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Review Article

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Clues for age of Kolhan Basin: tectonic implications

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Abstract

The age of the Kolhan Basin was mysterious. Careful literature review and logical constraints from available data in literature can constrain the age. The maximum age of Kolhan Basin (closing) is 1531 Ma from whole rock Rb/Sr age of Kolhan shale [1] and opening of basin corresponds to Dalma plume (1600 Ma) [2,3]. Hence the duration or life of Kolhan Basin corresponds to 30 Ma. The Dalma plume magmatism was possibly part of a 1600 Ma global tectono-thermal event. This is synchronous to the existence of the Columbia supercontinent. The implied age directly gives the tectonic implication of the basin.

The Kolhan basin in Singhbhum district is unique in many respects. Its narrow strip-like outcrop pattern, controlled by the NE_SW trend of the much older Iron-Ore Formation synclinorium abuts against the Singhbhum Granite in the east of a greater portion of its trend. A part of eastern and entire western boundary is in contact (fault) with the Iron-Ore Formation rocks. Its age, stratigraphic relationship and tectonic framework is still controvertial. The Kolhan Shale Formation is of course definitely younger than the Iron-Ore Formation as originally suggested by Dunn and is also younger than the Singhbhum Granite as is clear from the field relations.

The Kolhan Basin is set in a diversified lithological provenance, so that it exhibits the development of a rudaceous, arenaceous, calcareous and an argillaceous facies within only a few hundred feet of thickness. The various members of the Formation of the formation dip in general uniformly low to the west away from the contact with the Singhbhum Granite.

Keywords: Kolhan; Granite; Conglomerate; Limestones

The Kolhan conglomerate

It starts as usual with a basal conglomerate, which is thin, 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, devoid of structure, with a sandstone matrix very similar to the overlying sandstones with which they show a highly transitional contact. The dominance of iron and argillaceous matter is often observed. The pebbles are elliptical and rounded and vary in size from a few mm to a few cm. The mineralogy and structure of the conglomerate in different parts of the basin suggest a greater control of provanence of than of tectonism in their evolution. The poor and impersistent thickness is in agreement with the shallow nature of the basin, while the sporadic development of thicker beds may be ascribed to irregularities in the basin configuration or to local instability in the basin.

The Kolhan sandstone

The overlying Kohan Sandstone member is dominantly a fine grained (median= 3 phi) argillaceous arenite [4] along with a considerable development of pure arenite [4] and some quartzose arenite types [4]. Typical arkose and greywacke type sandstones are not found. The matrix is dominantly composed of illite-clay and there is not much corrosion of the various quartz types by the matrix. The quartz grains are rather well sorted, sub rounded to sub angular, with a moderate skewness (both +ve and –ve) and a moderate kurtosis. The heavy mineral content is low and the ZTR index is high. The high content of matrix is rather inconsistent with the high sorting values, roundness and mineralogical maturity of the sandstones (textural inversion) [5]. There is no evidence of the derivation of the matrix by secondary processes and the most likely sources are the clay-pellets, altered feldspar and detrital clay from the various types of source rocks. The few fresh feldspar grains do not truly reveal the contribution of the Granite in the evolution of the Kolhan sandstones. The general prevalence of iron oxides as a coloring agent and as a coating on quartz grains is observed throughout the Kolhan, but locally the color is bleached.

The abnormal size-roundness relationship, the mineralogy, the slightly bimodal distribution, textural inversion and palaeontological studies (based on apposition fabric analysis and few structures like ripple marks and current beddings etc.) suggest not only a source area with complex lithology but more than one provenance type-presumably a Granitic to the east and northeast and an Iron Ore Formation type to the southwest and northwest of the basin [6]. 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. A humid tropical climate might have prevailed in the source area which was responsible for the intense weathering of the rocks [7].

While the basin was definitely shallow during the deposition of the sandstones, a somewhat restricted circulation (low energy environment) is suggested in the northern part of the basin from the distribution of the various sedimentary parameters in the entire basin.

The Kolhan limestone

Towards the end of the sandstone sedimentation in the Kolhan basin, a change in the nature of the sedimentary facies from arenaceous to calcareous is revealed by the appearance of carbonate cement in the matrix of the sandstone [8]. This cement progressively increases at the cost of the earlier matrix and the detrital quartz grains so that a low grade arenitic limestone is produced locally at the lowermost horizon of the limestone member [9]. Besides this, lithocalcarenite is also developed very locally at the basal horizon by the accumulation of what appears to be detrital grains of calcite cemented by a calcareous matrix.

