). Six lithofacies have been observed in the area. This fining upward sequence alongwith the vertical and lateral facies variation in the Kolhan implies superimposition of retrograding shorelines on an earlier prograding alluvial fan sand complex. The variations in the size parameters are indicative of changes in the water depth and the velocity at the time of sediment deposition. The basin is thought to evolve as a half-graben under the influence of an extensional stress regime. This assumption of a tectonic setting for the NE-SW trending Kolhan basin can be related to the basin opening as a consequence of E-W extensional stress system that prevailed during the development of the Newer Dolerite dyke. The half-graben development and fault growth evolve differently through time and produce different basin-filling patterns. In the initial stage the basin evolution can be explained by detachment type half-graben filling model that incorporates a basin-bounding fault soling into a sub-horizontal detachment fault. Two types of genetic sequences reflecting variations in the generated accommodation space have been recognized within the sub-basins of Chamakpur-Keonjhar and Chaibasa-Noamundi. The lower sequence in Chamakpur-Keonjhar is characterised by shallow braided river deposits that lack repetitive facies patterns and were deposited during a period of the slower rate of fault growth and generated accommodation space. During the fault growth stage the Kolhan basin grew both wider and longer through time as the basin-bounding faults lengthen and displacement accumulated as evident in the sub-basin of Chaibasa –Noamundi. Younger strata consistently pinch out against older syn-rift strata rather than pre-rift rocks in the later fault-growth stage. The basin fill thus commonly forms a fanning wedge during fluvial sedimentation, whereas lacustrine strata tend to pinch out against older syn-rift strata. The fluvial strata progressively onlap the hanging wall block, whereas the lacustrine strata pinch out against older fluvial strata at the centre of the basin but onlap along the lateral edges. The transition from fluvial to lacustrine deposition and hanging wall overlap relationships are thoroughly observed in the sub-basins of Kolhans.

Keywords: half-graben, fan-delta lacustrine, braided-ephemeral

Introduction:

It covers an area around 800 sq. km along the western margin of Singhbhum Granite. It intervenes the Singhbhum granite to the east and the Iron Ore Group of rocks (IOG) to the west (Saha, 1994). It is one of the youngest and the least studied Precambrian stratigraphic unit in Singhbhum geology (Mukhopadhyay, 2001; Saha, 1994). The Kolhan basin is a time transgressive shale dominated supracrustal succession (shallow epicontinental) set in a passive continental rift setting, and caused due to the fragmentation of the Columbia supercontinent. The succession is represented by a sequence of subarkose-quartz arenite with lenses of conglomerate overlain by extensive thick shale-limestone package and show a non-cyclicity in the sedimentation history.

The depositional environment of the Kolhans varied from braided fluvial-ephemeral pattern to a fan-delta-lacustrine type. Previously, no such inference about the tectonic evolution of the basin has been drawn. Few workers from Geological Survey of India like Mazumdar(1996) has suggested the half-graben model for Kolhan supported by Acharya,1984; Bandhopadhaya and Sengupta,2004; Roy and Bhattacharya,2012. Half-graben has certain unique sedimentation pattern (Schlische 1991). The aim of the present paper is to fit the sedimentation pattern with a half-graben tectonic model of Kolhan (Roy and Bhattacharya, 2012).

Geological Setting of Kolhan Basin

Jones (1934) stated the members of the Kolhan Group as part of his Iron Ore Series. Dunn (1940) coined the term ‘Kolhan Group’ for a sequence of un-metamorphosed sedimentary formation overlying the Singhbhum granite. The geological map of the Kolhan basin Fig. 1 shows various lithologic units of the Singhbhum craton with the Kolhan Group being the younger. The various stratigraphic units according to Saha (1994)are (a) Older Metamorphic Group (OMG) (b) Older Metamorphic Tonalite-gneiss (OMTG) (c) Singhbhum granite Phase II and Phase III (d) Iron Ore Group {shales, tuffs, phyllites, banded iron formation (BIF), banded hematite jasper (BHJ), banded hematite quartzite (BHQ), sandstone, and conglomerate} (e) Jagannathpur and Malangtoli lavas, and (f) Kolhan Group. The structure of the Kolhan basin is controlled by the trend of the Iron Ore synclinorium (Saha, 1994). There is also a strong asymmetry in the basin architecture that has given rise to lithofacies variations within the Kolhans.

The area of study is concentrated in the two sub-basins of Chamakpur - Keonjharh and Chaibasa-Noamundi respectively. The two sub-basins have a general NE-SW trend with a faulted contact with the Iron ore Group and to the west and unconformity with Singhbum Granite. The Chaibasa-Noamundi basin extends from Chaibasa (85^0 48' – 22^0 33') in the north to Noamundi (85^0 28′ – 22^0 09′) in the south (length: 60-80 km; width: 8-10 km). The Chamakpur - Keonjhargarh (Long. 85°20'-85°35' E **;** Lat. 21°35'-22°10' N) on other hand covers an area approximately 375 km2 (length : 50-55 km ; width : 6-8 km).

