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Lithological variations and drainage evolution in a marginal region: A case study from Chandrapur block of the Pranhita-Godavari Basin, Central India

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Abstract
Field mapping and interpretation of sedimentary structures in Gojoli region of Chandrapur block along the eastern margin of the Pranhita-Godavari valley suggests westward flowing channels during the Neoproterozoic. Present channels in this part of Chandrapur block are south/ southeast flowing and possess clear imprints of the basin-margin faults and lineaments. Drainage parameters in its Neoproterozoic stratigraphic sequence suggest impervious substrates probably due to high degree of consolidation and filling of rock-fractures by hydrothermal solution activities. However, the same for the Gondwana's friable sandstone (towards western region) and Archaean gneisses (in the eastern part) has been observed consistent probably due to its porous nature and development of thick weathering profile. The affiliation of drainage with tectonism is therefore, from Neoproterozoic to present day within contrasting lithology, was out of synchronization intermittently.

Key words: Pranhita-Godavari basin, Drainage, Hydrothermal.

Introduction

Drainage network at the Earth's surface exerts a first order control on relief dynamics and the erosion of mountain belts. It is mainly controlled by the coupling between surface and deep crustal processes such as tectonic and climatic variations (Viaplana-Muzas et al., 2015). the topographic gradients and structural attributes of a region also contribute to the development of the drainage system. The study area of Chandrapur block exhibits predominant structural controls over drainage network due to its protofabric. As cratons came closer from Mesoproterozoic onwards, initial paleo-mesoproterozoic cratonic amalgamation governed it temporally (Torswik et al., 2001). The drainage patterns may reflect original slope and structure or the successive episodes of perturbations, which has caused the surface modifications by uplift, subsidence, tilting, warping, folding, faulting, and jointing, as well as deposition by the sea, glaciers, volcanoes, wind, and rivers. Manifestations of such tectonic activities are exposed regionally in the Cratons, especially along the Cratonic margins similar to the present scenario. Their impacts are in ample abundance in this region due to its proximity to the boundary of the Craton (Sharma et al., 2018).

In such conditions, the paleo-drainage characteristics can be deduced from the distribution of the paleochannels, associated facies and sedimentary structures. Also, presence of streams in a landscape imparts the effects of a long geologic history while decrypting the structure and surface conditions (Schumm et al., 1987). The sedimentary, geomorphic and structural features observed in parts of Chandrapur block provide significant implications for topographic evolution and associated subsurface processes from Neoproterozoic to Cenozoic era.

The drainage density exhibited by a region is the balance between climate, geomorphology and hydrology, which in turn shows the degree of fluvial dissection of a region (Lin and Oguchi, 2004). The rate at which erosion proceeds depends on the susceptibility of the rock surface to erode and the runoff intensity (Strahler, 1956). Convergence and offsetting patterns of streams are common in faulted terrains (Pati et al., 2011; Bhosle et al., 2009; Singh et al., 2006), which are very much prominent along the boundary faults in the study area. Slope influences rates of runoff, soil creep (depends on the cohesiveness and angle of repose), and soil flowage (Strahler, 1956). It changes due to faulting and differential erosion changes the local geography and hence the drainage geomorphology.

Being a discrete and active part of Godavari watershed, where the differential erosion are effective throughout the region (Ghosh and Paul, 2020), it is imperative to understand the tectono-sedimentary setup and Neoproterozoic channel behaviour with its geology. Therefore, in this study, we have compared the orientation of the Neoproterozoic drainage system of Gojoli region where most of the streams are non-perennial. This has been done with the help of morphometric parameters to describe processes (Ghosh and Paul, 2020) as well as their underlying link between geology and basin geomorphology (Rai et al., 2019). An integration of morphometric analysis, sedimentary evidence, geomorphological and geochemical analyses is carried out to understand the geomorphic evolution in terms of drainage under marginal tectonic controls of the basin.

Study Area

The Study area lies between the longitude 79°30' to 79°45' and latitude 19°30' to 20°00' in Chandrapur district, Maharashtra, Central East India and covers ~160 km^2 (Fig. 1). It falls in parts of the Survey of India toposheet 56M/9 and 56M/10. Geologically, the study area is lying along the eastern margin of the Pranhita-Godavari basin infringing the Western Bastar craton within the Cratonic nuclei. The deposition

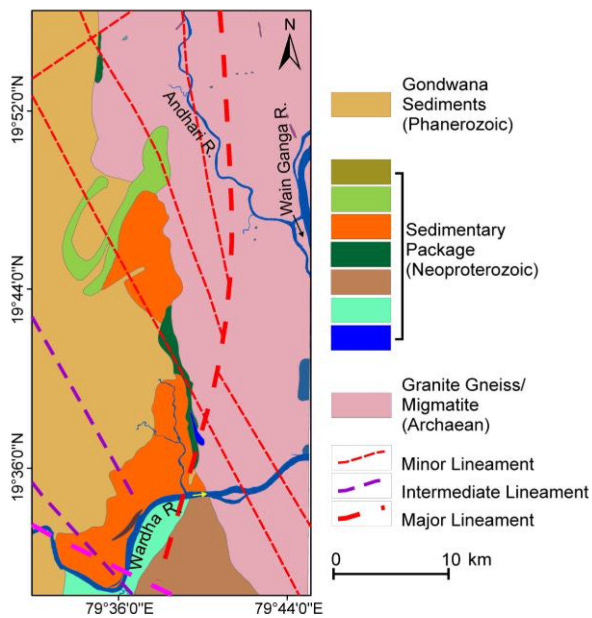

Figure 1 Lithological assemblage (GSI, 1983), and lineaments of the study area. (Lineaments are redrawn from Seismotectonic Atlas of India and after Das et al., 2003)

probably started from late Mesoproterozoic and early Neoproterozoic to Cenozoic Era. It has been evident from the depositional ages of ≈970 Ma from detrital Zircons of the Cycle III of Sullavai Group over which the Gondwanas are resting separated by unconformable surface (Amarasinghe et al., 2015).

