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A Study on Geological History of Sona River Basin, Jharkhand, India

Sanjib Sau [1*], Dr. Surbhi Sahu [2]
[1] Research Scholar, Department of Geography, Ranchi University, Ranchi, Jharkhand, India
[2] Assistant Professor, Department of Geography, Ranchi Women's College, Ranchi, Jharkhand, India

Corresponding Author: *Sanjib Sau

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Abstract

The landscape in fact, is the manifestation of folds, faults, joints, height of rocks, their constitution, and resistance to previous processes operating on them. It is necessary to present the aerial distribution of the various rock groups or litho-tectonic settings and to indicate the role of these rock formations relating to the study of geomorphological problems. Proper understanding and assessment of the geomorphological features requires the study of the geology of the entire area as well as the knowledge its history. The rocks are much older than the geomorphological forms developed upon them. This paper presents the faulting, folding, and igneous institutions, sedimentations, etc. have attributed complexity to the geology of the Sona River basin lying in the southern part of the Chotanagpur upland. The vestiges of several geological occurrences have been completely wiped out by denudational processes. The sequential orogenic cycles are closing at 3200, 2700 and 850 mya, in the Singhbhum and it adjoining regions in eastern India, is strikingly similar to those in another Precambrian shield area of the world. The sediments derived through those processes were arranged in horizontal layers. It was in the Archean era itself that these sedimentary layers were folded into tangled masses of hill ranges by regional metamorphism.

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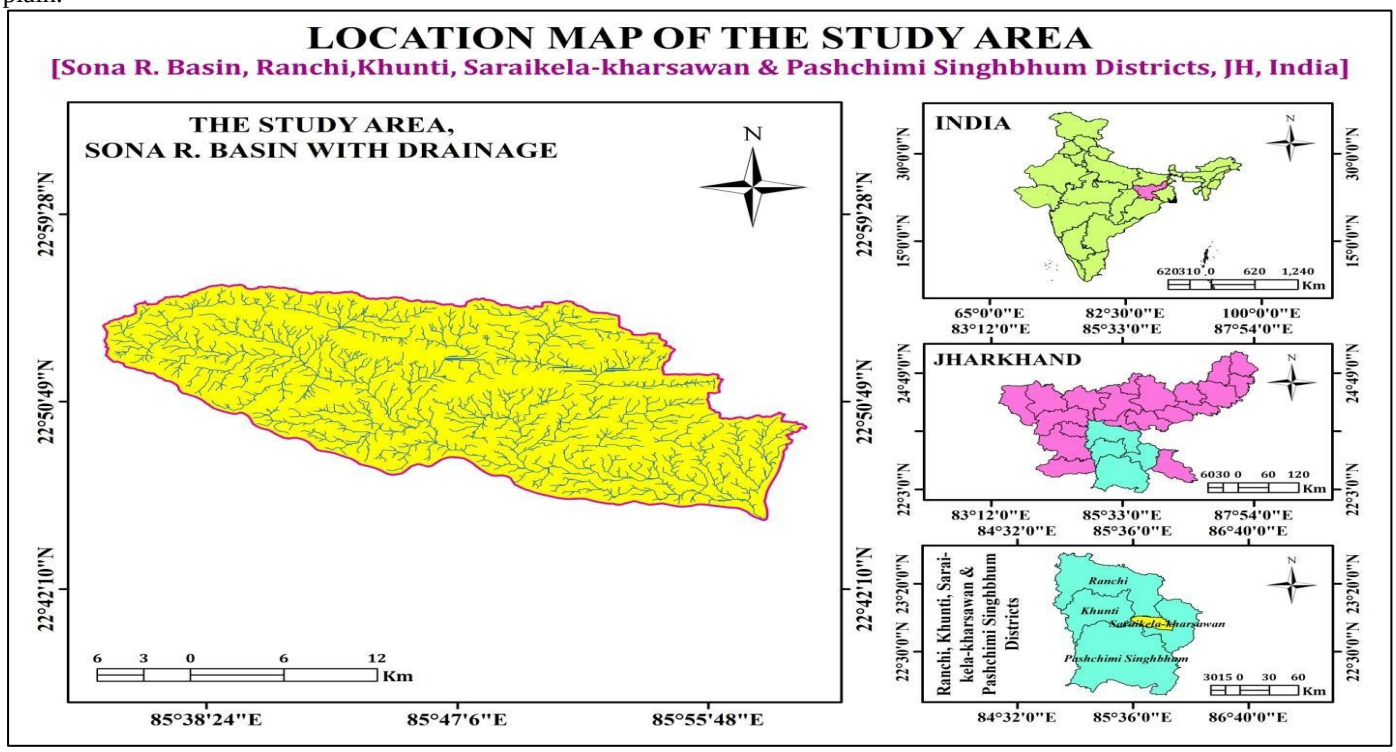
1. INTRODUCTION