Materials and Methods

Fieldworks were carried out to describe and characterize the lithounits of the Kolhan basin from Chaiabasa to Chamakpur. At each exposure, the different lithounits were studied and were identified on the basis of their bed geometries, gross lithologies, and sedimentary structures. Fence diagram

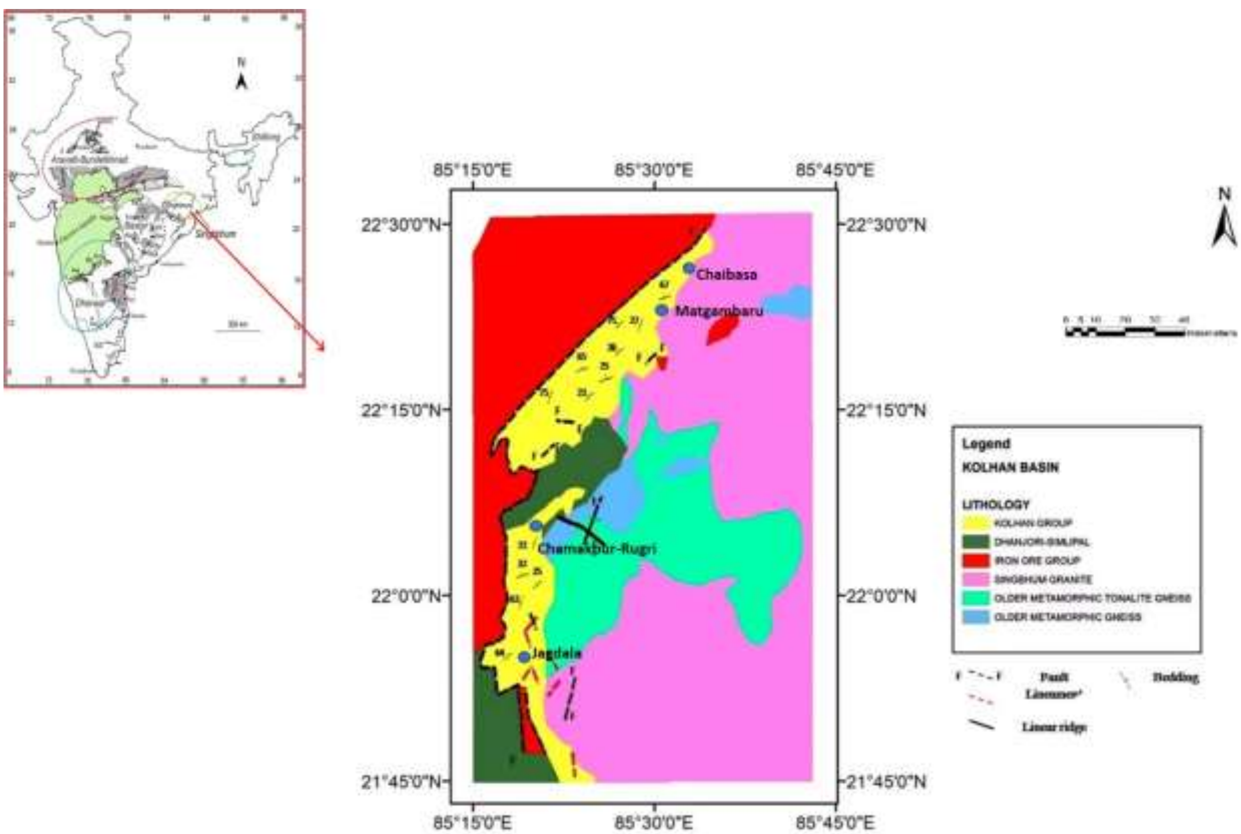


Fig. 1: Location map of India (top-corner).The geological map of Kolhan basin showing the two sub-basins (After Saha, 1994).

was prepared based on the litho-log data using ROCKWORKS16 for the two-sub-basins. The sedimentation pattern of the Kolhan basin was correlated with a half graben model. A predicted Depositional Model correlating the two sub-basins sedimentation history was prepared based on this using CANVAS 8 software.

RESULTS

Lithofacies analysis of Kolhan sandstone

The lithofacies analysis based on the field descriptions has been done for assessing the sediment depositional framework and the environment of deposition. The detailed examination of outcrop patterns along with the variations in the sedimentary structures appears to be the most effective means for analyzing and interpreting the stratal geometries and the depositional history. The architectural elements used in the present study are the field stratal characteristics, primary sedimentary structures, textures, fabrics of the lithofacies and their geometrical relationships (Miall, 1985, 1996).

Granular lag facies (GLA)

Granular lag facies, overlying the Singhbhum granite, is reddish brown in color and moderately to poorly sorted, with presence of subrounded to rounded pebbles of chert, vein quartz, phyllite and jasper. It is characterized by the occurrence of laterally impersistent, massive, matrix supported conglomerate which is oligomictic in nature towards south and polymictic towards north of the basin. These conglomerates are mostly immature to sub-mature, and quite similar to the overlying sandstone. This fine matrix-supported GLA facies can be the product of a more or less laminar, cohesive flow of relatively dense, sediment –fluid mixture of plastic behavior. Clasts float on the debris as a result of small density variation between the clasts and the debris, plus the cohesive strength of the clay-water slurry (Rodine and Johnson, 1976).

Granular sandstone facies (GSD)

The GSD facies is identified by reddish brown to brown color granular sandstone overlies the GLA facies (Fig.3.6B). This facies is characterized by moderately to well sorted, moderate clast: matrix ratio, textural bimodality and development of normal grading. Planar cross-stratification is more commonly found in compare to trough cross-stratification (Fig. 2B, 3a).

Sheet sandstone facies (SSD)

The SSD facies is characterized by sheets of subarkose-quartz arenite with occasional intercalations of thinly laminated siltstone. The facies shows abundant development of planar cross bedding and locally developed herringbone cross-bedding (foreset dips NNE). Paleo-current data was measured from this cross-beds (Fig.2A).This facies forms the dominant type among all the other facies. Sandstone beds in this facies tend to be sheet like with almost constant bed thickness.

