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Assessment of geoheritage and prospects of geotourism: An approach to geoconservation of important geological and geomorphological sites of Puruliya district, West Bengal, India

Avijit Ghosh [a,*], Sutapa Mukhopadhyay [a], Saurodeep Chatterjee [b]

[a] Department of Geography, Visva-Bharati, Santiniketan, West Bengal 731235, India
[b] Department of Applied Geology, Indian Institute of Technology (ISM), Dhanbad, Jharkhand 826004, India

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ABSTRACT

Exploration of geoheritage sites is a new venture in tourism studies. The objective of the study is centred around the Geoheritage site conservation for geological and geomorphological interpretation and introduction of Geotourism involving the local people in Puruliya district. The main litho-unit of Puruliya district belongs to Chhotanagpur Granite Gneissic Complex of Archean era. Nine geological/geomorphological important sites are chosen for assessing their geoheritage values and analysing the Geotourism potential. A modified model of Kubalikova (2013) is adopted for the evaluation of the selected nine important sites, where five important criteria i.e. scientific (intrinsic) values, educational values, economical values, conservation values and added (cultural, ecological and aesthetic) values are considered. The result reveals that sites like Durgabera dam, Bhanratongri hill, Garpanchakot and Jaychandi hill can be assumed as top potential Geotourism site occupying highest geoheritage values, whereas Jabar hill, Poradih hill and Tamakhun old mine are quite low in the context of Geoheritage values. Based on the result, few strategies are suggested which can help to develop Geotourism in the study area and raise awareness about the geoheritage values among the students, general visitors and the local residents of the area.

1. Introduction

Geoheritage and geoconservation are two conceptions deal with the protection and conservation of earth science features. It concerns with rock monuments, fossil parks, geological marvels/features, geomorphological landforms. In a broader sense, geoheritage also includes cultural sites (such as mining sites)/archaeological sites (made of stones) that have an integrated value in response to a particular region. Preservation of natural heritage and associated cultural values to education, interpretation and entertainment is the main aim of Geotourism (Gordon, 2018). Therefore, a link can be established between the two notions Geotourism and Geoheritage. According to Hose and Vasiljević (2012) Geotourism can be defined as "*the provision of interpretative and service facilities for geoheritage sites and geomorphosites and their encompassing topography, together with their associated in situ and ex situ artefacts, to constituency-build for their conservation by generating appreciation, learning and research by and for current*

* Corresponding author.
E-mail address: avijitgh042@gmail.com. (A. Ghosh).

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and future generations" (Antić & Tomić, 2017; Hose, 2012; Kubalíková, 2013). Though it is a widely accepted definition of Geotourism concept, the scope of the concept in this definition has remained narrow in sense. Dowling (2013) truly remarked that *"Geotourism is a form of sustainable tourism with a primary focus on experiencing the earth's geological features in a way that fosters environmental and cultural understanding, appreciation and conservation, and is locally beneficial"*. According to Panizza (2009), all the physical attributes over the earth surface, for example, a gorge, a mountain peak, a sea cliff have some kind of cultural values as it belongs to the certain cultural territory. Sometimes the natural heritage sites also become the sacred place for human being and is regarded an important element for geo-cultural understanding. Landscape often considers as a component of expressing architectural design, literature, poems, paintings and so on (Lindberg et al., 1997). So in this context, landscapes (including both geological and geomophological landforms/features) can be considered as a cultural component which not only posses scientific and aesthetic value but also bears an immense cultural value. All these aspects incorporate within the concept of 'Geoheritage' for sake of geoconservation of the territorial resources. Geotourism helps to identify the geoheritage resources and try to use for sustainable economic development with active participation of the local community.

India is a country having rich in geodiversity. Hills and mountains, lakes and sea coast, plains and plateaus all diversified physical features can be observed in the country. These physical features speak about the geological history of origin in million years ago. Puruliya holds a curioustic palaeogeography to tale. The crust was formed about 4 to 5 thousand million years ago during the archean era when there was no sign of life and rest part of Bengal was beneath the sea (Bhattacharya et al., 1985). Peninsular shield made the greater part of the district. The whole region can be divided into two geomorphic sub-unit according to the geological age of formation a. Peninsular shield part of Archean era and b. glaciated and fluviatile sediment-filled Gondwana basin of upper Carboniferous-Triassic period. The two shear zones i.e. North Puruliya Shear Zone (NPSZ) and South Puruliya Shear Zone (SPSZ) pass through along the north and south border of the district which made a great effect on the rock structure, rock alignment, fold, fault as well as the whole landform of the district. The northern boundary of Puruliya district was gone through two phases of shear related deformation and two phases of folding deformation along the line of NPSZ (Goswami & Bhattacharyya, 2008). The type and structure of the rock are mostly influenced by regional metamorphism due to deformational activity especially at the north-western part (Belamu-Jabarban area) of the district (Baidya, 1981; Akhtar et al., 1985). In the north and north-eastern portion of the district, two lineaments have passed through, a. the NPSZ in E-W direction and b. ENE trending mega-lineament, which made a significant contribution in the geology as well as landforms characteristics of the region (Goswami et al., 2018). At the marginal area of the north-eastern portion of the district sedimentary rocks can be found to deposit of Panchet and supra-panchet formation of Gondwana group. The SPSZ is the part of crustal scale Tamar-Porapahar lineament trending east to west in an ESE to WNW direction (Acharyya et al., 2006; Talukdar et al., 2012) and it separates two paleoproterozoic fold belts i.e. CGGC to the north and North Singbhum Mobile Belt (NSMB) to the south (Gupta & Basu, 2000; Acharyya et al., 2006).

As a part of CGGC, Puruliya district lies at the western margin of West Bengal state in India. The undulating topography having numerous hills and hillocks with preferably infertile red soil in most of the part, the district suffers from misery of crop production. Moreover, as the district has no big industrial farm, it remains economically very poor. In such condition where the district holds lot of important geological and geomorphological resources to show (Fig. 1), it can be inferred that Geotourism may have an alternative pathway for the economic development of the poor people of the district. Thus certain objectives can be selected for the present study based on the above discussion.

a. Selection of the geological and geomorphological sites based on the 'principle of geoheritage site selection' with their descriptive analysis.

b. Evaluation of all the selected geoheritage sites based on the proper assessment method.

c. Analysis of Geotourism potential of the selected geoheritage sites and proposition of some strategies for their conservation as well as development of Geotourism.

2. Geotourism development and Geoheritage assessment in context of India

The history of the identification of geological and geomorphological heritage sites is not very old in India. Geological Survey of India (GSI) in 2001 first identified twenty six geologically important sites in aim to insights into the geological history of India, especially to preserve fossil sites, rock monuments, geological marvels and enhancing the spirit of educative tourism for the geologists, students and the general visitors (https://www.gsi.gov.in/webcenter/portal/OCBIS/pageGeoInfo/pageGEOTOURISM/pageGeoTourismHome_) Later in 2016 ministry of mines with the help of GSI added six more Geoheritage sites in order to preserve them with the support of individual state government (Ministry of Mines Report, Government of India,2016). Most of the identified sites by GSI are concentrated over western and southern India namely Rajasthan, Gujarat, Maharashtra, Kerala, Karnataka, Tamil Nadu and Andhra Pradesh with sporadic occurrence in other parts of India.