The main horizon of the Kolhan Limestone is a micritic mud precipitated in a shallow basin and subjected to pronounced diagenetic recrystallization. The northen half of the basin where the limestone is developed in much greater thickness than the southern half shoes also a much greater degree of recrystallization and many other features such as abundance of coarse calcite and quartz veins, presence of stylolites and occasional cross lamination, mineralization of manganese, iron and molybdenum, etc. as compared to the southern half [10]. It is pertinent to note here that such quartz and calcite veins qwith sporadic hematite-molybdenite mineralization are not encountered in the sandstones. These features are attribuited not only to a slightly greater depth of the shallow basin to the north as compared to the south, but appear mostly to be due to the effect of some localized unstability in this part of the basin caused by concealed intrusives or some other factors. The occurrence of a small outcrop of an ultrabasic rock (chlorite talc rock) in the Limestones is intrusive in this connection [11].

The dominance of micritic and microsparitic material coupled with the paucity of recrystalllization effects and the poor development of the horizon in the southern part of the basin testify to quite deposition of carbonate mud in the low energy environment of the shallow sea, undisturbed by unstability conditions due to intrusives and other factors [12].

The uppermost horizon of the Limestone member consists of a very different type of phyllitic limestone, coarse-grained and recrystallized and contains thin argillaceous laminae. This layer, particularly developed in the northern part of the basin, is clearly replacive in origin being formed by the late diagenetic replacement of the overlying phyllitic shale. In the southern part such silicification and development of phyllitic layer is not noted.

The Kolhan Limestoneis characterized by a great variation in color at short intervals and is notoriously erratic in its quality which is very well brought out by the insoluble residue analysis of this rock from different horizon and different places in the same horizon.

The Kolhan phyllitic shale

The third member of the Kolhan Formation, the Kolhan phyllitic shale, which represents the end phase of sedimentation in the Kolhan basin, is the only rock type which is consistently developed throughout the basin and is therefore inserted in the lithostratigraphical terminology "Kolhan Shale Formation" [13]. This rock type is siliceous, illitic, laminated shale deposited throughout in alow to medium energy environment, as evidenced by the consistentmode in the medium silt range (6 to 20 microns) [14], Very locally low energy environment.

In somewhat restricted circulation is indicated by the formation of clay rich unlaminated mudstone. The dominance of illite and the occurrence of authigenic glauconite supportthe formation in a shallow marine basin. Although diagenetic recrystallization aided by later tectonic effects might have converted at least a part of the originally clay-sized material into coarser silt size, it is probable that much of the silt material is of original deposition, because of its consistent occurrence throughout the basin [15].

Partial chemical analysis (SiO_2 and Al_2O_3) confirm the silica rich illitic and chloritic nature of the Shales, while the sand fractions conatin besides quartz some other aluminous minerals of the same size viz. glauconite and chlorite which are also endorsed by thin section studies. The shales are iron rich as is the case with the other members of the Formation and lamination are well marked by limonitic streaks. A characteristic feature of these rocks is the dominance of silica in thin streaks and cross cutting veins in thin sections besides the occurrence of abundant massive quartz veins even at localites far away from thje faulted contact with the Iron-Ore Formation phyllites. These silicifications are mostly late and post-diagenetic, but part of it might have been formed much later after the development of the foliation planes in the shales to which they sometimes run parallel. Such crumpled quartz veins contain remnants of the greenish phyllitic rock. The shallowing of the basin is evidenced by the tendency of the sand fraction to diminish from the east to west and also from the south to north.

Lithologic associations in the Kolhan basin

The lithologic associations of the arenaceous, calcareous and argillaceous facies of sediments in the Kolhan basin resemble more closely the unstable shelf association as given by Krumbein and Sloss. This is set out in tabular from in below.

Unstable shelf associations	Lithologic associations in the Kolhan Basin
Shales	Shales
Chiefly silty shales	Dominantly silty shale
Grey, green red, brown, black	Dominantly grayish purple and dusky red
Micaceous, carbonaceous, calcareous	Micaceous and occasionally calcareous
Feldspar may be common in silt	Feldspars of doubtful occurrence

Carbonates	Carbonates
Argillaceous, nodular micrite	Argillaceous,micritic
Thickened stable shelf types	Lenticular occurrence
Dolomitization less common	Dolomitization absent
Sandstones	Sandstones
Feldspathic arenite and wacke	Dominantly argillaceous arenite
“Blanket” arkose	“Blanket” type (arenite)

Table 1: Lithologic associations in the Kolhan basin

Discussion

The Kolhan Shale Formation is associated with certain other features viz. the intrusive rocks and the metallic and nonmetallic mineralization. The intrusive include the Newer Dolerite dykes which cut across the sandstone member which is thereby baked. Their total absence from the younger limestones and shales is explained by the absence of the intrusion in the Granite itself lying immediately in contact with the limestones. The intrusives are the late quartz veins with hematite molybdenite mineralization confined only to the limestones. They occur in the shales, where however they are barren.