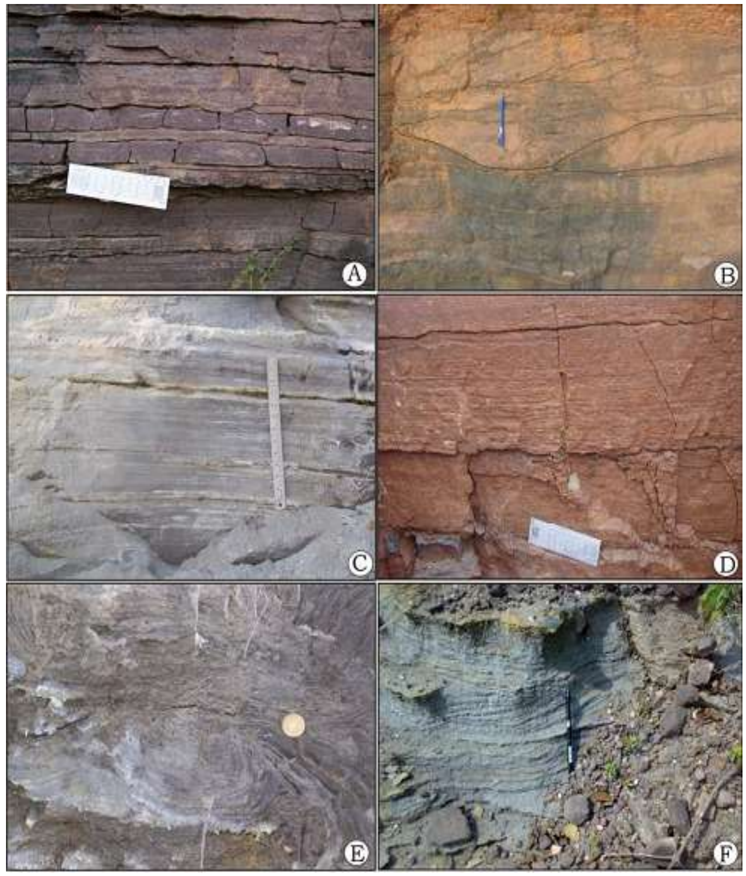


Fig. 2: (A)Sheeted sandstone facies location Bistampur, Scale: 12cm. (B) Cross bedded unit with multiple toe scour like structure locationGumua Gara river section, Scale: Pen, 12cm. (C) Rhythmic sandstone with alternate layers of sand and mud with thicker sand layer, location-Bistampur, Scale: 30cm. (D) Thinly laminated sandstone at Matgamburu, Scale: 12cm (E) Convolute lamination in rhythmic sandstone, 2.5cm diameter coin for scale, (F) planar cross bedding in rhythmic sandstone, location Bistampur, Scale: Pen,12cm.

Plane laminated sandstone facies (PLSD)

The PLSD facies is typically defined by well sorted subarkose-quartz arenite, with a moderate - high grain: matrix ratio. The sandstone is medium to fine grained. The dominant structures are planar cross bedding, wavy lamination, washed out/flat top ripples, herringbone cross-bedding (foreset dips NNE) and antidunes (Fig. 2C, D, F and 3d)

Rippled sandstone facies (RSD)

This facies is identified by profuse development of both symmetrical and asymmetrical ripples interference ripple, herringbone cross-bedding (foreset dips north westerly) (Fig.3b-c., Fig. 3 e-f), hummocky cross-stratification and multiple toe scour like structures .It is generally associated with thinly laminated sandstone facies and plane laminated sandstone facies. The wavy lamination beds occur with thin ripple laminated shale parting between two successive beds. Sandstone beds in this facies tend to be sheet like with almost constant bed thickness.

Thin laminated sandstone facies (TLSD)

This facies is characterized by the rhythmic alternation of sandstone and shale units (fig. 3.46F), in which sandy layers are thicker than shale layers.Prominent structures are convolute lamination, planar cross bedding and asymmetrical ripples (Fig.2D.).

Kolhan Shale:

The unmetamorphosed Kolhan shale sequence is more than 200 m thick, plane laminated with reddish brown colour. The Shale beds are composed of repeated alterations of very thin to thin plane bedded shale and subordinate amount of calcareous shale and siltstones. Kolhan shale is reported to be devoid of any Siliciclastic / carbonate components. The shale beds are commonly 2 cm to 8 cm thick and internally laminated.

Kolhan Limestone:

The Kolhan Limestone is impersistent and occur as patches in the shales. It is best developed towards SW of Chaibasa, near village Rajanka and Kondra and N and NW of Jagannathpur. In all these places the minimum thickness attained is nearly 20 ft. and the maximum is 65 ft. (Rajanka). The limestone can be divided into a white to pale grey, pink and pale green lower horizon consisting of thick bedded

Fig. 3 (a): Tabular cross-bedding in GSD facies characterized by parallel foreset laminae draping down between two layer parallel sets. Brunton for scale Location : Chamakpur (b-c) Exhumed Trough cross-stratifications (RSD facies).Scale Brunton Location : Surgutaria. (d) Climbing ripples with distinct migration and upbuilding of internal sediment laminae (PLSD facies). Brunton for scale. Location: Jajang (e) Mud flasers and laminated mud occurring as draped surface over ripple forms (RSD facies). Brunton for scale Location : Inganijoan. (f) Trough cross-stratifications separated by a thin erosional surface (RSD facies). Brunton for scale Location : Surgutaria rock traversed by calcite-quartz veins in which rhombohedral calcite and partly euhedral transparent quartz crystals are developed. The darker upper horizon has a foliated nature caused by parallel chloritic laminae.

