Paleoenvironmental Studies of Bijawar Group of Rocks around Hirapur, Sagar Distirct, Madhya Pradesh

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Abstract: ***The Bijawar Group of rocks shows different facies enabling to interpret that basin and basin environments which were dynamic during the deposition of sediments.Rock record of Paleoproterozoic Bijawar Basin having enough information regarding the paleoenvironmental condition during their deposition. Facies analysis may provide the atmospheric, hydrospheric and energy conditions for supply of sediment & depositional environment. Chemogenic deposition like ferruginous, phosphorite, dolomite and chert depends on water chemistry, and clastic sediments such as shale, sandstone and conglomerate depends on energy condition of geomorphic agents supplying the sediments. Water level and transgression, regression and ocean circulations are also important factors for the development of different facies.***

Keywords: Bijawar Rocks, Facies, Paleoenvironment, Deposition, Dolomite, Chert, Phosphorite

1. Introduction

Stratigraphical studies of sedimentary rock record of different ages give the indication for the paleoenvironmental situation in the geological time. The facies analysis is important study to reveal the paleoenironmental conditions prevailed in the geological past. Bijawar is such a sedimentary basin which is located in the South Eastern part of the Bundelkhand Carton. The name is on the basis of Bijawar town situated in the center of the basin. The trend of basin is ENE-WSW, having 100 km length and 4 to 20 km. width. The basin lying in the west side of Ken River and spread into Chhattarpur and Sagar district of Madhya Pradesh and adjoining Lalitpur district of Uttar Pradesh. It covers around 1200 sq. km. The study area is around Hirapur and falls on the South-eastern edge of Bundelkhand Granitic Gneiss Complex(BGGC) adjoining to the Chhattarpur and Sagar district of Madhya Pradesh. The study area fall under the Survey of India Toposheet no 54P/3, and bounded by N 24°15’ to 24°30’ latitudes and E 79°0' to 79°15' longitudes. It is on State Highway No. 15 joins the Sagar and Chhattarpur easily reachable form both the ends. The area comprises the rocks of different Geological events ranging in age from Archean to Proterozoic to Precambrian. Till date lots of work has been done by the various workers, researchers and officers of G.S.I., M.P. State Mining corporation development, AMD, Directorate of Geology and Mining (DGM) and Mineral Exploration Corporation Limited (MECL)etc. The GSI has carried out a detailed studies on the Geological aspects related to Petrology, Stratigraphy, Sedimentology and Tectonic history of this region. The first available Geological account on Bundelkhand area was by Medlicott (1859), who described the Schist and Banded Iron Formations (BIF) at Baraitha in the south west part in Bundelkhand area.

Regional Stratigraphy

Bijawar Group represents the paleoproterozoic volcano-sedimentary rocks of clastic and chemogenic nature, deposited under marine condition. The sediments includes conglomerate, basaltic intrusion, carbonate deposits, sandstone, shale, phosphorite and ferruginous sandstone and shale etc. Pericratonic / intracratonic rift related basin (based on gravity and airborne magnetic survey data analysis (Mishra & Rajasekhar, 2008) in Bundelkhnad Craton hosting the Bijawar Group of sediments which further overlain by the sediment of Vindhyan Supergroup.