The Archean cover in the eastern, Neoproterozoic sediments in the middle (PG-basin margin sediments) part and the Lower Gondwana sequences in the western part are resting within the intra-cratonic settings in this block. These three prominent litho-chrono-sequences can be distinguished by their present-day drainage characteristics (Fig. 1). The Gondwana Formation in the western part show moderate to semi-sparse presence of streams revealing dendritic to sub-dendritic type of drainage pattern, the Archean granite gneiss and migmatites show mostly dendritic to parallel and sub-parallel drainage patterns. The central

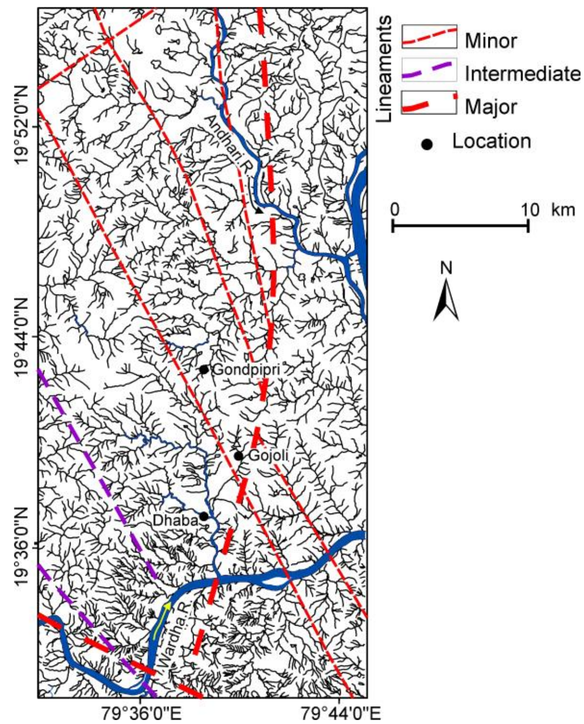

Figure 2 Drainage map of the study area (drawn from the Survey of India toposheet and Landsat TM image) superimposed by the lineaments. The lineaments are characterized by water divides and channel convergence, offset and straightness of river courses.

marginal region of Neoproterozoic sequences is characterized by dendritic drainage (Fig. 2). Hence, overall drainage of the region could be considered as dendritic type because impervious to moderate permeability of the strata with flat or rolling topography generally expresses it. The NW-SE trending prominent lineaments are characterized by convergent and straight channels. Drainage divide certainly owes its existence to various physical properties of its lithology and tectonic control over topography. The region has been bounded by faults and lineaments and partial parallel drainage along its lithological boundary within the basin margin.

The draining streams has behaved according to the gradient and permeability of various lithologies considering the factors of erosion rate and precipitation. Presence of several deformation features in the Proterozoic belts as well as extensional structures on different scales within the bounded basin (Deb., 2003) has integratively governed overall slope of the region other than protofabric related tectonism. The varied slope of topography in the study area can be attributed to the subsidence and intra-deformational activities, leading to development of dendritic and parallel drainage pattern in the basin. The region is segmented by five sets of lineaments (Das et al., 2003; Neogi and Das., 1998) and in the present study area, four sets are prominently present.

The study area is mainly composed of three prominent chrono-sequences i.e. Archean granite gneiss and migmatites in the eastern margin (Bastar Craton). Its presence has promoted the hydrothermal activity initially at the base of the deposited limestones in the basin marginal region (central strip of the study area) which was of Neoproterozoic age (Amarasinghe et al., 2014) probably due to faster mantle upwelling affecting the average thinner crust. Although, such activity were the result of diagenesis and solution movement induced by accumulation of heat and extensive partial melting at lower crustal levels within unconformity bound surfaces in the intra-cratonic basinal settings (Deb, 2003). The evidences are also visible in the form of the Iron enrichment in major fractures within this zone. These are the active zones of weakness giving channel-ways to few metallizing solutions or hydrothermal fluids. The Proterozoic age has been given by the radiometric dating for surrounding major Proterozoic basins (1276 > 20 Ma) in this region like this P-G basin. However, the upper part of Sullavai group, along the margin, unconformably lies over the Pakhal sequence has K-Ar dates of 871±14 Ma (Chaudhuri and Howard, 1985) correlates with subarkosic sandstones (Fig. 3 a, b) found in Dubarpet, in this part of Chandrapur block,, which are partially affected by mild metamorphic effect and micro fracturing (Fig. 3 c, d), provides the basic idea of later disturbance and the formational time frame in space. It has larger clasts in between matrix show depositional instability due to intermittent fluctuating energy conditions and tectonism. The Meso-Neoproterozoic platformal successions occur in the two belts along the margins of the P-G Valley. The medial part of the valley