Chamakpur Keonjhar Sub-Basin Depositional Environment and Facies Association

Braided fluvial plain facies association

The granular lag (GLA) and granular sandstone (GSD) facies are a part of shallow braided fluvial plain facies association. These two facies were formed in fluvial channels and bars in braided streams that gradually fanned outwards. This led to the gradual avulsion of the braided streams. The braided stream deposits gave way to the deposition of sheet-like deposits, where the process of recycling of sediments started in conjunction with the related hydrodynamic factors. The evidences in support of the braided stream are:

- Presence of lenticular or wedge shaped bed geometry (wedge thickness increases downslope) showing a transition from ortho conglomerates to granular sandstones and oriented approximately parallel to the paleo-strike of the basin.
- Elliptical pebbles oriented normal to the paleocurrent directions are rare. Presence of angular grains and abundance of rock fragments suggest a short transport from the source area. The coarsest deposits at the base of the channel are those carried in the thalweg (Allen, 1982) in between the sand bars. Local coarsening upwards sequence indicates a rapid shifting of the braided streams (channel avulsion) during deposition (Collinson, 1996).
- Where the bar is gravelly, the deposits consist of cross-stratified granules, pebbles or rarely cobbles in a single set. Where the bar is sandy, stacked sets of subaqueous dune deposits have been observed, that form a succession of cross-bedded sands whose top surface is occupied by finer sands and silts, representing the abandonment of the bar.
- Presence of local fining and coarsening upward sequence that reflect a low fluctuation in the basin tectonism and a changing scenario in the climatic condition at the time of deposition. Presence of

unidirectional (with occasional cross-paleocurrent) patterns and channel scours that suggest braided fluvial sedimentation.

- Presence of laterally intercalated, well sorted, coarse - medium - fine grained, trough cross-bedded, planar cross-bedded, and flat-bedded units suggest a rapid fluctuation in sediment supply.
- Presence of irregular boundary between the coarse and the fine grained sediment layers frequently marked by channel scours. Trough and planar cross-beddings are common structures developed as a result of the lateral and downstream advance of a mid-channel bar that finally coalesced into the adjacent branch channel.

Ephemeral Sheet Flood Facies Association: The association of sheet sandstone (SSD), plane laminated sandstone (PLSD), rippled sandstone (RSD), and thin laminated siltstone-sandstone (TLSD) facies are typical ephemeral sheet flood facies (Miall, 1996). The evidences in support of this facies association are:

- The lower part of the sheet sandstone facies is characterized by trough and large scale high angle (foreset dip 20-28 degree) planar cross-bedding almost at right angles to the elongation of sand bodies.
- The upper parts of the sheet sandstone and the plane laminated sandstone facies are characterized by both low angle frontward and high

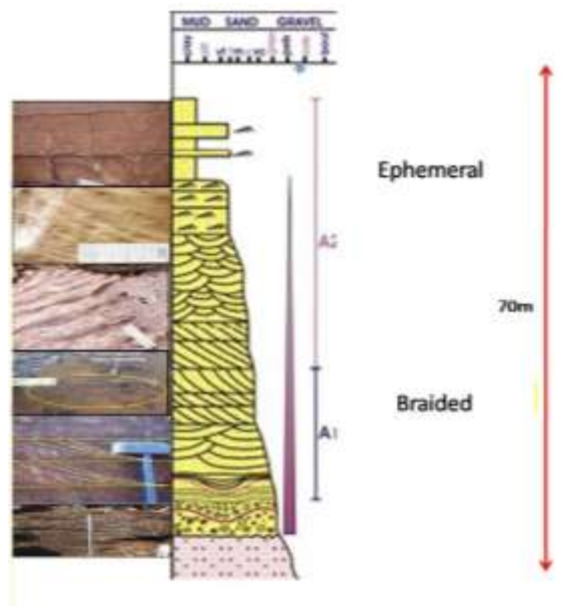


Fig.4: Composite log of the Chamakpur-Keonjharh Basin showing the sedimentary structures in each facies and the braided ephermal vertical succession

angle backward cross laminations, asymmetrical ripples, isolated lunate and linguid megaripples, and antidune cross-stratifications.

- Reactivations of erosional surfaces are often marked by thin granules and pebble layers.

- Subhorizontal parallel laminations with occasional shale chips and landward climbing-ripple laminations are also prevalent in the plane laminated sandstone facies.
- Presence of antidune cross-stratification and climbing-ripple laminations are indicative of rapid sedimentation under high suspended load (Clifton, 1969). A possibility is there of the existence of a cross-channel and transverse movement of sand bodies as transgressive sheet sands (Swift et. al., 1971; Johnson, 1975).