Many researchers have done scientific analysis addressing potential geoheritage sites in different parts of the country in the recent past. Suryawanshi and Ranyewale (2018) have made a comparative assessment of beach sites as potential geomorphosites of Sindhudurg coast (Maharashtra). Kaur et al. (2019) have highlighted the significance of some old abandoned basalt and trachyte quarries of late Cretaceous-Paleogene (Deccan traps origin) period in building architectonic heritage of Maharashtra (India). Shekhar, Kumar, Chauhan, and Thakkar (2019) have concerned on seven important geosites of the Cenozoic succession that needs to be preserved as geoheritage sites and for the development of geotourism in western Kutch (Gujarat). Roy,

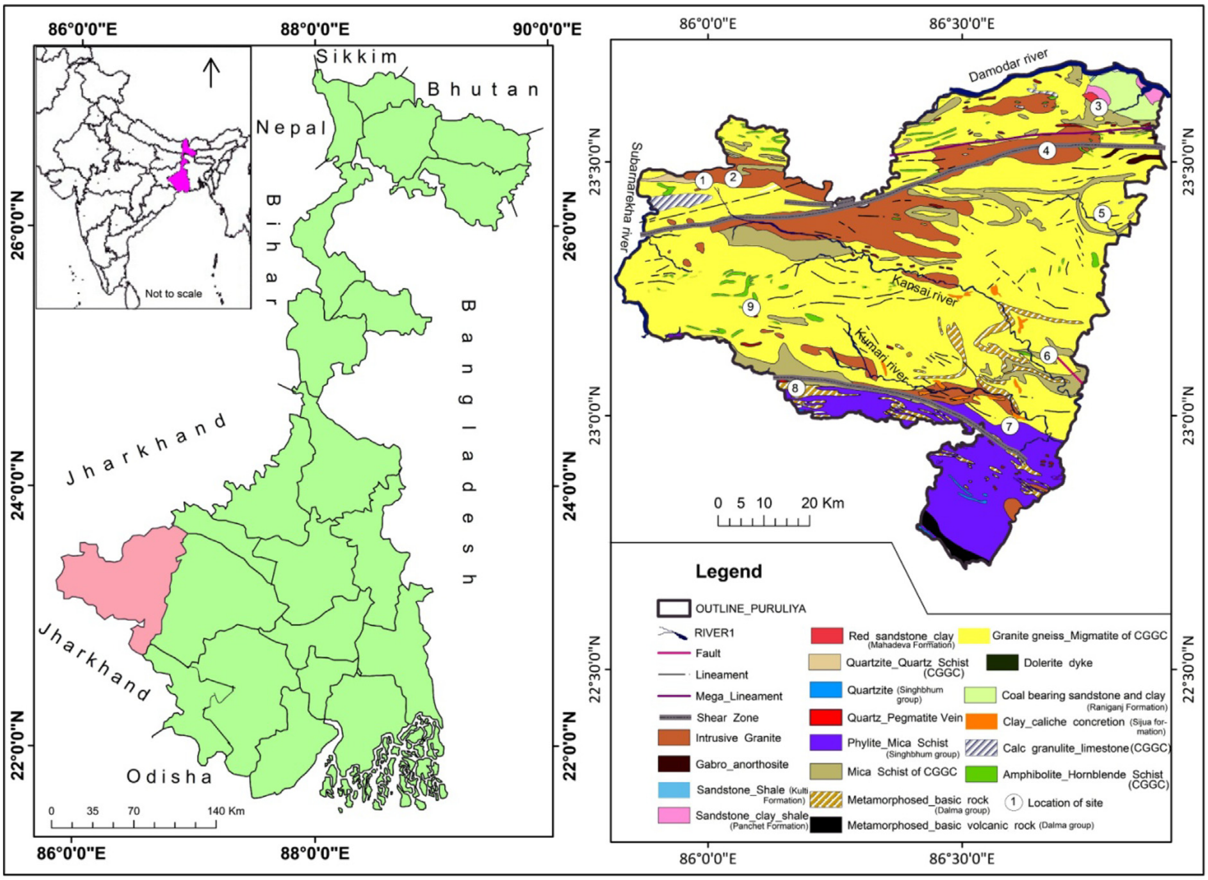

Fig. 1. Location map of the study area

Pandey, and Rani (2020) have explained the importance of Majuli island of Assam, NE India (nerve centre of Neo-Vaishnavite culture in India) as it supports a huge number of people those are economically dependent on it and regarded as the geo-cultural heritage of India. Bhosale et al. (2021) have analysed scientific, educational and conservation value of diversified fossil flora and fauna of Mesozoic and Cenozoic era as potential geopark in Kuchchh rift basin of western India. In regard to West Bengal, Datta (2020) has addressed on the Mama Bhagne hill of Birbhum district as a geomorphologically important site which is currently in deteriorate condition and formulated some strategies that will help to conserve the geoheritage resource of Bengal. Therefore, most of the geoheritage sites as well as resources addressed in the discussion belong to northern and western India. Only a few literatures can be found discussed over eastern India and thus the present study draws a special attention as it emphasizes on geoheritage resources of CGGC, most prominently of West Bengal (eastern India).

Most of the selected sites for the present study exist as inactive (abandoned) or partially active rock mining sites which are now in endangered stage. Some of the sites are also selected based on its geomorphological significance. Thus, the paper has tried to accommodate all the details regarding each geological/geomorphological sites and analysed its Geotourism potential in aim to preserve the geoheritage resources of Puruliya district.

3. Description of the Geoheritage sites of Puruliya district, West Bengal (India)

3.1. Jabar hill (#1) (23°28'05" N. & 85°59'48" E.)

The hill range is stretched in an east-west direction for approximately 20 km distance shearing the border between Puruliya district and neighbouring state Jharkhand. The study has been conducted for the analysis of geological and geomorphological features is bound in and around near Simni village, approximately 18 km distant from nearest town Jhalda. On the southern edge of the hill, a thick band of quartzite can be seen to be exposed parallel to intrusive granite rock (GRm) on its north face (Fig. 2.a). Due to locating along the North Puruliya Shear Zone (NPSZ), during the tectonothermal events the sandstone changed its state into hard non-foliated quartzite rock by the metasomatic effect (contact metamorphism due to excessive pressure and temperature) and virtually wiped out the sedimentary features of the supracrustal rock (Mukherjee, Dey, Sanyal, & Sengupta, 2019). The quartzite of Jabar hill is the finest example of pure quartzite rock which consists of quartz entirely, with few trace elements like zircon, rutile, magnetite etc and represents the oldest rock group in the area. The occurrences of Calc-silicate rock of the Archean

Fig. 2. (a) Quartzite band of Jabar hill range, (b) Bornhadt formed of granite-gneiss of archean era, Jabar hill range.

era is also reported from the south-eastern part of Jabar range (Baidya, 1981). This skarn rock has formed due to the metasomatic effect of the younger granite on the limestone (Baidya, 1981; Sanyal & Sengupta, 2012). Apart from that several bornhardts (low rounded hillocks) (Fig. 2.b) and granitic domes (few meters north from simni village) can be observed at the south of the quartzite belt, representing excessive erosional activity in this area since the archean era and posses immense educational value.