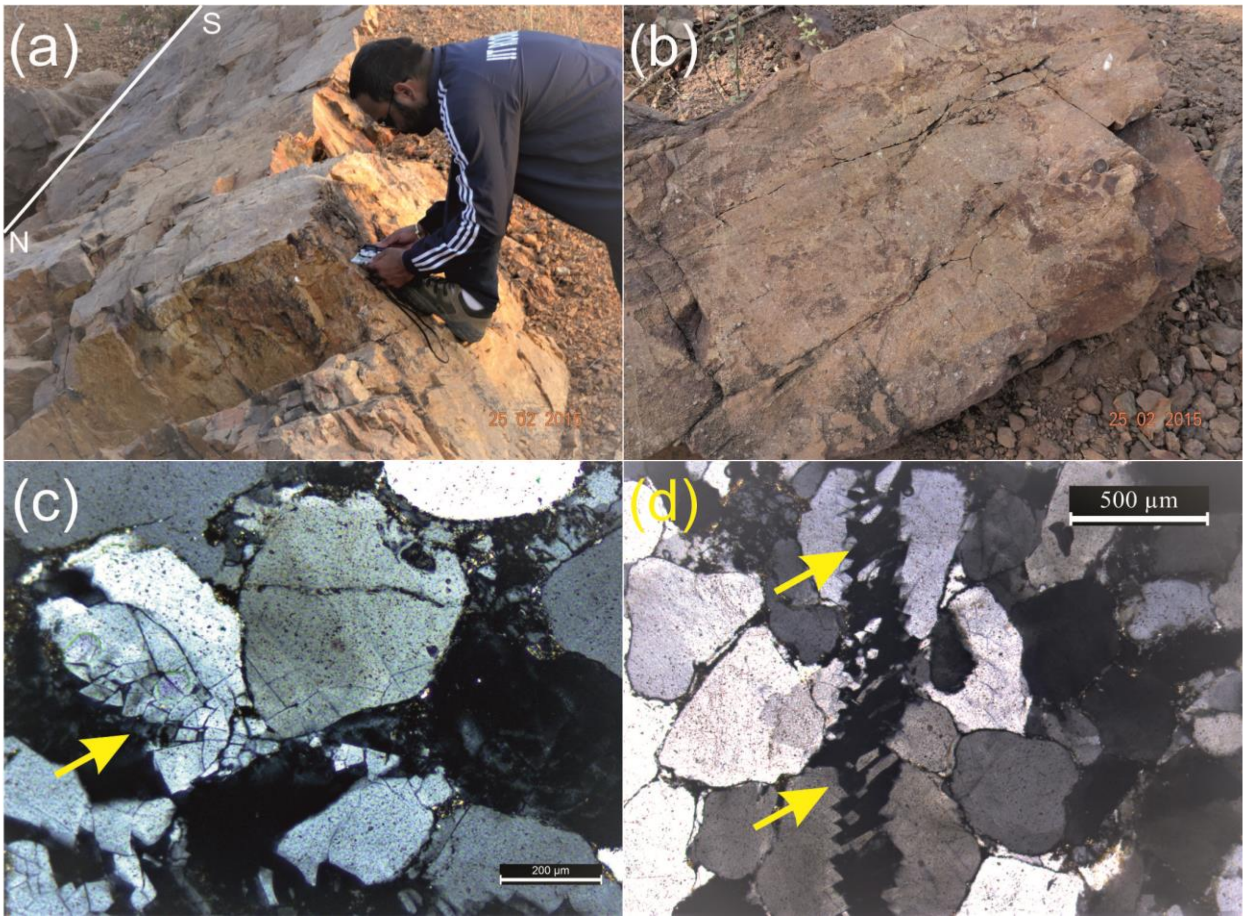

Figure 3 (a) Massive sandstone with its trend direction (b) Sandstone showing ungraded behaviour due to the presence of gravels and lithic fragments present between the martrix indicating varying energy conditions and depositional fluctuations (c, d) Fractured zones within the thin section showing the impact of tectonic disturbances and effect of shearing.

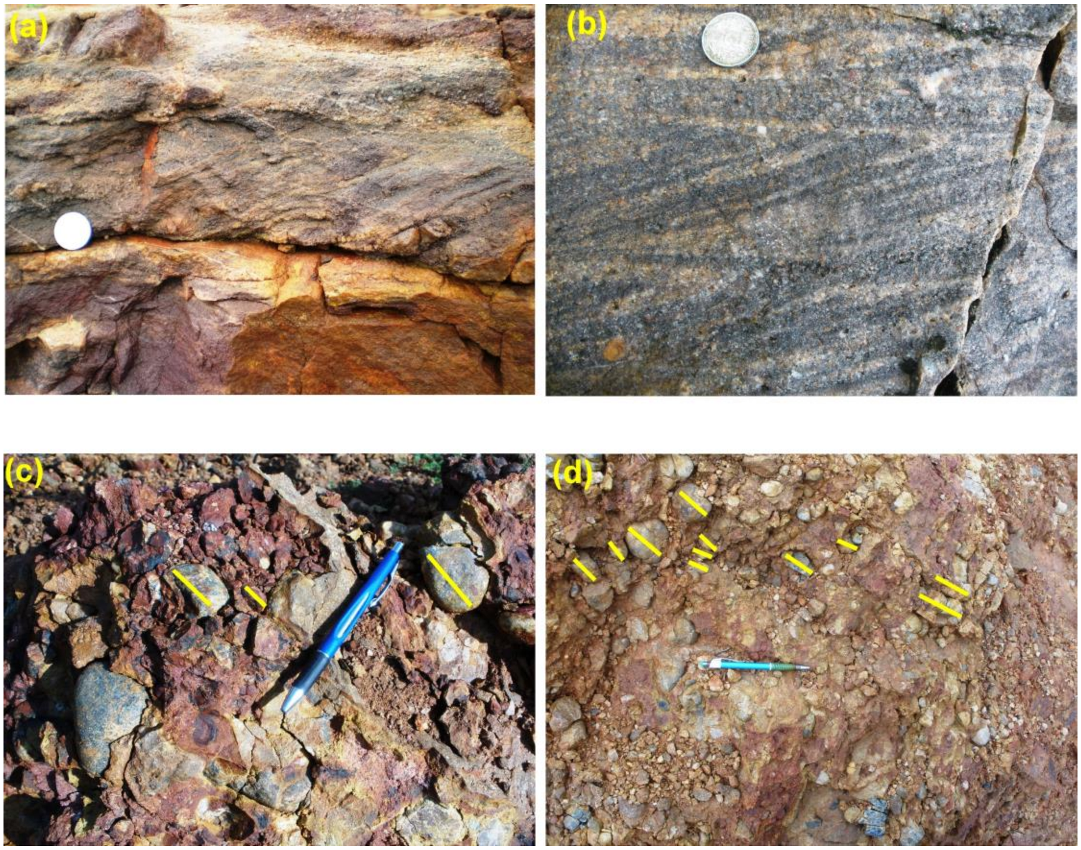

Figure 4 (a) Cross bedding of sandstone showing westward flowing channels near Dubarpeth (b) near Dongargaon. (c) & (d) imbricated pebbles (yellow lines) in the conglomerate beds at Dongargaon hill showing flow direction.

contains Permo-Triassic Gondwana Supergroup (Deb., 2003) which is the youngest deposit recently exposed other than Quaternary to Recent alluvium over it.