Chaibasa – Noamundi Sub-Basin Depositional Environment

Fan Delta Lacustrine Type: Fan-deltas are deposited immediately adjacent to highland region, usually a fault-bounded margin, and occupy a relatively a narrow space between highland and a standing body of water of shallow depth (Mc.Pherson.et.al. 1987). The geological set-up of Chaibasa-Nomundi fits the definition. The evidences in support of this are as follows (Fig 5):

- Presence of fine - medium grained, well sorted quartz rich sandstones (RSD) frequently interbedded with thin laminated siltstone-sandstone (TLSD) resemble heterolithic facies. The variability of sedimentary structures in the facies associations reflects rapid fluctuations in the supply of sediments. Records of low energy suspension fallout in the TLSD facies, presence of asymmetric ripples on the top surface of the fine-grained sandstones, and mud cracks in the TLSD facies indicate a low energy, suspension fall out during the waning phase of the sedimentation.
- Cross-laminations, antidunes, and supermature quartz arenite indicate sedimentation recycling. The sediments have been transgressed by the continuous lateral and transverse shifting of longitudinal bars that resulted in the development of sheet flats and transgressive sand sheets.
- Presence of scoured surfaces with granule layers in the GSD and PLSD facies, diffused nature of the contact between RSD and TLSD facies, and poor linkage between SSD, PLSD, and RSD facies indicate a rapid sedimentation in the upper reaches of the stream (Allen, 1982).

The Kolhan succession starts with a basal conglomerate, which is thin, laterally impersistent and becomes more and more oligomictic to the South, with the dominance of chert and jasper pebbles. Pebbles of granite and quartz are common in the somewhat polymictic types developed towards the north. The Conglomerate are mostly sub mature to immature,

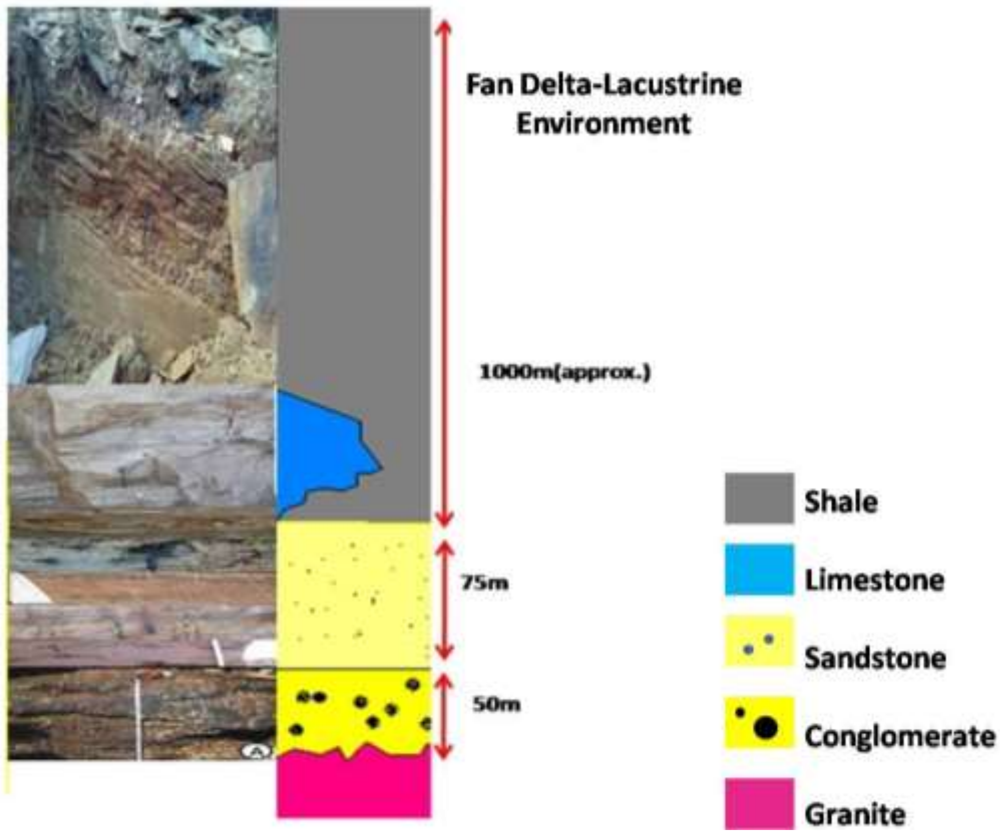


Fig. 5: Composite log of the Chaibasa-Noamundi Basin showing the sedimentary structures in each facies and the fan-delta lacustrine vertical succession.

devoid of structure, with a matrix very similar to the overlying sandstones with which they show a highly transitional contact and wedge shaped geometry. The dominance of iron and argillaceous matter is often observed and the rapid conversion of shale from calcareous to argillaceous to ferruginous is an indicator of its non-marine nature. Presence of herringbone cross-bedding washed out ripples and occurrences of rhythmic sandstone (tidal bedding) are the evidences of tidal activity. The patches of limestone present confirms it to be of non-marine body. The sudden huge thickness of shale can be attributed to the landlocked nature of the basin.

The shallowness of the basin is indicated by the general development of thin sequences of rocks, while the stability and generally subdued morphology of the source area is suggested by the slow transport of detritus containing very little fresh feldspar grains by the sluggish streams contributing sediments in moderate amount to the Kolhan sea of the epicontinental type.