3.2. Belamu hill (#2) (23°27'42" N. & 86°03'18" E.)

The hill is located just 1.2 km east of Jabar. Belamu hill is primarily made of intrusive granite rock of the Proterozoic period. On the south-western part, occurrences of metasediments e.g. calc-silicate (a metamorphosed form of silica-rich limestone) and quartzite (a metamorphosed form of sandstone) are predominate (Baidya, 1981). The intrusion of granitic magma adjacent to impure limestone and sandstone strata forced to alters the chemical composition of existing rock through contact metamorphism process (Baidya, 1981; Bhoskar, 2005; Sanyal & Sengupta, 2012). Due to presence of gentle slope, the unconsolidated red soil present over the western part of the hill causes to slump by heavy rainfall during the monsoon season. Talus of disintegrated calc-silicate rocks found to see as debris flow, an exciting geomorphic feature to observe (Fig. 3.a and 3.b). The rest of the part is composed of granitic rock which consists mainly of quartz, microcline, biotite, NA-rich plagioclase, garnet, sphene and magnetite (Baidya, 1981). Two *'Joint springs'* (23°27'49" N. and 86°02'42" E.) can be observed at the base of the southern cliff along a linear direction. Both two springs are only active during monsoon season. Rrainwater percolate within the joints and cracks of granitic rock blocks and comes out through some fractures present at the base of the hill as spring.

3.3. Garhpanchakot hill (#3) (23°36'20.6" N. & 86°46'6.4" E.)

Garhpanchakot or Panchet hill is situated at the north-eastern margin of the district, 10 km distance from Raghunathpur town. Fluviatile and lacustrine Shale and sandstone are the two most important sedimentary rocks that were deposited in Upper Gondwana period (Triassic to Jurassic) and formed this hill (Bandyopadhyay, 1999; Bandyopadhyay, RoyChowdhury, & Sengupta, 2002; Bhattacharya et al., 1985). The sediment of Gondwana supergroup is deposited and folded over the Precambrian granite gneiss of CGGC (Dunn, 1929; Bhattacharya et al., 1985; Goswami & Ghosh, 2011). It is to be mentioned that the Panchet hill lies at the downthrown side of the Damodar through, sunk almost 3 km depth relative to the older crystalline rock but the denudation process equalized both the downthrown and upthrow side in such a manner that it is the downthrown side now exhibits as a hill made of gritty sandstone (Fig. 4.a). The hill has a terraced type of landform which can be divided into upper, middle and lower sub-terrace (Fig. 4.b). At the west and northwestern part of Panchet hill, the ferruginous red sandstone of Mahadeva formation (geological unit) can be observed which is very rare in the whole Puruliya district. Few perennially active springs can be found over the hill, among them *Hanuman dhara* (mythologically important) is the most prominent spring situated at its eastern part (Fig. 4.c). The formation behind this spring is perhaps easy percolation of rainwater through permeable sandstone and

Fig. 3. (a) Heavy rainfall causes unconsolidated red soil to slump, western part of Belamu hill; (b) Deposition of talus at the foothill through debris flow, west part of Belamu hill (southern face).

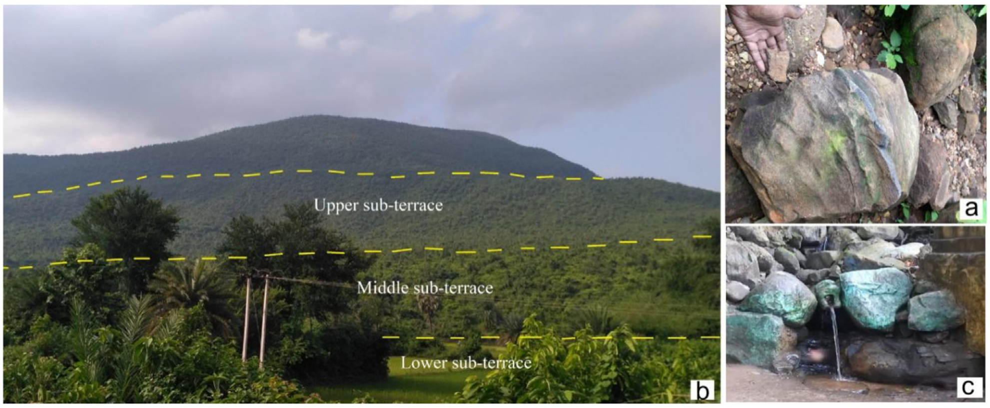

Fig. 4. (a) Gritty Sandstone traced at the southern part of Garhpanchakot hill; (b) Terrace sections of Garhpanchakot hill; (c) Spring *Hanuman Dhara* located at the eastern part of the hill.

coming out with immense pressure through fractures or joints across the bedding plane as the hill is formed by the sequential deposition of sandstone, siltstone, shale and mud stone of Panchet and supra-panchet formation.

3.4. Jaichandi granitoid batholith (#4) (23°31'30" N. & 86°40'7" E.)

Four domed structures having a continuous intrusive granitic (GRm) body of late Proterozoic era, is significantly situated over North Puruliya Shear Zone (NPSZ) known as Jaichandi hill. The hill is a well known religious place for Hindus located near the Raghunathpur town of Puruliya district. Geologically, this giant porphyritic granitoid batholith is formed by mixing of mantle derived mafic magma and crustal melts in continent-continent collisional settings (Goswami & Bhattacharyya, 2008, 2014; Goswami et al., 2018). Pegmatite veins are common within the country rock. The site can be recognized as one of the exemplary geoheritage site for observing the *tor* formation. Over the two domes, tors can be observed prominently which ranges in height from 7 ft. to 13 f. (Fig. 5.a). These are developed as a result of 'secondary jointing' which is caused by stress release within compartments on the domes (through rapid removal of overlying rock cover) and further more localized weathering (Ehlen, 1990;

Fig. 5. (a) Formation of *tor* over the northern dome, Jaichandi hill. (b) Rock blocks accumulated at the pedestal of the hill formed the *Blockfield*, southern face of Jaichandi hill.

Gerrard, 1974; Gerrard, 1978). Innumerable number of giant rock blocks can be found to deposit at the pedestal of the domes representing as *blockfield* or felsenmeer. Mechanical weathering due to intensive heating at the day time and cooling at the night causes to breakdown of granitoid rock along the vertical joints. Thus wearing down of loosened rock blocks from the dome due to its steep slope and denudation process, helps to accumulate the blocks at the pedestal of the hill, formed the *blockfield* which is a significant landform feature from the geomorphological context (Fig. 5.b).