It is necessary to present the aerial distribution of the various rock groups or litho-tectonic settings and to indicate the role of these rock formations relating to the study of geomorphological problems of the Sona River basin of Jharkhand state. Proper understanding and assessment of the geomorphological features of the Sona River basin (a part of Chaibasa plain) requires the study of the geology of the entire area as well as the knowledge its history. The rocks are much older than the geomorphological forms developed upon them.[1] The landscape in fact, "is the manifestation of folds, faults, joints, altitude of rocks, their constitution and resistance to previous processes operating on them."[2] Faulting, folding and igneous institutions, sedimentations, etc. have attributed complexity to the geology of the Sona River basin lying in the southern part of the Chot Nagpur upland. The vestiges of several geological occurrences have been completely wiped out by denudational processes. "The sequential orogenic cycles are closing at 3200, 2700 and 850

mya, in the Singh hum and it adjoining regions in eastern India is strikingly similar to those in another Precambrian shield area of the world."[3] The sediments derived through those processes were arranged in horizontal layers. It was in the Archean era itself that these sedimentary layers were folded into tangled masses of hill ranges by regional metamorphism. *"Some anticlines (The Sonapet valley section, etc.) arranged en echelon at the north-west side of the basin expose. Pre-Cambrian rocks, and at the north end of the Sanjai basin is a line of folds, dike-wise arranged en-echelon, which appear to represent an extension southward of the Porhat-Dalma uplift into this part."*[4] It is also a notable fact that this region remained almost aloof from the earth's movements since the Archean uplift up to the beginning of the tertiary times. The forces at work are the processes of weathering and erosion actively humbling down the huge Archean plications to a faint relief. Dunn (1929) also holds that the Sanjai plains (Sona basin is also a part of Sanjai plain area) is no doubt, erosional plains which came into being due to the head wards erosion of the extensive systems like the Kharkai and Sanjai, although Chatterjee (1946) has doubted the efficiency of the river systems like the Sanjai in carving out such a plain.[5]

Location of Study Area: The Sona River basin of the Indian state of Jharkhand is a very significant geomorphological unit. This basin area deals with a versatile topography, lithology and rocks. It is also a part of Chaibasa plain. Sona river basin is situated across some part of Ranchi, Khunti and Paschimi Sinhbhum districts of Jharkhand. The study basin covers an area of 484.58 square kilometers which is 0.75% of the Chotanagpur plateau and 21.57% of the Chaibasa plain, respectively. This river basin occupies 93.82% of the total area i.e., 456.68 square kilometers, within the Saraikella-Kharswan district and the remaining 28.24 square kilometers area of this basin is in Ranchi district, 0.32% in Khunti district, and only 0.15 square kilometers or 0.03% area in Paschim Medinipur district. The maximum altitude of the basin is 918m, and the minimum altitude of the basin is 148m. The Chandil-Gamharia range and Ranchi plateau are already situated in its northern corner. Paschimi Singbhum and Chsibasa forest range are in its southern side. Dalma Hill and Purba Singbhum took place in its eastern corner, and Khunti situated in its west side. The Sona River basin has a latitudinal extent of about $22^0$44'39" N to $22^0$57'12" N and a longitudinal extent of $85^0$35'22" E to $85^0$58'52" E.



2. OBJECTIVES

The objectives of the study are as follows:

1. To identify the geological formation of the Sona River basin.
2. To trace the geological history of the Sona River basin.
3. To understand the relation between relief & structure of Sona River basin.