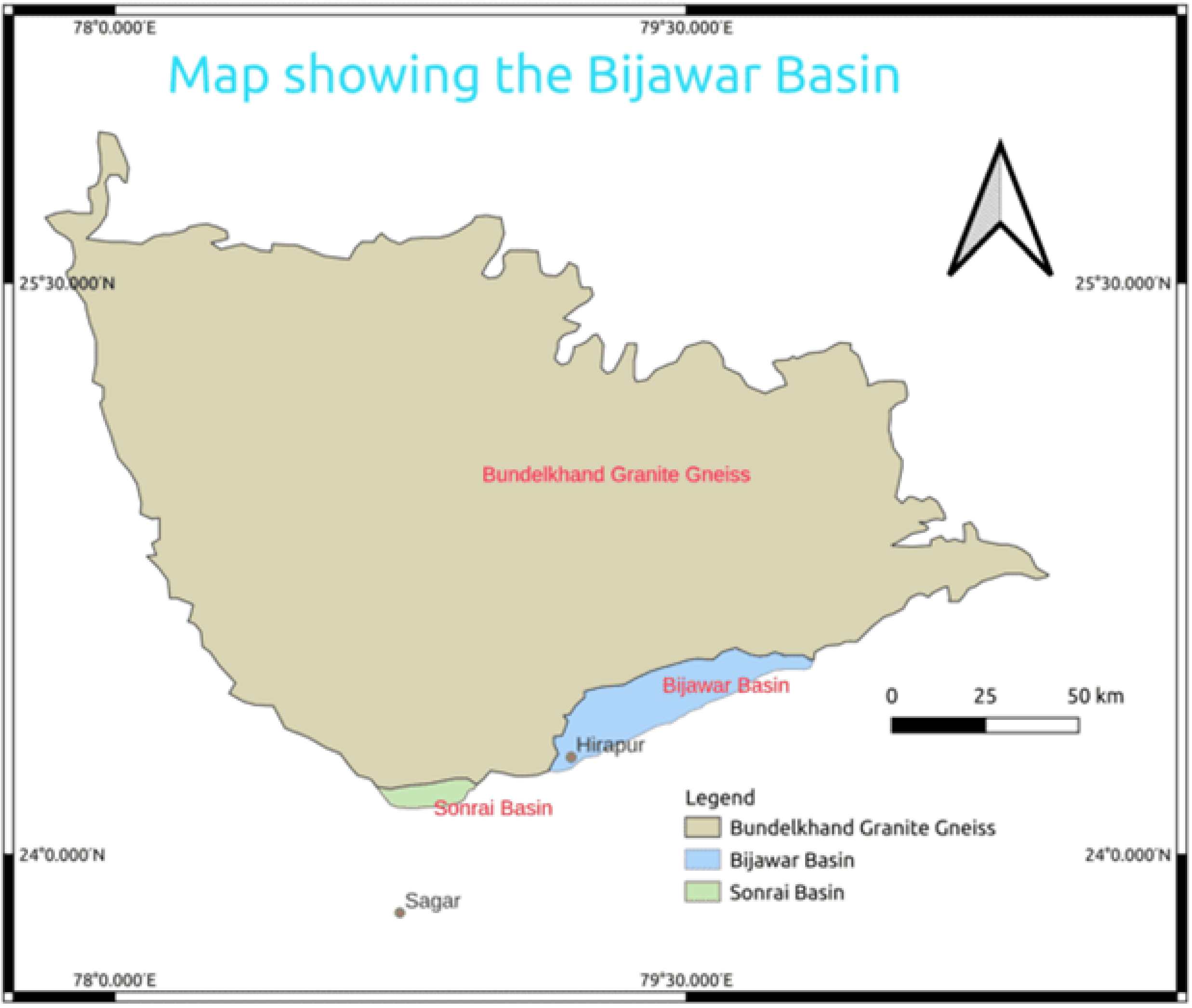


Figure 1: Map showing the Bijawar Basin (modified after Ahmed 1962).

The age of Kurat lava and the Dargawan sill are dated as 1691 +/- 180 and 1789 +/- 21 Ma by Rb – Sr systematics (Haldar & Ghosh 2000). Further the 1630 Ma date obtained from the porcellanites of Lower Vindhyan succession (Rasmussen et. al. 2002; Sarangi et. al. 2004), hence Bijawar Group can be assigned Palaeoproterozoic time (Pandey et. al. 2012).

Table 1: Stratigraphic succession of Bijawar Group of Rocks

Bijawar Group	Karri Ferruginous Sandstone	Gangau Subgroup
	Hirapur Phosphorite	
	------Unconformity ------	
	Malehra Chert Breccia Formation	Moli Subgroup
	Phukhra Sandstone	
	Dargawan Intrusive Formation	
	Bajno Dolomite Formation	
	Bhusor Basalt	
	Kawar Conglomerate	
	-----------Unconformity ----------	
	Bundelkhand Granite Gneissic Complex (BGGC)	

Shales and sandstones of the Paleoproterozoic Bijawar Group (India) have been studied to decipher their paleo-weathering conditions and provenance based on geochemistry. Shale samples are composed of K-feldspars, mica, quartz, and fine iron-oxides, whereas sandstones are composed of quartz and K-feldspars. The predominant positive correlation of K_2O vs TiO_2, Na_2O vs Al_2O_3, and K_2O vs Al_2O_3 indicates that the elements are associated with detrital phases (Dar et. al. 2020).