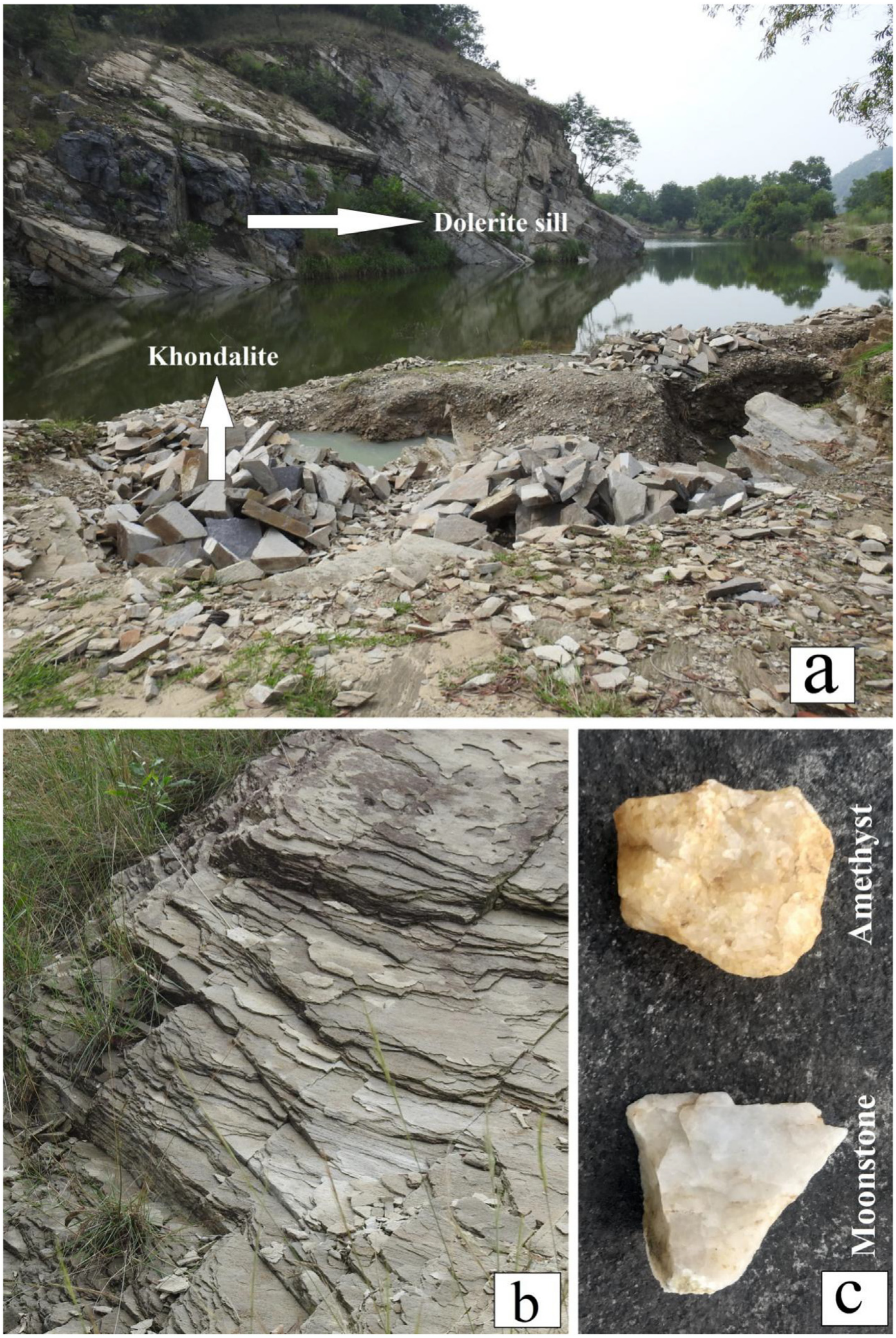

Fig. 6. (a) khondalites and dolerite intrusion in Paharpur hill; (b) wearing down of khondalite rock like as sheets; (c) Amethyst and moonstone found at Paharpur area. (d) Exfoliation and gully formation in west Dhanardih hill (western face). (e) Augen Gneiss traced at east Dhanardih hill, (f) The greenish metabasaites with numerous joints, east Dhanardih hill.

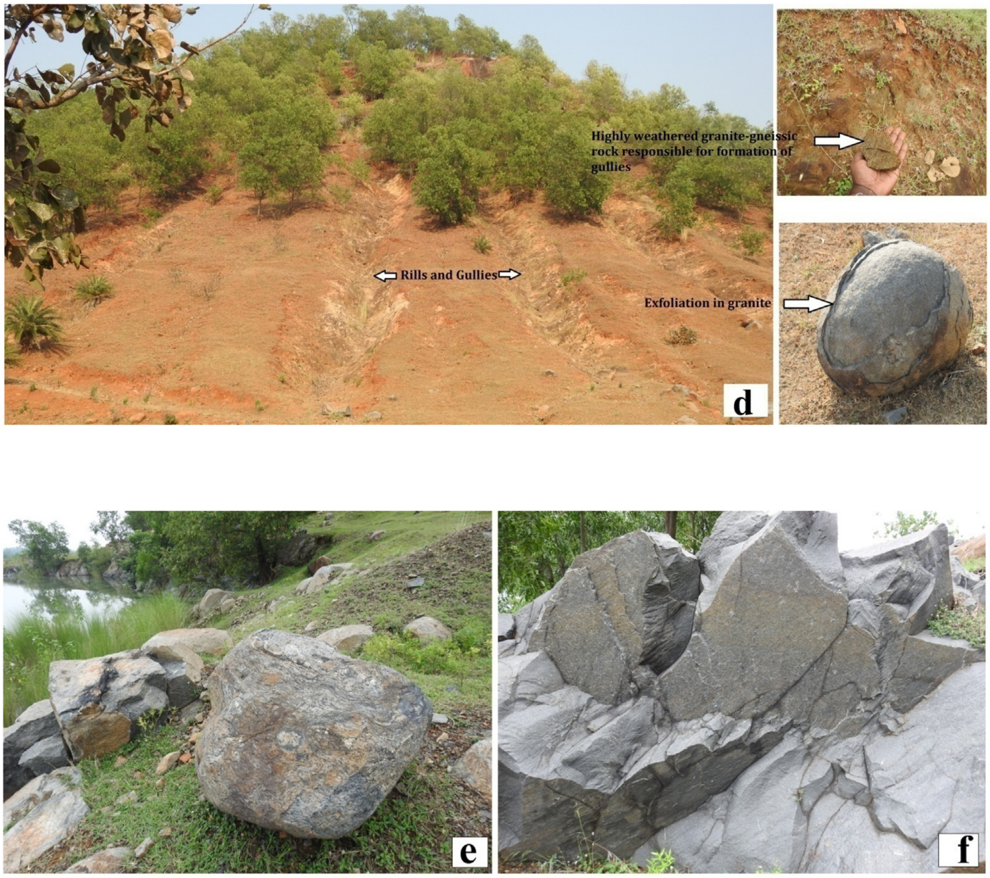

Fig. 6 (*continued*).

3.5. Paharpur Khondalite hill (23°23'48.27" N. & 86°46'38.49" E.) and Dhanardih granite gneissic domes (23°24'21" N. & 86°46'37" E.) (#5)

Three domes (hillocks) are recognized for its excellent geological characteristics situated in and around the Paharpur-Dhanardih area in eastern Puruliya near the town Kashipur. The Paharpur area consists of rocks like khondalite, alumina-silicate rich schists quartzites, amphibolites, granulites, local migmatites and numerous pegmatites and pneumatolytic hydrothermal veins. Based on colour index, the rocks observed over Paharpur hill are much more felsic (highly rich in silica) than the other locations mostly due to the dominance of khondalite and migmatites. This is a partially active rock quarrying site. Among the rocks of the granulite facies, Khondalite is typically reported here with excellent distribution of the needle like sillimanite grains (Fig. 6a). The properties of the rock with the association of seasonal change in weather condition have able to wearing down the rock like as sheets which possess immense educational value (Fig. 6b). The dolerite intrusions occurring over here are in the form of sill parallel to the layer of regional scale foliation. The dolerite intrusions belongs to 87040 Ma, situated in E-W to NE-SW trend (Chatterjee, Mondal, Roy, Gain, & Bhattacharya, 2018; Mandal, Ray, Debnath, & Paul, 2012). Survey around the area also gives the opportunity to encounter gem and semi-gem variety of Quartz (Amethyst) and Feldspar (Moonstone) form pegmatite samples (Fig. 6c).