3. DATABASE & METHODOLOGY

In recent years, the integration of remote sensing and GIS-based methods has revolutionized morphometric studies. Digital Elevation Models (DEMs), such as SRTM and ASTER, enable precise extraction of terrain features including flow direction, flow accumulation, and watershed boundaries. GIS software like ArcGIS, QGIS, ERDAS, TCX Converter, etc. with tools such as ArcHydro and TauDEM, are extensively used to automate stream network generation, order assignment, and spatial

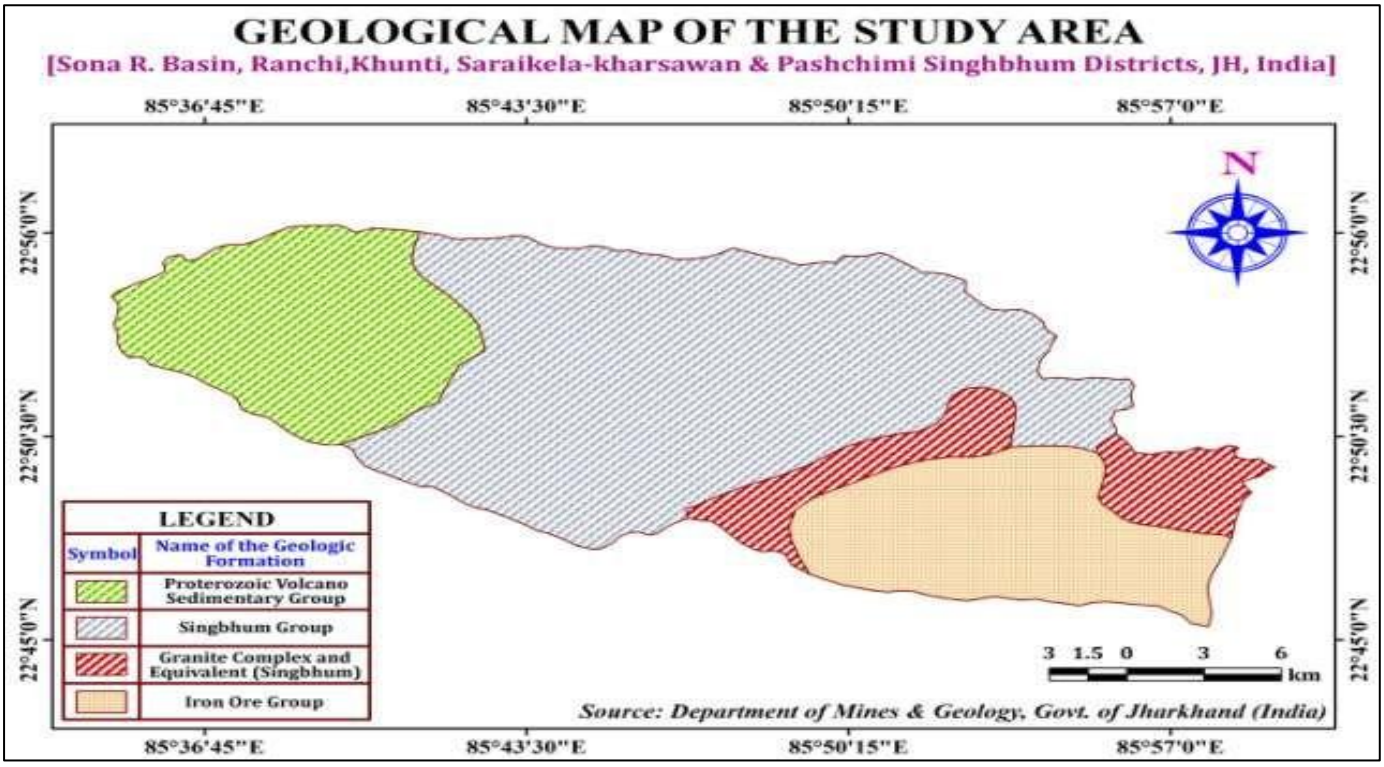
analysis of morphometric attributes. These platforms also facilitate the development of thematic maps representing geological attributes, which are crucial for visualizing spatial variability across the basin. Furthermore, geospatial models have allowed for sub-watershed prioritization based on compound morphometric indices, supporting watershed management planning.