Meso-Neoproterozoic. The presence of trough cross-bedding (Fig. 4 a, b) and the imbricated conglomerate (Fig. 4 c, d) associated with the basin-margin fluvial

Figure 5 Autoclastic conglomerate showing clast within the clast configuration near to the basin margin. The mass flow sequence has played major role for its formation.

Lithology and facies association suggests rivers in the study area followed the slopes from the Bastar Craton in the east to the PG-basin in the west during sequences around Dubarpet and Dongargaon region are sedimentary evidence. They indicate west (towards the shelf) flowing channels during Proterozoic. It is supported by mass flow sequence towards the shelf and clast in clast containing larger clasts of limestone. However, as the whole sequence is unexposed, detailed nature of the paleochannels (channel width and depth ratio) cannot be studied due to lack of sufficient outcrop flowing streams. Dhaba and Andhari rivers in the central part of the area represent the similar settings within basin marginal faults and its proximity. Also, sedimentary structures in ancient and modern environments, other than exposed within marine settings, has explained about

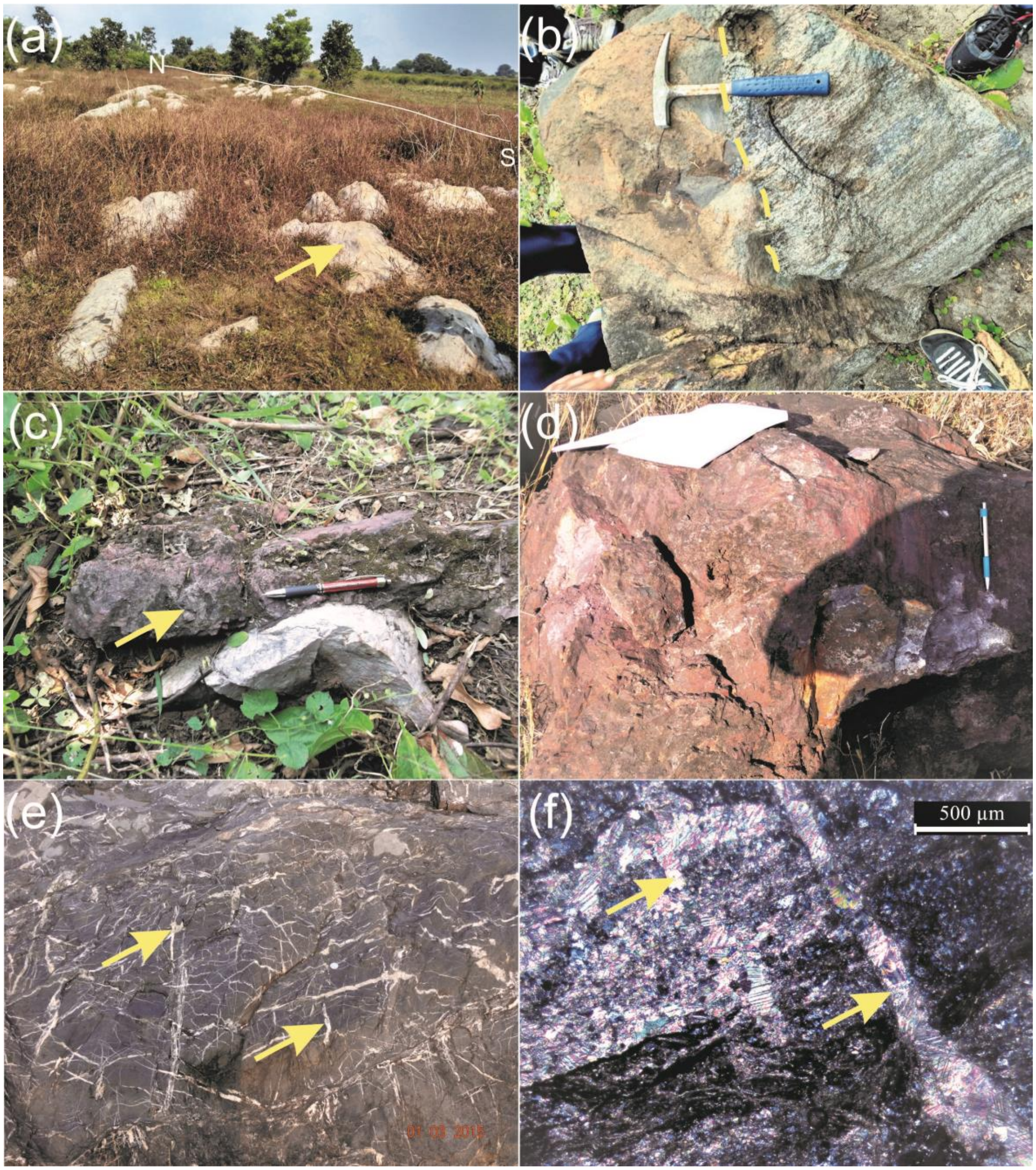

Figure 6 (a) Central Neoproterozoic terrain of massive west-dipping dolomitic limestone. (b) Contact between Archean Basement (TTG) and dolomitic limestone visible at some places due to exhumation. The Archean basement has been exposed towards the eastern part of the study area. (c) Presence of Iron enriched lithology in between the weak zones of dolomitic limestone showing hydrothermal solutional impact. (d) Iron-enriched lithology observed in between the dolomitic limestone. (e) Presence of cross-cutting veins in dolomitic limestone showing multiple episodes of hydrothermal activity. (f) Photomicrograph showing the presence of calcitic-veins in dolomitic limestone proving hydrothermal activity under thin-section.

exposure in the area. Primitive structural control in relict form can be seen in some of the straight and fault guided the slope and geomorphic conditions of the area. Previously, presence of various rounded clasts and clast within clast at the base of marginal environment indicates that the topography was not rolling and the underlying tectonic activity due to active faults was quite appreciable (Fig. 5). It was supported by the fact that marginal clastic mass accumulation along fault and its deposition with lithified scree and fine groundmass pertaining to multiple mass flow events were also present. It had a valid amount of slope affiliation which has been evident from the 36°–40° degrees dipping dolomitic limestone in eastern (Proterozoic) part of the block (Fig. 6). The presence of abundant water enabled easy transportation of the material. It implies that intermittent tectonic activity and geomorphological factors controlled the evolution of drainage in the region. Due to temporally prevailing more or less flat-lying character of Proterozoic basins in the peninsula, available visible evidences out of these sedimentary sequences which was the implication of the drainage and tectonic play observed in this part of P-G basin. There is visible perturbatory evidence, along major lineaments, over the drainage paths. The regional exhumation of the basement (TTG) and subsequent carbonate precipitation formed the platformal ramps over the slopes. Later, tectonic micro fracturing has caused iron enriched zones due to differential hydrothermal fluid movements through crosscutting veins in the form of micro conduits.