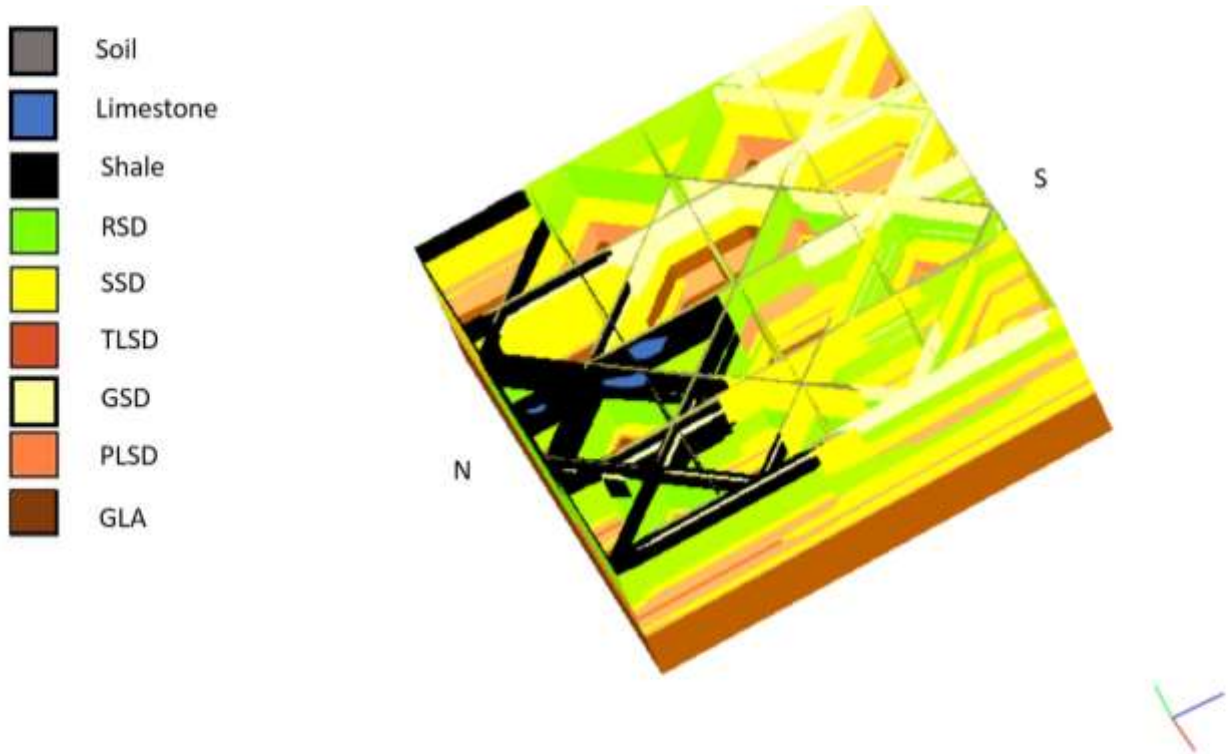


Fig.6: Fence diagram showing facies variation across the Kolhan basin

DISCUSSION

Half-Graben Basin Filling Model

In the initial stage the fault model incorporates an intrabasinal fault that soles into a sub-horizontal detachment fault; the change in the rate of increase in the volume of the basin during uniform fault displacement is zero. (Detachment type). (Fig.7a)

Both basin-bounding faults, intrabasinal faults and the intervening fault blocks rotate during extension and as a consequence, there is a change in the rate of increase of the volume of the basin.(domino type). (Fig.7 b)

During the fault growth models, the Kolhan basin grew both wider and longer through time as the faults lengthen and displacement accumulates; the change in the rate of increase in basin volume is positive. (Fig.7c). Basin fill commonly forms a fanning wedge during fluvial sedimentation, whereas lacustrine strata tend to pinch out against older synrift strata.

The transition from fluvial to lacustrine deposition and hanging wall onlap

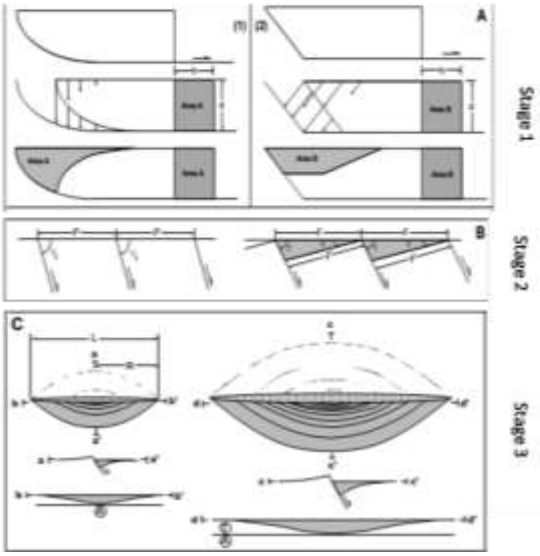
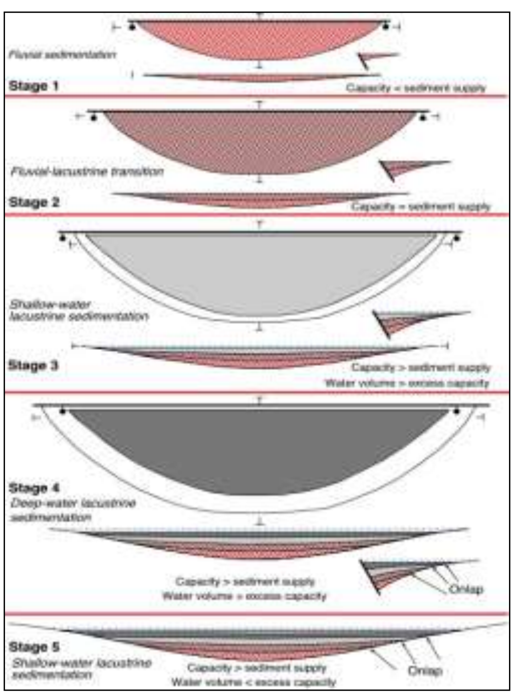


Fig.7: Illustration of half-graben basin-filling model.(A) Planar fault geometry (taken for simplicity) where there is horizontal displacement (h) on the detachment fault (B) domino fault block model in which both the faults and the intervening fault blocks rotate during extension. i is the initial dip angle of the faults; is the dip after extension; is the dip of a horizon that was horizontal before extension; F' is the initial fault spacing; F is the fault spacing after extension. (C) Essential elements of the fault growth model. All the 3 end member half-graben basin- filling models are applicable in various stages of the basin evolution. Modified from Schlische (1991).



relationships observed in the individual basins of Kolhans are best explained by these basin filling Models (Fig 8) (Schlische 1991; Schlische and Anders, 1996; Gui .et.al., 2014).