4. RESULTS & DISCUSSION

Geological Formations of the Sona River Basin:

This basin area of west Singbhum district abounds in rocks like conglomerate, shale-phyllite, mica-schist, abounded quartzite, granite, dolorite (newer) and the like showing their affiliation with the Archean era. The hill ranges of the Sona River basin of the south and south-eastern parts are composed mainly of granite and granite-gneiss ultra basic rocks, cholorite-sericite and talc-schist of the Dalma volcanic and shale of the overthrust zone while those in south-western part consists of iron ore series including epidiorite and hornblende-schist. Eastern part of the study area composed by Proterozoic volcano sedimentary type rocks. The lack of any fossil's records except for some rare alleged organo-sedimentary structure, slromatolites, makes any attempt to determine temporal constrains of these rocks solely dependent on isotope geology (Sengupta and Mukhopadhaya, 2000; Mukhopadyaya, 2001).

Isotopic data from rocks of this crustal provinces, although meagre indicate an age range from 3500 Ma to 1400 Ma (Sharma *et. al.*, 1994; Goswami *et. al.*, 2000; Sengupta and Mukhopadhaya, 2000) and references the Sona River basin formation (eastern part of the study region). The extensive granite, gneiss, and magmatite terrains are in the eastern part known as Chotanagpur gneiss complex. The Archean proto-continental nucleus in the Singbhum crustal provinces is grid by an elongated and arcuate belt of sedimentary and volcanic rocks, deformed and metamorphosed to green schist (locally amphibolite) facies (Naha, 1965; Saha, 1994). This belt also recorded a wide array of sedimentary and volcanic successions attributed to varying sea level, continental freeboard and tectonic regime (Erikson *et. al.*, 1999; Mozumdar *et. al.*, 2000; Mozumdar, 2003). Singbham group rocks spreads all over the middle portion of the Sona basin. Although the Singbhum group rocks has been subdivided into a lower Chaibasa formation and upper Dhalbhum formation. Earlier researchers couldn't find any lithological differences between these two formations (Sarkar and Saha, 1962, Sarkar, 1984 and Sarkar *et. al.*, 1992). Both these formations are entirely siliciclastic & deformed and metamorphosed, generally at green schist to upper amphibolite facies. The older Chaibasa formation consists of sandstone, shale and sandstone shale inter banded. This study area formed in a shallow marine setting; both the shale and heterolithic facies.



The stratigraphical sequence of rocks encountered in the study region is as under:

Table 1: Geological Formation

Sl. No.	Structural Group (s)	Major Components
1.	Proterozoic Volcano Sedimentary Group:	Conglomerate, coarse-grained sandstone, shale, arkasani granophyres, sodagranite, and breccia
2.	Singbhum Group:	Amphibolite, green schist, sandstone, and sandstone-shale
3.	Granite Complex and Equivalent (Singbhum):	Chakradharpur granite-gneiss, shale, phyllite, hornblende and mica-schist
4.	Iron-ore Group:	Epidiorite and hornblende-schist

Source: Departments of Mines and Geology, Government of Jharkhand

A

B

Fig A: Towering Granite Tors near Maranghatu in the Kanke Sub basin of the Sona Watershed
Fig B: Striking Exposure of Quartz seams Embedded within phyllitic structures along Kantanta Juria

1.1 The Archeans Rock Features:

The Archean era saw tremendous placation as a result of reverse diastrophism. The present hills, hillocks and ranges that cover the middle part of the Sona basin area and its adjoining areas area a tamed reproduction of the dramatic Archean folds. These parts, the Precambrian rocks form the "basement complex" consisting of the older metamorphic series.