Solution induced fracture-filling at about supergene depth has played a major role in the infiltration process which in turn affected the drainage characteristics. This supergene effect at shallow depth is exposed at certain places due to upliftment and exhumation along the fan-deltaic settings of the marginal area with lot of effects like chloritization which has been now visible. The chloritization and sericitization of rocks in northern part of the block (in Dubarpet) indicates the impact of differential weathering along tectonically affected zone (Fig. 7a, b).

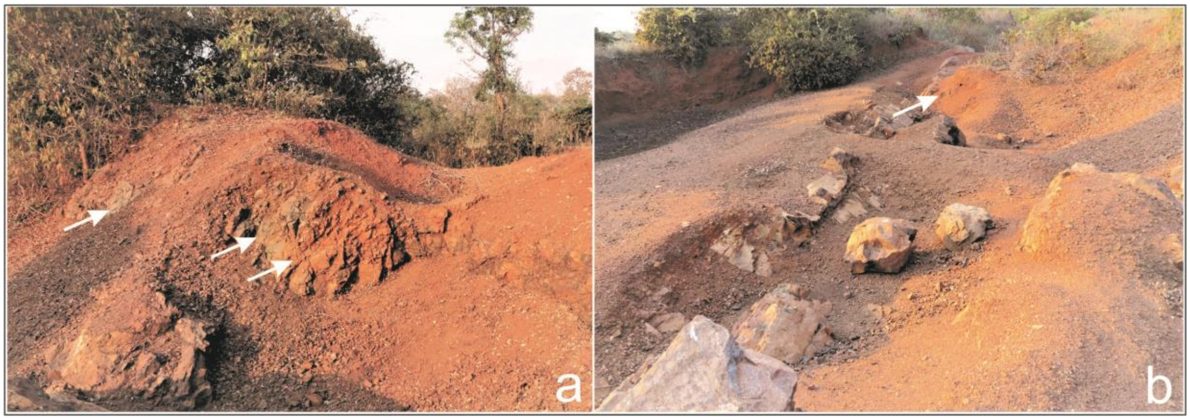

Figure 7 (a) Massive marginal sandstone (b) Zones of chloritization and shearing in parts of massive sandstone.

Methodology

Initial work stimulus was to observe the study area using remote sensing and GIS data through ArcGIS platform. Landsat-TM imageries were the primary reckoning guide for the same. Further, creation of 3-D model was an imperative element to understand the correlation of the study area with imagery using surfer platform. Basic layers of regional spot heights and contour data were also reproduced using SOI toposheets of 1:50,000 scale. Correlation of data extracted from Landsat-TM imagery with the 3-D model acquired with the help of surfer platform helped the demarcation of major geomorphological pattern and major slope characteristics of the region. Field work for the collection of sedimentological, morphometric, and other data were done. Later, regional behaviour of drainage with lithological variation coupled with the impacts of tectonism in the study area were interpreted. Hence, discussion of the same enhances the regional sedimentological and geomorphological behaviour.

Results

Morphometric Interpretations

Geomorphic analysis

In this study, Landsat-TM image (Path 143 and Row 47) acquired in May-2011 was used for preliminary investigations (Fig. 8a). Contrast of colour tone and texture represents different lithologies in the central part. Since, the area is almost flat with some relict hillocks, conventional digital elevation model (DEM) provided by SRTM was not effective to detect the minor topographic variations in the plains due to its low height resolution. Therefore, point heights were retrieved from the Survey of India toposheets using ArcGIS 10.2. Kriging interpolation method was used to prepare a Digital Elevation Model (DEM) for regional study of the topography (Fig. 8b). Structural impressions of the faults (Das et al., 2003; Verma et al., 2017) can be interpreted with the help of DEM.