As depicted in Table 1 stratigraphically, the Bijawar Group is subdivided into two subgroups Moli Subgroup (Lower) and Gangau Subgourp (Upper). The above succession of Bijawar Group of rock modified after Kumar et. al., 1990 and GSI, 2004.

Moli Subgroup:

The rocks of Bijawar Group un-conformable overlie the Bundelkhand Granitic and Gneissic Complex as basal quartz pebble conglomerate known as Kawar Conglomerate. This conglomarate is overlain by Bhusor Basalt, a thick pile of vesicular mafic lava earlier known as Bijawar lava occur in the eastern part of the basin. The Bhusor basalt is about 90 m thick and consists of five simple flows with intervening volcanic breccia and tuff. The flow is generally massive and also amygdular and pillowed with columnar, platy and hackly joint systems. Composition of this basalt is subcalcic augite, bronzite, plagioclase (An 65-85), olivine (Fo 65-70) and glass. These are continental tholeiitic basalt and basaltic andesites having low P and Ti, high LREE and LILE.

Qwench texture of basalt occur in the basal section as picrobasalts. Next overlying formation is Bajno Dolomite which is stromatolite bearing dolomitic limestone intermixed with chert. The Bajno Dolomite Formation is intruded by the Dargawan Sill Formation in the central portion of the basin. Phukhra Sandstone Formation overlies the Dargawan Sill Formation. The Phukhra Sandstone Formation grades into the Malhera Chert Breccia Formation. Kurat pillow lava occur in the western part of the basin (Ramakrishnan &Vaidyanadhan 2010).

Gangau Subgourp:
In this Subgroup Hirapur Phosphorite Formation is having ferruginous shale and phosphatic siltstone. Hirapur Phosphorite Formation is overlain by the Karri Sandstone Formation composed of ferruginous sandstone and shale with intraformational conglomerate and breccia (Ramakrishnan & Vaidyanadhan 2010).

2. Discussion

Bijawar Group of litho packages are exposed around the Hirapur, Sagar district of Madhya Pradesh. Hirapur lie in the southwestern part of the Bijawar Basin. In Moli Subgroup Bajno Dolomite and sporadic exposure of Malhera Chert Breccia Formations are exposed around Hirapur. Further both the formations of Gangau Subgroup namely Hirapur Phosphorite and Karri Sandstone are also well exposed in the Hirapur area. Bundelkhand Granite and Gneiss are exposed around the Hirapur forming an inlier.

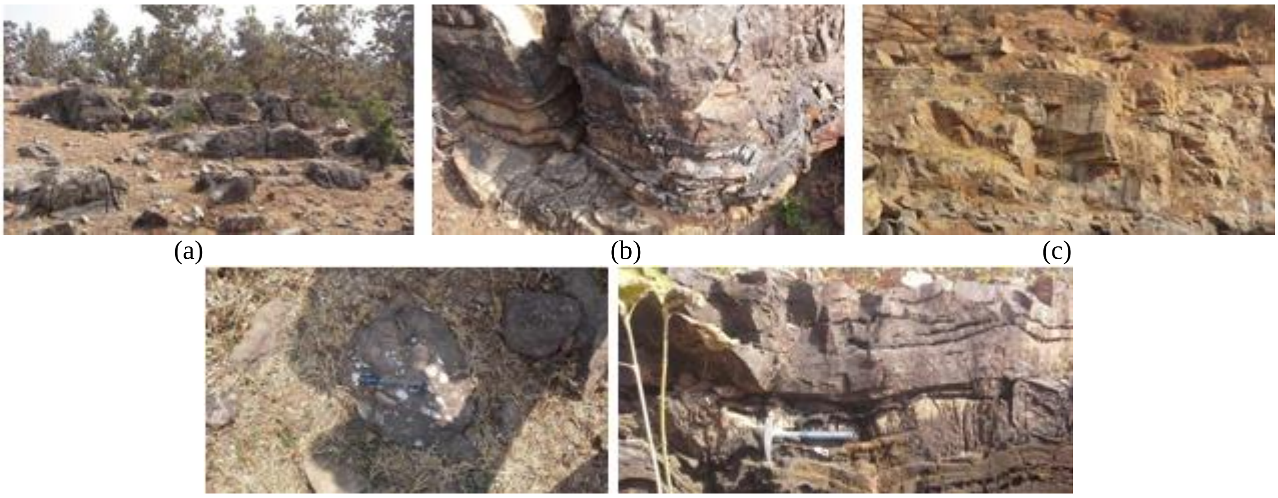
Bundelkhand Granite and Gneiss Complex
The lithology of Bundelkhand Granite and Gneiss Complex (BGGC) mainly comprises tonalite-trondhjemitegranodioritic (TTG) gneisses, metasupracrustals (amphibolites, banded iron formation, komatiitic basalts (~modern boninite), metaperidotite, calc-silicate rocks, corundum-bearing phengite schist, quartzsericite schists, fuchsite quartzite and quartzite), granitic rocks (plutonic, hypabyssal and volcanic variants), giant quartz veins, mafic dykes and some noritic intrusions in the western part of Bundelkhand Craton (BuC) (Basu, 1986; Sarkar et. al., 1996; Sharma and Rahman, 2000; Mondal et. al., 2002; Malviya et. al., 2006; Pati et. al., 2007; Saha et. al., 2011, 2016; Kaur et. al., 2016; Verma et. al., 2016; Joshi et. al., 2017; Singh et. al., 2018; Roy et. al., 2018; Nasipuri et. al., 2019; Singh et. al., 2019; Alfimova et. al., 2019).