The compositional characteristics of the fluvio-deltaic deposits attest to the reworking of a sandstone- and conglomerate-bearing sequence in the source area. Therefore, the overall style of sedimentation suggest a switchover from low sinuous avulsed channels developed within an overall fluvial ephemeral streams to a delta complex under a warm humid climate system. This switchover also accounts for the carbonate platformal dominated sedimentation during the basinal closing phase. The location of half-graben development during a syn-Kolhan extensional regime is likely to have been reactivation along the Singhbhum shear zone (SSZ). Cratonic sutures such as the SSZ may have been prone to reactivation during any

Fig.8: Filling of an evolving half-graben basin shown in map view alongwith longitudinal cross section, and transverse cross section. Dashed line represents lake level. The relationship between capacity and sediment supply determines whether sedimentation is fluvial or lacustrine. For lacustrine sedimentation, the relationship between water volume and excess capacity determines the lake depth. Modified from Schlische and Anders (1996).

subsequent tectonic episodes, leading to complex structural and sedimentological relationships as basins are created, inverted and superimposed along a long-lived shear zone throughout successive tectonic regimes (Deb and Chaudhuri, 2007). The tectonism responsible for sedimentation and deformation of the Kolhans may be related to a ca. 2.0-2.2 Ga tectonic event or by intra-cratonic reactivation of structures within a previously assembled greenstone belt. This establishes a sequence of tectonic regimes of north–south orientated compression, tectonic quiescence, denudation and north–south orientated extension, following the 2.0 Ga event in the Singhbhum region. The syn north–south orientated extension in the region may have been related to orogenic collapse of the Singhbhum shear zone (Roy and Bhattacharya, 2012). The equivalent basins of the Kolhans is the Mankarchua basin falling north of Pala Lahara (21°26': 85°11') has also been included within Kolhans by Saha(1994). It shows a faulted and sheared contact with the Pala Lahara gneiss in the south and an unconformable contact with the Malangtoli lavas in the north. Sarapalli- Kamakhyanagar (20°58': 85°35') basin has also been identified by (Saha, 1994) as another Kolhan basin. It extends for about 100 km in an east -west direction. The width of the basin is about 3km. Cross- bedded ortho-quartzite and cherty quartzite dipping steeply southward represents the dominant lithology in this basin. Near Kamakhyanagar, the quartzite is in contact with the metasediments of the Iron Ore Group.

However, it is prudent to restrict the Kolhan Group of rocks to the main Kolhan basin with its typical assemblage of Sandstone-limestone-shale /phyllite assemblage rather than sandstone/sandstone-shale or only as shale/clayey rock (Tarafdar et. al., 1974) association overlying other rocks as equivalent of Kolhans, which is present either as isolated bodies over Singhbhum granite or as outliers elsewhere in this part of eastern India.

CONCLUSION

General models for sedimentation in half-graben set-up incorporate large-scale alluvial fans as indicated by GLA-GSD-SSD-RSD-PLSD facies, entering the half-graben from the low-gradient footwall. Significantly, the model predicts a contrasting facies change between the transverse alluvial fans and the major longitudinal trunk rivers flowing along the axis. The presence of lacustrine-related facies within the Kolhans proves significant development of lake sedimentation caused

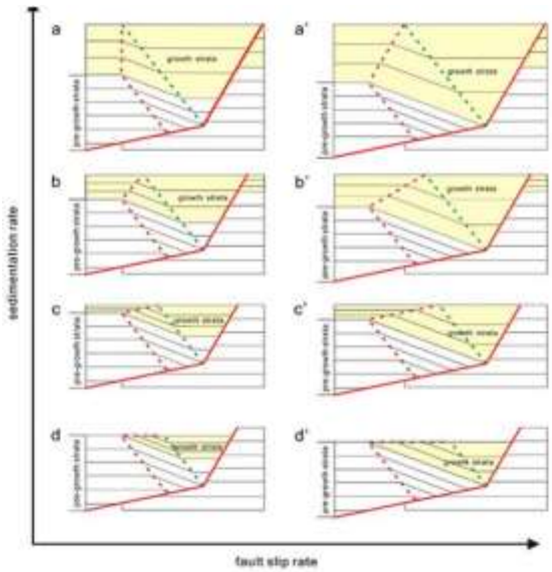


Fig. 9: Variation of sedimentation and fault rate that occurs in a half-graben set-up (After Gui *et.al*. 2014)

by interior drainage within the half-graben. The Kolhan serves as an example of sedimentary response to changing tectonic regimes associated with the SSZ (Fig. 9). Facies variation in a basin supports a hypothesis for two-stage development of the half-graben. In the initial stage, an irregular east-tilted half (Fig. 10) graben was formed by high-angle faulting on cratonic basement reactivated structures. In the later stage, movement began on the fault system, and the Iron Ore Group rose rapidly. In the process, the northern basin reversed its half-graben tilt to westward.