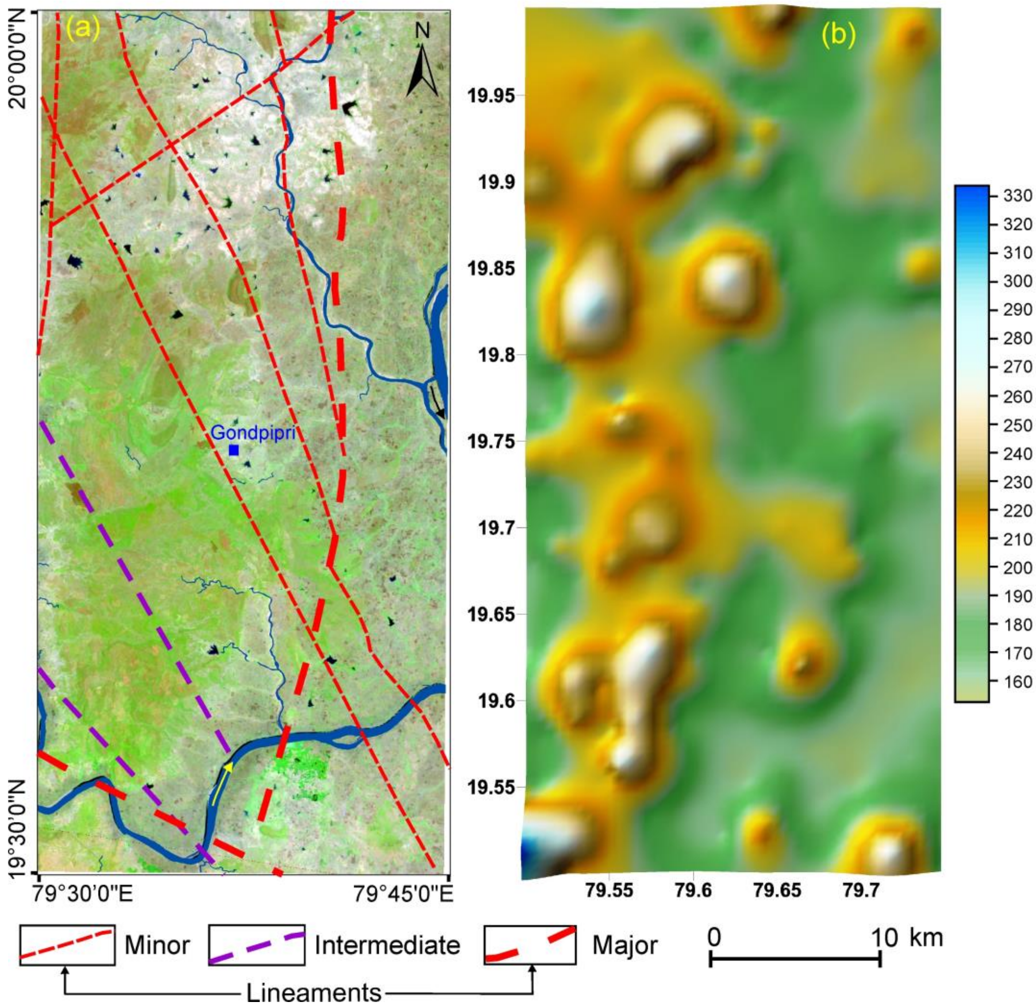

Figure 8 (a) Standard FCC (R:7 G:4 B:3) of Landsat TM image of the study area with lineaments superimposed (b) Digital elevation model (DEM) of the study area showing topographic variation.

Drainage analysis

The morphological studies are ready reckoning tool for the assessment of hydrological response of any watershed as well as the geomorphic maturity (Khurana et al., 2020). Geomorphologically, the terrain is rugged with hills and frequently changing lithology within the small area giving rise to varying drainage patterns. The valleys are filled with varying thickness of sediment cover. The drainage network is also prepared from the SOI toposheets at a scale of 1:50,000. The peninsular terrain of the Cratonic nuclei has displayed dendritic to sub-dendritic and sub-parallel drainage pattern over deposited lithology in the study area. Morphometric analysis is imperative to understand the basic relationship between the geology and its drainage.

Drainage anomalies are local offset deviations or deviation from basic stream pattern which elsewhere accord with the known regional geology or topography (Howard, 1967). Therefore, the impact of tectonism and lithology over drainage within geomorphological constraints converge to the evolutionary understanding. Parameters like drainage patterns, drainage density, stream frequency, channel sinuosity, and infiltration number show and validate each other signifying the structural, lithological and slope variability for the region. It has been observed that major streams are more or less following the Proterozoic belt trend of NW-SE if overviewed in the PG-Basin as a whole. But it is interesting to see one of the major streams showing N-S trend merging with the locally eastward flowing Wardha River in this region. The anomaly in the regional streams indicates lithological and/or structural control over the drainage evolution.

Drainage pattern and drainage density

Drainage pattern depends mainly upon the lithological variation, geomorphology of the region, its structures and climate mainly. In general, surficial low-gradient of around 5°-10° in the area has helped the development of mostly dendritic to sub-dendritic drainage pattern in the area (Fig. 2) which is observable in standard FCC of Landsat TM image. Convergence of channels along a linear zone mainly indicates structural discontinuity (fault) along the basin margin. Fault controlled areas along the basin margin shows offsetting of channels of Dhaba and Andhari rivers (Fig. 2). Some lineaments represent the regional water divides. Apart from the structures, convergence of many first and second order streams are seen in the south-eastern and eastern part of the area due to variation in slope. Also, there is a strong similarity of structural control concordance with the streams as we follow the same marginal N-S faults towards northern or southern part. The same has also been followed by the adjacent major streams as well. Therefore, previous structural fabric has overall control on the topography as well as lithology causing present drainage patternin the study area.

Channel sinuosity

Sinuosity (S) is a measure used to quantify the difference between meandering and straight channels. Hence, it also gives some account of tectonism in the given region and movement along certain lineaments. Here, the major streams in the study area show an average sinuosity of 1.25 to 1.35. Hence, relict of the protofabric or fault zone has moderate effect on the channel geometry when feeble amount of structure is observable due to sediment cover just like a torned sheet in which shallower torned part is filled with sediments when overviewed from top.