The Bundelkhand Granite and Gneiss Complex exposure shows deformed (Fig. 2) as well undeformed granites.

(a) (b)

Figure 2: (a) Bundelkhand Granite Gneiss showing the Shear zone conversion of granite to gneiss (b) Bundelkhand Granite Gneiss showing folding of quartz vein in the Shear zone near Maddewra Government High School.

Bajno Dolomite Formation
This Formation is well exposed in Hirapur area. This is a chemogenic formation owes to their deposition by chemical precipitation. This initiated with enrichment of carbon dioxide gas in atmosphere by volcanic activity that took place during the Bijawar sedimentation Carbon dioxide in the atmosphere combines with the water vapor and forms carbonic acid. The acid rain precipitated in this condition, combines with the rocks in the basin catchment and forms the bicarbonates.



(a) (b) (c) (d) (e)

Figure 3: (a) Exposure of Bajno Dolomite at Maddewra. (b) Dolomite showing inter bedded with chert showing fluctuation of depositional environmental condition at Maddewra. (c) Gentle dipping dolomite beds showing post depositional deformation near Hirapur along river section. (d) Paleo braided river channel deposits with dolomite indicating regression of sea level during its formation, near Tigoda Village. (e) Stromatolitic bio-harm mat deposits on top of dolomite showing shallow marine clear water deposition near Maddewra Mandir.

Bicarbonates reaches to ocean basin and react with calcium and form the calcium carbonate that precipitate in the ocean basin floor as sediment, further formation of limestone and ultimately diagenetic change results in the dolomite formation. For this basin floor must be above the Carbonate compensation depth (CCD). Carbon dioxide is greenhouse gas and raises the earth's temperature enabling more evaporation, precipitation, and dolomite formation and ultimately lower down of earth's temperature. Continuous and discontinuous exposures of Bajno Dolomite Formation shows elephant skin weathering (Fig 3a). Most of the exposures of the formation shows interbedded with the chert (Fig 3b). Fresh exposures along the river section shows lamination in the formation (Fig 3c). Few conglomerate exposure along with the formation indicates paleo braided stream (Fig 3d). Algal activity can be inferred on the basis of presence of overlaying Stromatolitic bio-harm mat exposure on the Bajno Dolomite formation (Fig 3e).

This shows that the earth's environment was warm and Bijawar Basin was shallow. After the deposition of Carbonate formaton within the basin it consumed atmospheric CO_2 and resulted in the lowering of the atmospheric temperature.

Basic Intrusives.

The basic dolerite dyke intrudes the Bajno Dolomite Formation in the study area which is dark in color and massive in nature (Fig. 4) .They do not show any sign of deformation indicating the cratonic stability had not been attained even after the deposition of carbonate formation.

(a) (b)

Figure 4: (a) Massive dolerite dyke occurs as exposure in the study area. (b) Dykes showing fine crystal development indicating shallow depth of intrusion, around Maddewra Government High School.

Malhera Chert Breccia Formations

This Formation is less exposed in the Hirapur area, some exposures are there along the Hirapur-Buxhwaha road. In this Formation brecciated chert are in the ferruginous siltstone and shale matrix. Chert breccia can be traced back to their original position but matrix is not showing any sense of movement in it (Fig. 5b). There is micro folding are seen in the chert breccia (Fig. 5a & 5c).