The Singhbhum Granite against which the Kolhan abut in the eastern portion is not only one of the important source rock for the sandstones but it also acts as a basement to the sediments. Irregularities in the configuration of the basement rock produce small inliers of this rock exposed occasionally in the basin amidst the sandstone and the limestone (dome and basin configuration). The Granite is not the source for the quartz veins in the Kolhan rocks not only because it is older than the Kolhan but also because of the absence of such veins in the sandstones directly in contact with the Granite. The Iron Ore Formation rocks provide another lithologically complex provenance for the Kolhan.

Conclusion

The metallic mineralization in the Kolhans includes manganese which is however a low grade, iron-rich uneconomic ore formed syngenetically within all the three members. It is later locally concentrated into pockets due to weathering etc. particularly in the shales (lateritic manganese ore). The other type of metallic mineralization is an epigenetic hematite ore associated with coarse quartz and calcite veins later replaced by molybdenite. Both are uneconomic and sporadic in occurrence. The nonmetallic mineralization for which the Kolhan are well known includes the Limestone which serve as the raw material for a flourishing cement industry.

The Proterozoic sedimentary sequence consisting successively younger Dhanjori, Chaibasa, Dhalbhum, Dalma and Chandil Formation of the Singhbhum crustal province, India records sedimendation in a quick changing tectonic scenario. The cooling down of the vast volume of Archaean Singhbhum Granite induced an isostatic readjustment. The associated tensional tectonic regime and deep seated fractures controlled the formation of the Proterozoic Kolhan basin.

The entire Late Proterozoic volcano-sedimentary package displays post-depositional compressional deformation and greenschist to amphibolite facies metamorphism which has been dated at ca. 1600 Ma, forming the North Singhbhum fold belt. The volcano-sedimentary package lying south to the Dalma volcanic belt was pushed south towards the Singhbhum granite batholith complex as a result of uplift related to the Dalma plume. The Singhbhum granite batholith acted as a rigid body. This gave rise to compressional stress regime that induced shearing/thrusting at ca. 1600 Ma along the Singhbhum Shear Zone. The Dalma plume magmatism was possibly part of a 1600 Ma global tectono-thermal event.

A simple model for the development and evolution of the Kolhan Basin is proposed. The first event consists of a rapid stretching of the continental lithosphere, which produced thinning and passive upwelling of hot asthenosphere. This stage is connected with block faulting and subsidence. The lithosphere then thickens by heat conduction to the surface and further slow subsidence occurs which is not connected with faulting. The slow subsidence and the heat flow depend only on the amount of stretching, which can be estimated from these quantities and from the change in the thickness of the continental crust caused by the extension. The maximum age of Kolhan Basin (closing) is 1531 Ma from whole rock Rb/Sr age of Kolhan shale [1] and opening of basin corresponds to Dalma plume (1600 Ma) [2,3]. Hence the duration or life of Kolhan Basin corresponds to 30 Ma. The Dalma plume magmatism was possibly part of a 1600 Ma global tectono-thermal event. This is synchronous to the existence of the Columbia supercontinent (supported by Figure 1 data). There was no glaciation during the existence of Columbia supported by Figure 2. This indicates moderate weathering rate during which the Kolhan Basin formed. This logical conclusion is supported by the predominance of quartz arenite in the sandstone of the basin [16]. This supports the findings of [16] that the Kolhan Basin is product of the rift basin that after gaining tectonic quiescence became an intracratonic region (passive margin). The paucity of feldspars in the thin sections supports the above findings.

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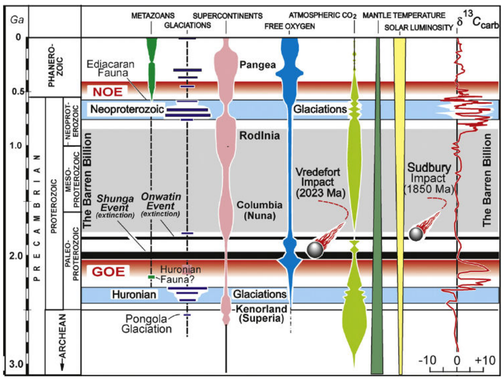

Figure 1: The diagram after Young et al. shows the existence of Columbia supercontinent at 1600 Ma.

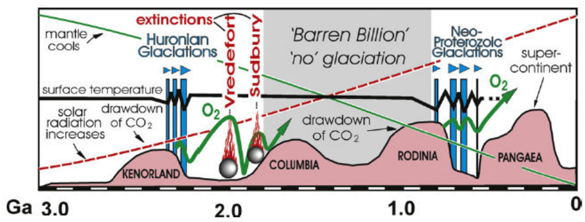

Figure 2: Climatic perturbations in the Proterozoic .

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