The other two domes near Dhanardih village are of Granite and Gneissic origin of Archean era. Exfoliation (onion weathering) can be observed over the granitic rocks in Paharpur-Dhanardih region very prominently. Several rills and gullies can be observed over the Granite Gneissic dome (23°24'21" N. & 86°46'37" E), near the west of Dhanardih village (Fig. 6d). High thermal variation in day and night fosters the weathering process in older Gneissic rock of the Archean era and steep slope with adequate rainfall further energizes the thin soil layer to erode down. Thus this type of typical landform feature (rills and gullies) is developed.

The rock types dominated in the hill (23°24'12" N. and 86°47'13" E.) at the east of Dhanardih village are granite-gneiss and metabasites. This is an abandoned rock quarrying site and represents as ideal place for geological understanding. The regional foliation (gneissic banding) trends E-W to NE-SW with northerly dips. This northerly dips can be attributed towards the presence of isoclinal folds (Chatterjee et al., 2018). The rocks are texturally porphyroblastic (one coarse grain called porphyroblast surrounded by finer ones). Unlike the other locations, the granitic gneisses of the east Dhanardih hill have an excellent feature which is termed as “Augen Gneiss” (Augen means eye shaped) (Fig. 6e). On close observation of the granitic gneisses, it is observed that the porphyroblastic feldspar grains assume the shape of an eye surrounded by finer grains of other minerals. The metabasites are fine grained greenish coloured rocks mainly consisting of pyroxene and plagioclase with minor coarse garnets. Numerous veins are found within the metabasites also which are likely to be syn-tectonic based on their local distorted nature. The rocks in the hillock are ubiquitously jointed in nature (Fig. 6f).

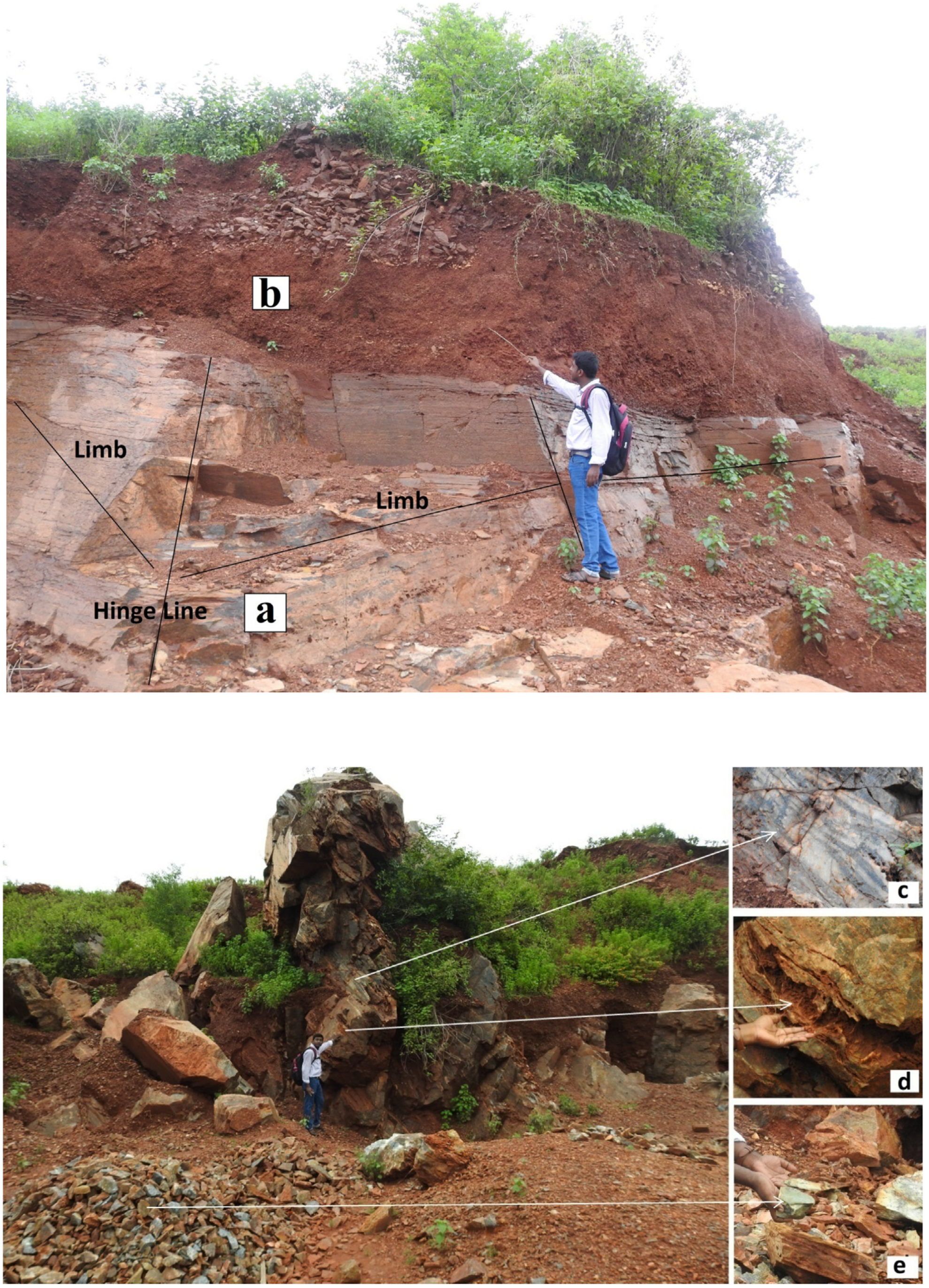

Fig. 7. (a) Vertical section along which a large scale plunging fold is exposed due to quarrying activity; (b) Red soil indicating dominance of oxidation process in iron rich schistose rock, Poradih hill. (c) Schistose rock present within the site, although alternative dark and light colour banding has appeared indicating transition from schistose to gneissic domain. (d) Evidences on extensive weathering due to oxidation process, (e) Presence of greenish coloured meta-basic rocks probably due to presence of chlorite representing metamorphism of basalt to greenschist facies.

Fig. 8. (a) Brecciated quartzite and loose debris dumped over the site; (b) Quartzite breccia containing malachite and oxidized iron minerals, Tamakhun.