(a) (b) (c)

Figure 5: (a) Chert breccia showing microfolding indicating compressional force for the development of microfolding. (b) Chert breccia showing tectonic forces active during the time. (c) Again shows the breccia developed due to compressional forces active during the time, along Maddewra-Buxhwaha road 3 km from Hirapur.

The deposition of both the chert and ferruginous siltstone matrix in different level of oxygen conditions. Chert shows the oxygen poor condition while ferruginous siltstone matrix shows high oxygen condition.

Formation of chert breccia is indicative of some tectonic activity during the time of its formation. The matrix of the chert breccia having no sign of movement. Ferruginous siltstone matrix shows medium water level depth and the deposition took place little far from the basin margin.

Hirapur Phosphorite Formation

This is well exposed in the Hirapur area and mining activity is also going on for extraction of phosphorite for economic uses (Fig. 6b). Disconformity between underlying Bajno Dolomite Formation and overlying Hirapur Phosphorite Formation indicate a gap in sedimentation and change in depositional environment (Fig. 6a). The X-ray diffraction studies indicated that carbonate flourapatite is the major apatitic phase in these phosphorites while crandallite develop on the surface outcrop (Banerjee, et. al., 1982). Effects of post-depositional digenetic re- crystallization noticed within phosphorite deposits (Chakraborty et. al. 2015). Thin sections, SEM and XRD studies revealed that apatite is the essential phosphate mineral while quartz and feldspars are the dominant gangue in the phosphorites of the area. The collophane is observed to be mostly oolitic in form and microspherulitic in texture (Dar et. al. 2015).

(a) (b)

Figure 6: (a) Disconformity between lower Bajno Dolomite Formation and upper Hirapur Phosphorite Formation. (b) Phosphorite quarry near Luhani village, Hirapur.

The solubility of phosphate in upwelling waters decreases as the temperature and pH increase near the surface (Kazakov, 1937; Kramer, 1964; Roberson, 1966), and apatite may be precipitated by organic or inorganic processes. Organic skeletons and excrement contribute phosphate in concentrated form to the sea bottom, and organic tissues may carry phosphate to the bottom in moderately soluble organic compounds, from which it may be released before or after burial (Van Vloten, 1955, Bushinski, 1964). Apatite, generally as carbonate-fluorapatite but under special conditions perhaps also as hydroxyapatite (Kramer, 1964), may also be precipitated from sea water by inorganic processes; a common textural type of phosphorite composed of unaggregated microcrystalline apatite may have formed in this way (Gulbrandsen, 1960). The phosphorite deposition also indicates the upwelling of basin water near shore or basin shelf with warm and alkaline condition favoring phosphorite deposition.

Karri Sandstone Formation

This formation is well exposed in the area and it is made up of ferruginous sandstone. This consisting of sandstone, shale, and conglomerates. Some faulting and slumping noticed in the area. Karri ferruginous shale exposure shows gently dipping beds (Fig. 7a). Paleocurrent directions can obtained from the record of Karri ferruginous shale, which shows ripple marks (Fig. 7b) as well as tidal wave generated ripple marks (Fig. 7c).