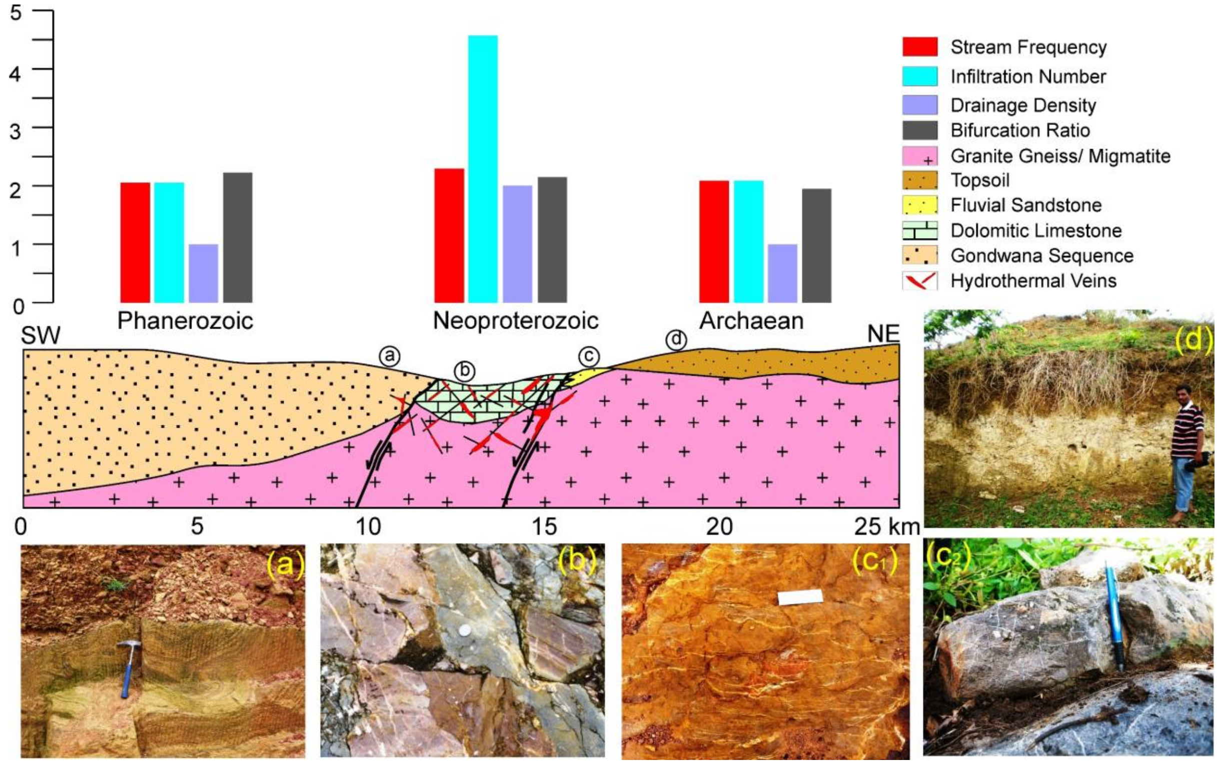

Figure 9 Diagrammatic representation of the lithological and structural disposition of the area with variation of drainage parameters. Circles represent the position of photographs shown below the figure. (a) Gondwana sandstone at Kirmiri, (b) Hydrothermal veins within the basin boundary limestone near Gojoli, (c1) Hydrothermal veins within the basin boundary sandstone surface at Dongargaon hill (c2) at Dubarpeth (below the surface) (d) Development of thick weathering profile on Archaean gneiss terrain near Dongargaon.

Stream frequency

The drainage frequency introduced by Horton (Horton, 1932) means stream frequency or channel frequency (Fs) as the number of stream segments (Nu) per unit area (A).

Fs=Nu/A

In the present study area shows low stream frequency i.e. varies from 2.1-2.3 /km^2. The Gondwana sequence and the basement part show similar value (*Fs*=2.1) but the Proterozoic sequence in the middle show relatively high (*Fs*=2.3) stream frequency. The development of the stream segments in the area is influenced by lithology, slope, rainfall, and temperature as well as the amount of perviousness developed due to secondary fracturing or weathering followed by post-solutional fracture filling (Fig. 6 e, f).

Basins having fault bounded nature and reduced draining of internal fluids to the external region along the margin harbours such conditions. Comprehensively, the region shows higher impact of physical weathering but erosion (Sharma et al., 2018) leading to high infiltration and lesser stream frequency in some areas.

Infiltration number

Infiltration number of a drainage basin is the product of drainage density (*Dd*) and stream frequency (*Fs*) given by relation

Infiltration number (If) = Fs × Dd (Faniran, 1968).

It is a parameter which gives information about infiltration characteristics of an area. The infiltration number is 4.6 in the Proterozoic part, which indicates low infiltration and high runoff in the regions of crystalline nature. Similar characteristics for the Archaean and the Gondwana show even lower values (*If*=2.1). This indicate porous and permeable nature of the Gondwana sandstone (Fig. 9) and development of thick weathering profile (Fig. 9) on the Archaean gneissic terrain, which support subsurface infiltration, rather than surface flow. As the lithology of the Proterozoic sequence is less permeable, higher values of infiltration number indicate the lower infiltration and the higher surface runoff (Das and Mukherjee, 2005).

Bifurcation Ratio

Bifurcation ratio is the ratio between number of streams of a given order (Nu) to the number of segments of the next higher order (Nu+1) (Reddy et al., 2004; Strahler, 1964)

Rb = Nu / Nu+1.

In the study area Rb varies from 0.82 to 2.54. High bifurcation ratio in any particular area indicates high drainage density (Chopda et al., 2005). In the present area, bifurcation ratio varies from 1.92 (Archaean gneiss) to 2.18 (Proterozoic sequence) which indicate a rolling or flat region without any structural control (Kalaivanan et al., 2014). Many times, the structural relicts are not visible over the surface due to thickness of sediment cover or thick weathering profile, although, presence of structure can never be ruled out which prevails in this region very well. Drainage density of the region too supports the bifurcation ratio. Usually these values are common in the areas where geologic structure and tectonics remain confined within the major streams only rather than affecting the later developed drainage pattern within the thick sediment profiles. The thick sediment cover which has been developed temporally accommodates small activities whose signatures merely show up unless major subsidence or upliftment. Such activities are mainly due to protofabric structure migration.

Lithological Correlation and Evolution

Drainage analysis is always useful in structural interpretation, local or regional, particularly in areas of low relief. The lack of outcrop exposure and vast forest cover does not allow the detailed field study of paleo-drainage characteristics in the area. However, westward flowing channels could be readily interpreted in the Gojoli region from the available sedimentary structures and facies assemblage within the Chandrapur tectono-sedimentary block. The associated facies assemblage (sandstone and matrix supported conglomerate showing imbrication) suggest that the channels originated from the Archaean basement and supracrustal rocks in the east. The presence of major transport pathways of the sediment from the east and south, dating back to Meso to Paleoproterozoic, especially for the Somanpalli, Sullavai and Penganga Group within the P-G Basin (Amarasinghe et al., 2014) gives an overview of the regional framework originating from the time when collision took place between SE India and Enderby land in Antarctica (Henderson et al., 2014).