The 'older metamorphic' are over lain unconformable by thick cushions of iron ore series, "the lower beds of iron-ore series have been found by Jones resting upon the upturned beds of the older metamorphic series in south Singbhum."[6] The older metamorphic are virtually the Chaibasa stage rocks (Dunn), which consists of mica-schist, hornblende-schist, etc. found in the great geoanticline north of the share zone and "stretches from north-west of Chakradharpur eastward across Saraikella-Kharswan and continues in a south-easterly direction towards Dhalbhum."[7] Its "northern margin appears to show some overlap by the overlaying basal beds of the iron-ore stage which build up range of the hills rising abruptly from the mica-schists".[8] The hills, hillocks and ranges in this study area indicate the Archean folds, which are primarily buried beneath the heavy covering of recent alluvium, particularly in the central and eastern pockets. "The rocks associated with the Chaibasa stage are generally soft and therefore, easily vulnerable to weathering and erosion. As a consequence, the rocks of the Chaibasa stage invariably do not make anywhere prominent surface features."[9]

The views of some scholars regarding the origin of Archean rocks merit mention. (i) It is thought that the earth, our mother planet, was originally in mother state. (ii) Archean rocks were created through solidification and consolidation of molten rock components. "The primeval solidified landmass must have constituted the original surface, where initial chapters of erosion and sedimentation might have been written".[10] (iii) It is also believed by the geologists that the para metamorphic rock such as quartzite and phyllite arc, the result of severe dynamic metamorphism of the primeval secondary layers of the Dharwar systems. (iv) It's believed that, some of the areas said to be metamorphosed forms of plutonic igneous rock masses.

Striking Exposure of Quartz seams Embedded within phyllitic structures along Kantanta Juria

A. The Archean Rocks:

(i) Mica-schist with abundant Hornblende-schist:

Small exposures of hornblende-schist occurring as conformable patches within the mica-schist are seen in the southern part of the Sona River basin and its adjacent areas. Around Barsupri, it is found abundantly too. "It is fine-grained melanonatic and is seen to be traversed by fine veins of quartz."[11] Tiny or very small pieces of chalcopyrite and pyrite are also observed. The rocks are "comprises a fine aggregate of green hornblende, quartz and little feldspar. Sulphide ores form the accessory group."[12]

(ii) Shale and Phyllite:

Shale and phyllite forms of the country rocks are mostly to the south of Chakradharpur granite. These fine-grained rocks are endowed with developed schistosity, defined by biotite and chloritesericite. "Cretaceous layers and cherty layer also mark bedding in them."[13] A bound of phyllite continues towards east

along the bank of the Sona River up to the south of Kadamadiha. It is pale greenish and buff in colour. Inter-layered bounds of grit are also noticed at places. The grits are composed of sub-rounded grains of quartz, feldsper and rock fragments in ferruginous and sericitic matrix.

(iii) Sheared Conglomerate with Associated Quartzite:

The outcrops of sheared conglomerate associated with micaceous quartzite are confined to the limited area. These rocks grouped under "meta-basic rocks" appeared to the metamorphic derivation of the same basic suite of rocks. A sheared conglomerate is exposed about 0.7 km E-SE of Rajkharswan railway station northward. This rock is composed of fattened and elongate pebbles of quartzite, mainly in an arenaceous matrix or rock masses in which crystals or fossils are embedded. It contains pebbles of various sizes. Another conglomerate horizon is inter-bedded with the metamorphics. It is exposed in the study area of Madhkanhata. It composed of rounded and flattend pebbles of volcanic origin. Some informal conglomerate is also found around Lotapahar region.

(iv) Phyllite and Mica-schist:

The core of the anticlinal valley of Sona is occupied by the deposits of phyllite and mica-schist. These deposits are also confined to the areas of the series of hill ranges to the north and south of the Sona river basin. Except at a few places in the valley portion, there is no good exposed in the western part of a hill, named Khanda Buru. Kanchanpur mica-schist is of brown colour on the eastern bank of the Sona and SSW of Gumantanr. The schist is very rich is garnet and mica. A small patch of similar rock is seen on the northern bank of the Sona River, NNE of Surmali. A greenish grey puckered variety is also seen on the bank of the Sona just ESE of Sini. Phyllite is found in close association with mica-schist here. This soft, friable rock rich in micaceous substances in pal greenish and buff in colour "the phyllites and mica-schists sometimes make prominent hill ranges or well defined ridges parallel to the strike as to the south of the Sanjai River.[14]

(v) Granite and Granite-gneiss:

In this study area, several granite intrusions such as Singhbhum granite, Aakasani granophyre, soda-granite, etc. are meet with Dr. Fermor[15] considered the possibility that they might to Dunn (1929) petrographic difference among the granitic rocks are "simply a result of their individuals metamorphic environments, different metamorphic conditions imparting distinct characteristics to rocks which originally were identical.[16] "Mineralogical variations are not much among them". Dunn and Dey (1942) though that the Singbhum granites, soda-granite, the granophyric rocks and the diorites come from the same magmatic region. Diorites were the first to be inrodded and were following by the Singhbhum granites, soda-granite and granophers in succession. Some recent workers have suggested to granitic intrusion in Singbhum ore characterized by Singbhum granite and the other by the Aakasani soda-granite. According to Sarkar and Saha, the Singbhum granite marks the end of the iron ore orogeny. The Singbhum granite occupies a vast area that stretches south from Saraikela town. It covers a wide area in the plain to the south and middle-east of Sona basin. "It is huge loss intrusive into the older Dharwar and the iron ore series which seduces to have very little metamorphic effects on the rocks into which it was intruded."[17] Chakradharpur Granitic-gneiss is the most extensive outcrop next to the Singbhum granite. It occupies part of the shear zone and over a large tract, it has been highly sheard. It has great similarity with the Aakasani granitic rocks. Though its great extents it forms a monotonous plain which is invariably covered by paddy fields. "The Aakasani granophyres or soda-granite is the name given by Sir Lewis Fermor to a line of small elongated exposure of granitic rocks amongst the phyllites and mica-schists in Kharswan and Saraikela."[18] The name was derived from the name of a hill (Arkasani) of this rock near Kharsawan, Dunn has traced the outcrops west of Chakradharpur and in Dhalbhum beyond Musabani. It has a strike distance. A part of east of Saraikela is included in the shear zone. "The granophyre and soda-granite which are intrusive into the Dhanjori group represent a later phase of magnetic intrusion, than the wider spread Singbhum granite mass." Arakasani rock was an earlier phase of the one great magma which included the Singbhum granite and granite-gneiss. But recent study shows that there is no close relationship among them. To the southwest of Rajkharswan, massive granite from cluster of small flat-topped elevations. The patch of granite is seen just south of the railway line near Jarkota. This whitish grey leucocratic granite is often mistaken for quartzite. It is another small patch is observed on the southern part of Sona basin where it grades into granite. Therefore, in a nutshell, it may be said that the study area possesses various categories.

(vi) Sheared Epiodiorite, Chlorite-sericite and Shale of Overthrust Zone:

This sheared zone stretching across the area through Rajkharswan consists mainly of sheared and altered epidiorite. This greenish grey rock is generally foliated. These rocks appear to vary from sheared and altered metavolcanics to fine grained sheared chlorite. Altered chlorite-quartz schist with sericite and secondary calcite are noticed in phyllite along the Sona river basin. Some patches of sheared granite and quartz, mica-schist are exposed on the Sona River just before their confluence. The origin of this rock is caused by shearing and alterations of volcanic materials.

(vii) Ultrabasic Rocks*:*

The ultrabasic intrusive of west Singbhum district in general and Sona basin in particular are of uncertain age, and while some are older than the Singbhum granite, the other relatively unaltered ones, are of post granite age. The ultrabasic rocks are serpentinised and converted to talc rocks and to talc and chlorite-schists. In Saraikela at Barabana, the younger ultra basics have given rise to deposits of asbestos of hydrothermal alternations. The most conspicious ultrabasic horizon has been observed at the base of the Ongaberia volcanic suits. "These are mostly pyroxenite and at times grade into gabbroid composition."