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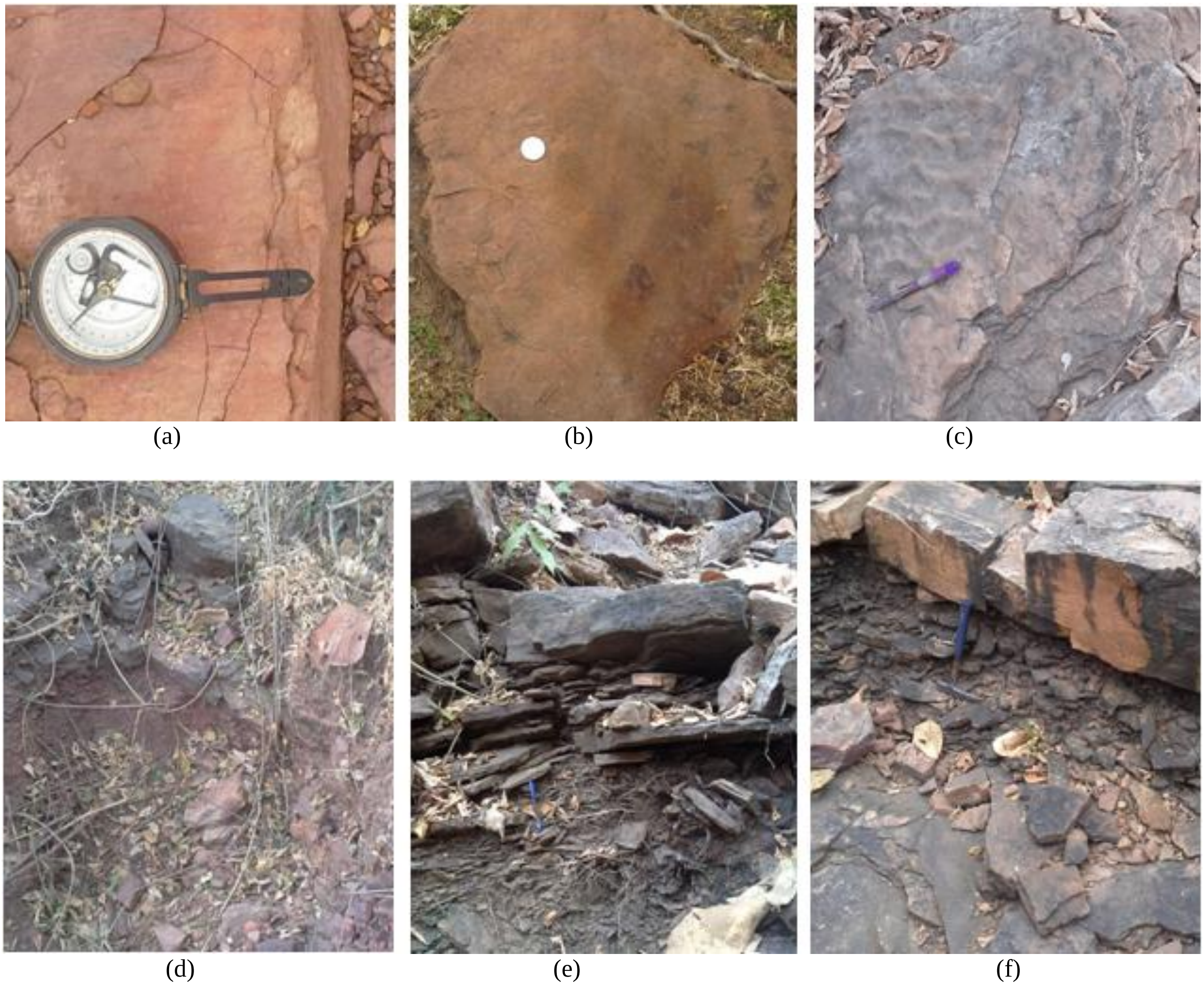

Figure 7: (a) Karri Ferruginous Shale showing gentle dipping due to tectonic activity. (b) Ripple mark structure in Karri Ferruginous Shale showing paleocurrent direction. (c) Symmetrical ripple mark indicating tidal flow. (d, e, f) Showing disconformity between lower Karri Ferruginous Shale and upper Semri Group of Vindhyan Supergroup. (Along Maddewra-Buxhwaha road)

Karri Ferruginous Formation is the topmost formation of Bijawar Group of rocks, which is disconformably overlain by the rocks of Semri Group of Vindhyan Supergroup (Fig. 7d, 7e, & 7f).

The sandstone, shale, and conglomerate lithology shows the medium to high energy condition with the fluctuating water level in the form of transgression and regression. These faulting and slumping indicates the tectonic activity during/after the deposition of Karri Sandstone Formation. Ferruginous iron oxide deposition due to Fe ion reaction with the high oxygen level during the deposition.

3. Conclusion

Bijawar Group of rocks in the Hirapur area showing marginal part of the basin deposition with fluctuating water level and clastic, chemogenic and intrusive rocks. The Bajno Dolomite Formation of Moli Subgroup indicates that the deposition was chemogenic without clastic supply of sediments in shallow water. During this time volcanic activity increased the atmospheric carbon dioxide leading to more dolomite formation. While depositing Malhera Chert Breccia, oxygen level was fluctuated, resulting chert with ferruginous matrix was deposited. Thereafter there were some tectonic forces crushed the Formation enabling formation of chert breccia. In the Gangau Subgroup Hirapur Phosphorite Formation resulted due to upwelling of basin water in the marginal part and deposition of phosphorite either organically or inorganically in warm and alkaline condition of basin water. The Karri Sandstone Formation formed in medium energy clastic cum chemogenic oxygenated environment.

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