3.6. Poradih hill (#6) (23°07'12" N. & 86°40'17.5" E.)

The hill is located 8 km north-east from Manbazar town. It is a partially active rock quarrying site. The main litho-unit that composed the hill is massive granites, amphibolites, gneisses of the archean era and psammo-pelitic metasediments rich in iron and manganese (Acharya, Mukherjee, & Basu, 1990). The psammo-pelitic meta-sediments are schistose in nature and they contain allumino-silicates like kyanite, sillimanite or andalusite. In many cases these schists display colour banding which occurs basically due to the differential concentration of the felsic and mafic minerals (Fig. 7.c). The lighter bands are mainly composed of quartz, feldspar accessory mica. The darker bands are composed of the allumino-silicates, biotite and accessory magnetite. Moreover, from field evidences it is quite clear that the schistose rocks are folded and their hinges are exposed in the dormant quarries which creates excellent scenic features (Fig. 7.a). The fold axes are near vertical or at least steeply plunging which is quite evident from the field exposures. The foliation planes within the schistose rocks are well preserved and they are horizontal to low dipping. The colour (red) of the soil is dark brown to red due to oxidation weathering (Fig. 7.b) and in some parts of the rocks this phenomena can be clearly observed. Iron bearing minerals in the rocks go through such a process by losing ions that alter its structure and size from one form to another. The wearing away of the rocks is thus sped up by oxidation as the resultant oxides are weaker than the original materials (Fig. 7.d). However, the greenish tint in some parts of the country rock is observed due to existence of mineral like chlorite (Fig. 7.e).

3.7. Copper mine of Tamakhun (#7) (22°58'57" N. & 86°35'46"E.)

The Tamakhun abandoned copper mine is one of the most important geoheritage sites of Puruliya district both from the mineralogical and historical point of view. The mine is located at about 640 meter south-east from Tamakhun village in the Manbazar II block (18 km south-east from Manbazar town). The evidence of old working can be found for about 630 meter length as brecciated quartzite and loose debris dumped over the site. The exposed area is stretched E-W within the shear zone running from Jilling (Puruliya) on the west and Dudhajharna (Bankura) on the east (Das Gupta & Bandyopadhyaya, 1963). The quartzite breccia primarily contains malachite and oxidized iron minerals. Malachite generally results from the weathering of copper ore and iron oxides made the quartzite breccia reddish tint outlook (Fig. 8.a & 8.b). According to a report of Geological Survey of India (1963), during 1916 this mine was used as for open casting of copper ore by a British company down to a depth of 12 meters from the surface. It is also said that the Jain merchants were used to extract copper ore from this mine particularly to export in the south-Asian country through Tamralipta port during 8th to 12th century (Roy, 2007; Roy, 2010).

3.8. Bhanratongri hill (#8) (23°03'15" N. & 86°10'25" E.)

Bhanratongri hill is an abandoned quarry of china clay located just near Malti, SSW of Balarampur town. Geologically this hill is located at the junction of Chhotanagpur Granite Gneissic Complex (CGGC) and the Singhbhum Group (SG) of rocks of Proterozoic age (Baidya, 1992; Gupta and Basu, 2000). A prominent shear zone namely South Puruliya Shear Zone trending towards East to West crosses over this region and as a consequence of that, a number of joints and fractures can be observed in and around this hill area (Acharya & Prasad, 2017). Here clay is interbedded with red-yellow ocher and carbon-phyllite trending east-west with a northerly dip following the shear zone (Das Gupta & Bandyopadhyaya, 1963) (Fig. 9). The red-yellow ocher is nothing but the china clay or kaolin which is typically oxidized due to presence of iron-oxide giving it a rust hue. For hundreds of years, this clay-rich red-yellow ocher is being used by the local tribal villagers as natural colour for the wall painting in their mud huts, which makes their culture distinct. So the site is also important from the geo-cultural context.

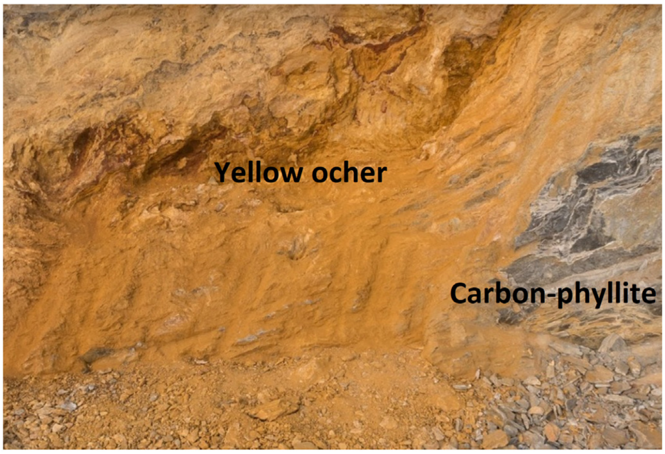

Fig. 9. Succession of Clay-rich yellow ocher above the cabon-phyllite, Bhanratongri hill.

3.9. Durgabera dam (Marble Lake) (#9) (23°12'47.4" N. & 86°5'9.9" E.)

Durgabera dam, popularly known as marble lake is a 12 meter (approx) deep artificial water body surrounded by majestic hillocks with deciduous forest located over the southern part of Ajodhya hill. This lake was created as a purpose to supply hard igneous rock for the construction of PPSP (Puruliya Pump Storage Project) dams (http://puruliatourism.in/tourism/durgabera.htmlhttp://puruliatourism.in/tourism/durgabera.html). This abundant rock mining site can be used as a small scale exemplary geosite (Table 1) for the educational interpretation of some important geological features like folds, dykes, sills and crystallized mineral veins. The lithology associated with the hills in and around the Durgabera dam is highly variable ranging from high grade metamorphic rocks to younger dolerite intrusions and associated structures. This basically makes the location a museum of Precambrian Geology. Metamorphic rocks in this site include hornblende gneiss composed chiefly of hornblende and biotite with accessory opaque minerals. The hornblende gneisses are folded to define open folds with nearly horizontal axial planes (Fig. 10.a). The folds are also locally isoclinal to overturned. Post folding, irregular patterns of jointing are also evident in the gneissic rocks along which very small scale abutments are also observed. Excellent surface features like hackle marks are also observed on the joint surfaces. One of the most important features of the rocks of metamorphic domain in this site is migmatization which is related to metamorphism in Ultra High Temperature (UHT) (Dey et al., 2020). This phenomenon has led to the development of spectacular colour banding along the lake. The dark coloured zones are called melanosome and the lighter ones are termed as palaeosome (Fig. 10.b). Thus, there are ambient evidences of partial melting in these rocks. Secondly, the rocks which belong to igneous domain are the dolerite dykes and sills, pegmatite veins and the quartz veins which are intruded post metamorphism and deformation, evident from the abutment relationship from of the igneous rocks with the folded structure whereby the hinges of the horizontal folds are disrupted by the veins (Fig. 10.c). However, the genetic sequence of the pegmatite veins and the dolerite dykes are a bit dubious. On close observation it seems that the pegmatite veins are younger than the dolerite dykes based on the cross-cutting relationship (Fig. 10.d). The pegmatitic veins over here are occurred due to invasion of

Table 1
Geological and geomorphological significance of the selected geoheritage sites.