The trough cross-bedding in the sandstone (Fig. 4a) also points the flow direction from east to west. Presence of clast within clast towards the dipping direction which is also the flow direction towards the shelf or basin interior is another evidence (Fig. 5). Moreover, matrix supported conglomerate supports a short distance of transport before debouching into the basin towards shelf region. Even the regional streams of various orders would have appended themselves into the major drainage while sediment transport from east towards west. These evidences support the origin of the channels to be not far from the basin and were flowing on a higher slope so that; matrix and clast were not separated. If overviewed, the P-G Valley itself has been formed due to the sediment transport from multi-directional sediment influx from multiple easterly provenances of Enderbyland (Amarasinghe et. al., 2014) which was opposite to the present flow direction of the streams.

The major structures (faults and lineaments) along the basin boundary are characterized by parallel to sub-parallel drainage pattern flowing towards south. Surface of the fault-bounded blocks shows dendritic to sub-dendritic drainage. This leads to the fact that even if the area is peneplained to much extent due to various surface and subsurface processes from the Proterozoic to Recent, the effects of structural features still persists on topography. The change of slope in and around the area is the result of temporal tectonic activity and erosion.

Also, morphometric study of the present-day east and southward flowing drainage characteristics well correlates to the geology and geomorphology. The

Neoproterozoic counterpart, however, and then active various surface processes, hence, gets decoded instinctively. This has been supported by geological responses in the form of sedimentary structures for west-flowing Neoproterozoic channels. These channels later debouched along the eastern margin of the P-G Valley towards the shelf from Gojoli, Dubarpet and Dongargaon.

The morphometric study includes drainage patterns, drainage density, stream frequency, channel sinuosity, and infiltration number (Table-1) for its geological correlation.

These morphometric properties, lithological characteristics, and geomorphological conditions enable us to delineate three major zones i.e., Archean, Neoproterozoic and Phanerozoic chronologically in the study area correctly syncing with particular values in each region respectively (Fig. 9). In the eastern part or gneissic basement part, stream frequency is 2.14 whereas basin margin region or central Neoproterozoic part of study area shows 2.3 and western part or Phanerozoic part shows 2.1 and their corresponding infiltration number values are 2.14, 4.6, and 2.1 respectively. This shows that lower surface runoff in the eastern and western parts but the central Neoproterozoic marginal zone. Drainage density value in the central part (*Dd*=2) shows higher runoff and low infiltration supports high infiltration number 4.6. This pertains to then effect of these sub-basinal paleoweathering conditions, hence, subsequently changing lithology and drainage. The low value of drainage suggests that the region is composed of highly resistant sub-soil materials (Srivastava, 1997) and rocks supported by diagenetic effects as seen in dolomitic limestones and sandstones. As the Neoproterozoic sequence was affected by fault movements, causing the rock fractures to be filled by hydrothermal solutions. The central strip of Neoproterozoic lithology can also be observed under the satellite image (Fig. 8a). The easterly juxtaposed Late-Proterozoic igneous activity fed the hot fluidal influx in to the fracture channel-ways as the structural perturbations has created conduits and chnnelways for the same temporally. Eventually, the whole process probably reduced the rock permeability and restricted the surface water to percolate downward thereby increasing the surface runoff. The Neoproterozoic sedimentary succession in the middle shows twice the drainage density (Table-1) compared to western and eastern part of the study area. This implies that impervious lithology and moderate slope aptly correlates with the observed drainage density in the area, and thus it can be deduced that lithology is another major controlling factor for drainage development.

Table 1: Table showing various values of morphometric parameters in different regions

Factor	**Phanerozoic**	**Neoproterozoic**	**Archaean**
Stream frequency (*Fs*)	2.1	2.3	2.14
Drainage density (*Dd*)	1	2	1
Infiltration Number (*If*)	2.1	4.6	2.14
Bifurcation Ratio	2.18	2.12	1.92

Normally, if the bifurcation ratio (Rb) is low, the basin produces a sharp peak of discharge, and if Rb is high, the basin yields a low but extended peak flow (Agarwal, 1998). In the present study area, bifurcation ratio value shows the area to be almost flat or rolling type character (Kalaivanan et al., 2014; Horton, 1945) producing above moderate yield. Therefore, due to thick sedimentary cover in the region, the geological structures and tectonics has exercised dominant influence on the present drainage pattern but visible within or along the major streams only. This gives an insight of probable protofabric migration. Also, stream sinuosity of 1.25 to 1.35 in the study area shows less sinous streams (Schumm, 1963; Leopold and Wolman, 1957) which is another indicative of less undulating topography due to denudational effect within later deposited restricted sediment cover.

Therefore, overall relict of the basin boundary faults still has certain influence on the present drainage system as proved by convergence, offsetting and straightness of the channel courses other than the lithology. All major channels in the block are south flowing following the basin boundary faults which when observed for the Neoproterozoic times were west flowing, based on evidence given by the facies and sedimentary structures. This shows a change in evolutionary pattern in topography and slope from the Proterozoic to Cenozoic era.

Conclusive Remarks

Based on remote sensing and GIS studies, tectono-sedimentary structural setup of block, and field study of the sedimentary terrain, it can be concluded that the Proterozoic channels were west-flowing as shown by the sedimentary structures. Facies assemblage and the present channels in the block are south and east flowing. Morphometric studies suggest, the present-day drainage characteristics are mainly controlled by lithology, slope and tectonic control conditions. Most of them are contained within the overlying sedimentary cover only.

The basin boundary faults still influence the major channels as shown by the stream convergence and offsetting patterns. It indicates that the proto-fabric of the region has control over the development of present-day drainage. Lithological contrast can be seen through the drainage density contrast in the block. The filling of rock-fractures by hydrothermal solutions in the fault zone had significant impact on drainage characteristics mainly in, the Neoproterozoic sequence, Surface of the fault-bounded blocks show dendritic to sub-dendritic drainage pattern, whereas, the boundary zone shows straight drainage controlled by faults. Therefore, topographic change from Proterozoic to Recent is due to tectonism, lithology, and erosion. Varied diagenesis in the different lithounits had also helped in the differential rates of weathering causing behavioural differences in the lithounits.

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