A **B**

A. Slaty Exposure along the river Kulachiki (Tributary of river Sona) near Chotabandhi Village
B. A scene of ultra-basic Rock formation near Jogohatu on the river Parambera

B. Recent Alluvium:

Contrary to the aluminium of the northern part of the Gangetic synclinorium which lies over the successive strata of the Nummulitic, Murree and Siwalik deposits, the alluvium of the Sona river basin area rests directly upon the Archean formations. These late tertiary sediments, especially in the lower valley, are comparable to more recent accumulation, i.e., middle Pliocene to Holocene. The flurialite aluminium along the valleys and in the lower reaches of the river is mainly 'Khadar' in nature. It gets deposited every year during the rains. Alluvium covers a major part of the Sona river basin area and engulfs the exposures, hillocks and hill ranges penetrating into their Jaws. The comparatively lower surface in the central and eastern parts looks like a vast sea of alluvium dotted with island like Archean hills and ranges. The surface close to dolerite dykes in granite and granite- schist country has loamy soil. "Over the mica-schist the soil cap is much more argillaceous. The red soils of the middle part of this basin area are in incipient stage in the formation of laterite."[19] Epidiorite produces dense clay soil. Shales are formed, a somewhat light grey soil. The sandy soil derived from quartz and mica-schist promotes the formation of badlands owing to the case of erosion. Away from the valley, the soil form caps of varying thickness over elevated parts and the nature of soil is guided by the types of underlying rocks there. The alluvium soils of the Sona basin are the product of the country rocks. The soil mantle is very thing in the hilly tracts of northern, western and eastern part of the study area. Some Alluvial soil becomes strictly during the rains, because they contain water for long. Cracks measuring up to 5 cm in width and few meters in length are developed in them during dry seasons. The Sandy and loamy soils are criss-crossed by such cracks. The alluvium in the river cliffs and bluffs is commonly bedded. "Here and there current bedding gives a false impression of high dip (Dunn, 1937).[20] A recent alluvium area is a flat monotonous fertile plain and almost absolutely covered by paddy fields. In spite of the best effort of the geologists to give concrete shape to the stratigraphy of the Sona basin, there are still certain minor gaps which are yet to be filled.[21]

1.2 Structural Features:

In addition to all the structural characteristics included in the narrower geologic meaning, structure, geomorphologically, comprises every inherent quality of the rocks substances that may influence to erosion and the effect of resistance on relief are important elements of structural geomorphology. Structure is generally reflected in the landscapes especially where the beds of different resistance are involved in folding and faulting.

The soft mica-schists, shales and granites of the study area have been eroded away by the fluvial processes of erosion and then, these great geomorphic units have been curved at a level of about 1000 feet or 350 m below its original level.[22] Granites are susceptible to weathering easily due to the presence of joints in them. Minor structures like cleavage, schistosity, and bedding plains, etc. have great effects on weathering. The dip of the beds also affects the landforms. Different rock faces of the same formation have different rates of weathering and erosion. "It is sometimes found that beds which appear to be hard form no significant relief features while at other places appreciable relief appease to occur without corresponding lithological differences."[23] Structure plays a dominant role in the evolution of landscape. The most important structural features of the geology of the Sona River basin area is a series of great anticlines and synclines which veer round this study area. A series of highly metamorphosed rocks form a great anticline which commencing from the east in south Sona basin extend through Saraikella turning south-east near Jamshedpur. North-west of Kharswan, a north-westerly branch of the anticline forms an almost done.

CONCLUSION

It would this appear that the iron ore series of sedimentary rocks were folded into well-defined anticlines and synclines over folded towards the south and formed a mountain ranges, extending east to west across southern section of the study area. South of the main axis of folding earth movements were less intense and the rocks of the northern section of the Sona basin area generally less metamorphosed. The rocks of the iron ore series show a rapid change in the degree of metamorphism across

the strike from phyllites to mica-schist and a similar but gradual change towards the west along the strike. Tongues of soda-granite and granophyre have been injected along the zone of thrusts Saraikella.[24] Copper belt, for its most part, follows this area of a trust. The apatite-magnetite veins and the copper loads are genetically related to the soda-granite and granophyres of the Saraikella-Kharswan belt.[25] Saraikella-Kharswan like shear zone is another place that consists of epidiorites which are often completely altered to quartzites and conglomerates.[26]

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Mr. Sanjib Sau is a Research Scholar at the University Department of Geography, Ranchi University, where he is currently pursuing his Ph.D. His research interests include Geomorphology, Human Development, and Coastal Studies. Mr. Sau is actively involved in curriculum development and has made notable contributions to academic research and student mentoring.