Sl. no.	Name of the Geoheritage sites	Scope (Brocx & Semeniuk, 2007)	Special features	Scale (Brocx & Semeniuk, 2007)
1	Jabar hill	Petrological site, geomorphological site	Band of pure quartzite rock, calc-silicate skarn rock of Proterozoic age; presence of bornhardts, rounded knoll of granite-gneissic rock	Large Scale
2	Belamu hill	Petrological site, geomorphological site, hydro-geological site	Occurrences of meta sediments like calc-silicate, quartzite; block disintegration; occurrence of debris flow; joint springs	Medium Scale
3	Panchet hill	Petrological site, hydro-geological site	Rare red sandstone of upper Gondwana period; terrace formation, perennial springs	Medium Scale
4	Jaichandi hill	Petrological site, geomorphological site	Presence of porphyritic granitoid rock; block field, tor	Medium Scale
5	Paharpur-Dhanardih hillocks	Petrological site, structural site, geomorphological site	Khondalite hill, dolerite dykes and sills; Rills and gullies, waterbody	Medium Scale
6	Poradih hill	Petrological site, structural site, mineralogical site	Psammo-pelitic meta sediments; active oxidation weathering	Medium Scale
7	Tamakhun mine	Mineralogical site, historical site	Quartzite breccia with malachite stain	Small Scale
8	Bhanratongri hill	Petrological site, structural site	Succession of Red-Yellow Ocher and Carbon-phyllite	Medium Scale
9	Durgabera Dam	Hydrological site, petrological site, structural site	Waterbody; occurrences of dolerite dyke intrusion, sill, melanosome, palaeosome, open folds, pinch and swell	Small Scale

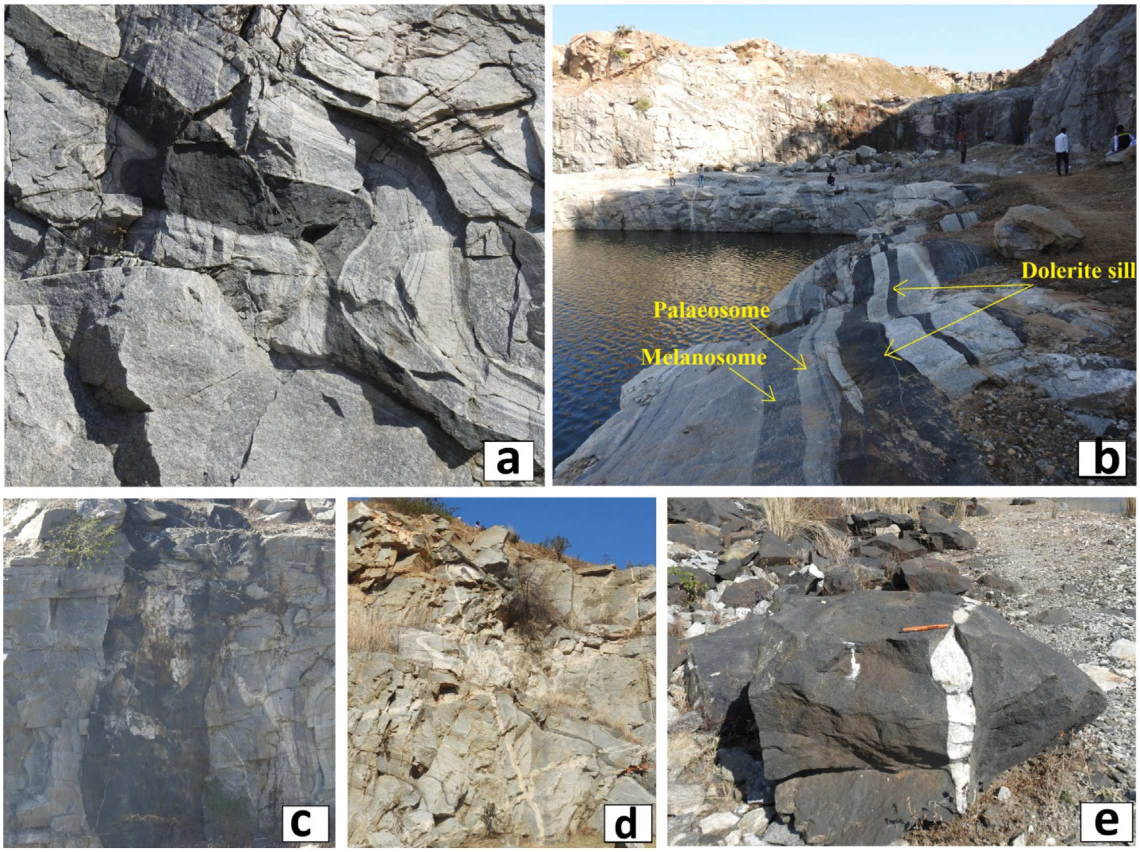

Fig. 10. (a)Horizontal folds (horizontal axial planes and fold axis) with radial cracks at the hinges. Moreover, the dolerite dykes that are intruded must be syntectonic (i.e. at the same time of folding) as evident from the distortion of the dyke at the core of the fold; (b) Melanosome and palaeosome displaying colour band in hornblende gneiss along the lake.Dolerite sills are arranged along the direction of foliation; (c) Dolerite dyke intrusion within the country rock; (d) Dolerite dyke cut by Pegmatite vein representing cross-cut relationship (e) Quartz vein and 'Pinch and Swell' structure, Durgabera dam (Marble lake).

hydrous fluid displaying coarse crystals of feldspar, quartz and mica. The quartz veins are often boudinaged resulting in another mesmerising feature which is called the "Pinch and Swell" structures (Fig. 10.e). In such structures, the width of the quartz veins alternatively increases and decreases.

The site is very popular to the visitors as because of many regional films are being shot due to its aesthetic appeal in recent, but there is no board or placard about the geological details and mining history of the site which can foster the educative tourism and serve as an ideal geoheritage site of the district.

4. Method of Assessment

The sites having important geological and geomorphological characteristics are assessed based on the 'method for assessing the geosites and geomorphosites' of Kubalíková (2013). This method has been prepared based on the several assessment methods of geosites (Bruschi & Cendrero, 2005; Coratza & Giusti, 2005; Pereira et al., 2007; Pralong, 2005; Reynard et al., 2007; Serrano Cañadas & Gonzáles-Trueba, 2005; Zouros, 2007), and principles of Geotourism. The assessment of method is primarily guided by five important criteria following the aim of evaluation of geoheritage sites. These are scientific (intrinsic) values, educational values, economical values, conservation values and added (cultural, ecological and aesthetic) values. The distribution of the value within some particular sub-indicator under a specific criterion has been redistributed or modified to fit the model in Indian context.

4.1. Scientific assessment

Based on the literature survey it can be inferred that any kind of geoheritage sites must have some amount of scientific values. It is the basic intrinsic values that a site posses such as rarity, integrity, number of physical or chemical processes and features (diversity) and contribution in the field of education (publication of paper/conference in national or international level) etc (Table 2). Following table has prepared based on Kubalíková's (2013) assessment method of scientific values:

Table 2
Criteria used for scientific assessment of geosites (according to Kubalíková, 2013).