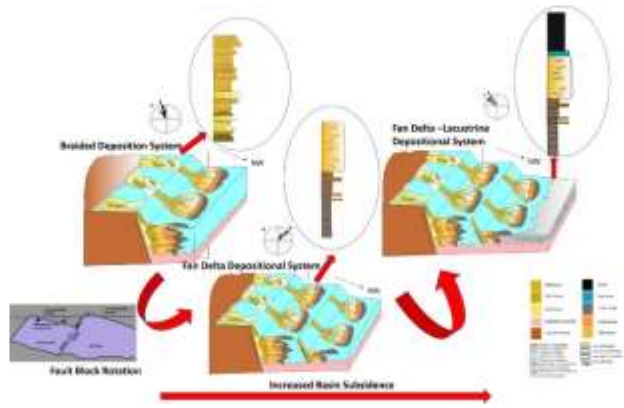


Fig. 10: Tectono-Sedimentary Model of Kolhan (The fault block rotation is denoted by schematic Diagram showing domino type fault which rotates during progressive extension. The fulcrum is the position where displacement of the hanging wall block is zero; either the limit of roll-over in isolate tilt block/half-grabens or the transition from areas of the hanging wall undergoing positive motion due to footwall uplift to areas undergoing negative).

Acknowledgement

The author is grateful to Head of the Department of Geology and Geophysics, IIT Kharagpur for providing opportunity to carry out the research and field work.

References

Acharya, S.(1984), Stratigraphy and structural evolution of the rocks of Iron Ore basin in Singhbhum, Orissa Iron Ore province: Indian Journal of Earth Science, Seminar Volume on Crustal Evolution of Indian Shield and its Bearing on Metallogeny,p.19-28.

Allen, J.R.L. (1987), *Sedimentary Structures*, Their Character and Physical Basis. Elsevier, Amsterdam, p.515- 645.

Bandhopadhaya, P.C. and Sengupta, S. (2004), Paleoproterozoic Supracrustal Kolhan Group in Singhbhum Craton, India and the Indo-African Supercontinent: Gondwana Research, v.7, p.1228-1235.

Clifton, H.E. (1969), Beach lamination: nature and origin: Marine Geology, v.13, p.607–610.

Collinson, J. D. (1996), Alluvial Sediments, in Reading, H. G. (eds.), Sedimentary Environments-Processes, Facies and Stratigraphy, Blackwell Publication, Oxford, p.37-82.

Deb,S.P. and Chaudhuri,A.K.(2007), A retreating fan-delta system in the Neoproterozoic Chattisgarh rift basin, central India- Major controls on its evolution: Bulletin of American Association of Petroleum Geology, v. 91,p.785-808.

Dunn, J.A. (1940), The stratigraphy of south Singhbhum: Memoir Geological Survey of India, v.63, p.303-369.

Gui, B., He, D., Chen, W. and Zhang, W. (2014), Migration of growth axial surfaces and its implications for multiphase tectono-sedimentary evolution of the Zhangwu fault depression, southern Songliao Basin, NE China: Journal of Geodynamics, v.75, p.53–63.

Jones, H.C. (1934), The Iron ore deposits of Bihar and Orissa: Memoir Geological Survey of India, v. 63,167-302.

Mazumder, S.K. (1996), Precambrian Geology of Peninsular Eastern India - a selective review: Indian Minerals, v. 50, p.139-174.

McPherson, J.G., Shanmugam, G., Moiola and R.J. (1987), Fan deltas and braid deltas: Varieties of coarse-grained deltas: Geological Society American Bulletin, v.99, p.331–340.

Miall, A.D. (1973), Markov chain analysis applied to an ancient alluvial plain succession: Sedimentology. 20,p. 347-364.

Miall, A.D. (1984), Principles of Sedimentary Basin Analysis. Second Edition, Springer Verlag, N.Y.; 490p.

Mukhopadhyay, D. (2001), The Archean nucleus of Singhbhum: the present state of knowledge: Gondwana Research, v.4, p.307-318.

Johnson, H.D. (1975), Tide and wave dominated inshore and shoreline sequences from the Late Precambrian, Finnmark, north Norway: Sedimentology, v. 22, p.45-73.

Roy,A.B. and Bhattacharya, H.N. (2012), Tectonostratigraphic and Geochronologic Reappraisal Constraining the Growth and Evolution of Singhbhum Archaean Craton, Eastern India: Journal of Geological Society of India, v.80, p.455-469.

Saha, A.K. (1994), Crustal Evolution of Singhbhum-North Orissa, E. India: Memoir of Geological Society of India,v. 27, 341p.

Schlische, R. W. (1991), Half-graben filling models: New constraints on continental extensional basin development: Basin Research, v.3, p.123-141.

Schlische, R.W., and Anders, M.H. (1996), Stratigraphic effects and tectonic implications of the growth of normal faults and extensional basins, in Beratan, K.K., (eds.), Reconstructing the History of Basin and Range Extension Using Sedimentology and Stratigraphy, Boulder, Colorado: Geological Society of America Special Publication, v.303, p.183-203.

Swift, D.J.P., Stanley, D.J. and Curray, J.R. (1971), Relict sediments on continental shelves:A reconsideration: Journal of Geology, v.79, p. 322-346.

Tarafdar, S.N. and Lari, T.A. (1974), Geological mapping and preliminary appraisal for iron, manganese and limestone around Gua-Chotanagra-Kumdi area, Singhbhum district, Bihar: Report GSI, 1-100p.