Sub indicators	Description of the sub indicators	Values/Weight
Integrity	Present condition of the geosite	0 = totally destroyed 0.5 = disturbed site, but with visible abiotic features 1 = site without any destruction
Rarity	Number of similar sites present in and around particular geosite	0 = more than 5 sites, 0.5 = 2 to 5 similar sites 1 = the only site within the area of interest
Diversity	Number of different visible partial features and processes within the geosite or geomorphosite	0 = only one visible feature/processes 0.5 = 2-4 visible features/processes 1 = more than 5 visible features/processes
Scientific knowledge	Number of scientific paper on the particular geosite represents in nation or international level	0 = unknown site 0.5 = scientific papers/reports on national level 1 = high knowledge of the site, monographic studies about the site.

4.2. Educational assessment

According to Tormey (Tormey, 2019), *"telling the geological story of a protected area is the equivalent of telling people about a slice of Earth's history"*. So in this sense, a site having important geological and geomorphological features and processes must have educational importance which might help to increase the knowledge about dynamic phenomena continuously happening on the earth surface. The educational importance of a particular geoheritage site will also help in the conservation process of natural resources, which is one of the important principles of Geotourism. The assessment of educational values typically evaluates the representativeness of the features or processes, exemplarity and educational usage of the particular geoheritage site (Table 3). The detail information on educational assessment has been given in the following table according to the assessment method of Kubalikova (2013).

4.3. Economical assessment

Economical assessment signifies assessment procedure of economical value of the sites like infrastructural facilities (availability of parking lots, transport facilities to reach the site), availability of food and lodging and situation of any emblematic site of local products near the geoheritage site etc (Table 4). The main purpose of assessing economic values is to check whether the geoheritage sites have enough potential to accommodate the visitors or not. Here the value distribution for two sub-indicator has been redistributed i.e. accessibility and presence of tourist infrastructure. In 'accessibility', value 1 has given to the 'distance less than 1000 meter from nearby bus stop' whereas in original model value 1 indicates the distance more than 1000 meter from the bus stop which is not rational for the judgment of this particular sub-indicator and thus replaced. In the case of sub-indicator 'present tourist infrastructure,' the total value ascertained for the particular sub-indicator has been divided into two halves. One halve has dedicated for 'availability of hotels and restaurants' and other halve has dedicated to the 'accommodation facilities' (Table 4). The detail information about the distribution of weights under each sub-indicator has been mentioned in the following table.

Table 3
Criteria used for documentation of educational assessment of geosites (according to Kubalíková, 2013).

Sub indicators	Description of the sub indicators	Value/Weight
Representativeness and Visibility	Clarity of the forms and processes	0 = low representativeness/clarity of the form and process. 0.5 = medium representativeness, especially for scientists. 1 = high representativeness of the form and process, also for the general public.
Exemplarity, pedagogical use	Pedagogical usefulness of thee particular forms and processes/features	0 = very low exemplarity and pedagogical use of the form and process. 0.5 = existing exemplarity, but with limited pedagogical use. 1 = high exemplarity and high potential for pedagogical use, Geo-didactics and Geotourism.
Existing educational product	Availability of maps and information about the site on webpage or directly on the field as interpretative panel	0 = no products. 0.5 = leaflets, maps, web pages. 1 = info panel, information at the site.
Use of the site for educational purpose	Educative use of the site through excursions, guided tours etc.	0 = no educative use of the site. 0.5 = site as a part of specialized excursions (students). 1 = guided tours for public.

Table 4
Criteria used for documentation of economic values (modified after Kubalíková, 2013).

Sub indicators	Description of the sub indicators	Values/Weights
Accessibility	Possibility of approaching to the site and availability of parking place	0 = more than 1000 m from the parking place and metalled road connection, 0.5 = less than 1000 m from the parking place and metalled road connection, 1 = less than 1000 m from the nearby bus stop.
Presence of tourist infrastructure	Distance of hotels, restaurants and accommodation from the site	0 = hotels or restaurants located more than 10 km from the site, 0.25 = hotels or restaurants located within 5 to 10 km, 0.50 = hotels or restaurants located less than 5 km 0 = accommodation centre located more than 10 km from the site 0.25 = accommodation centre located within 5-10 km 0.50 = accommodation centre located less than 5 km
Local products	Existence of any emblematic sites of local products near the site	0 = no local products related to a site, 0.5 = some products, 1 = emblematic site for some local products

Table 5
Criteria used for documentation of conservation and protection of the site (according to Kubalikova, 2013).

Sub indicators	Description of the sub indicators	Values/Weights
Actual threats and risks	Degree of degradation risk (natural and anthropic) present at or near around the site that can harm the site	0 = high both natural and anthropic risks, 0.5 = existing risks that are disturbing the site, 1 = low risks and almost no threats
Potential threats and risks	Possibility to degrade the site due to natural or human impact	0 = high both natural and anthropic risks, 0.5 = existing risks that may disturb the site, 1 = low risks and almost no threats
Current status	Present status of the site i.e. either destruction process continuing or any management strategies are being taken	0 = continuing destruction of the site, 0.5 = the site destroyed, but now with management measures for avoid the destruction, 1 = no destruction
Legislative protection	Existence and implementation of rules or regulations that can protect the natural site from further damage	0 = no legislative protection/protection rules are not being operated, 0.5 = existing proposal for legislative protection, 1 = existing legislative protection

4.4. Assessment of degradation risk and conservation status

The concept of Geotourism typically emerged out as a means to conserve the geoheritage sites through appreciation of the landscape. It promotes awareness about the geoheritage to the general visitors beyond the geosciences community for sake of sustainable tourism development (Gordon, 2018). The assessment of conservation values particularly deals with both natural and anthropogenic risk and threats, protection level as well as the current status of the geoheritage site (Table 5).

4.5. Assessment of added values

Assessment of added values examines the cultural values, ecological values and aesthetic values of a particular geoheritage site (Table 6). Interpretation of cultural links can enhance the importance of the geoheritage site and offers an alternative path of attracting and engaging the visitors (Ren et al., 2013). Moreover, the meaning of cultural value has changed over time. Appreciation of landscape aesthetics through poetry, art and literature have become a new approach to Geotourism. It helps in changing the perception of the landscape from physical to cultural construct. This can span a spectrum of interests to a range of visitors from pure geologists and geotourists to general visitors (Dowling, 2011; Hose, 2012; Watson, 2010). However, in this paper the distribution of weight has been modified in the case of 'aesthetic value'. Following the original model of kubalikova (2013) three parameters have been taken in which total maximum value has been restricted to 1 (for 'colour' maximum value 0.25; for 'landscape pattern' maximum value 0.25 and for 'viewpoints' maximum value 0.5), whereas in the original model the aggregates of all the parameters under aesthetic value exceed more than 1 which is very much illogical, as the maximum value for all the sub-indicators has restrained within 1.

Table 6
Criteria used for documentation of added values (modified after Kubalíková, 2013).

Sub indicators	Description of the sub indicators	Values/Weights
Cultural values	Presence of historical/archaeological/religious aspects related to the site.	0 = no cultural features/historical facts, 0.5 = existing cultural features/historical facts but without strong relation to abiotic features, 1 = existing cultural features/historical facts with the strong relations to abiotic features.
Ecological values	Influence on local ecology (plant and animal species) by the geologic or geomorphic feature in around the site.	0 = not important, 0.5 = existing influence but not so important, 1 = important influence of the geomorphic feature on the ecologic feature
Aesthetic values	Landscape appreciation through looking into colour, structure/pattern of the landform and number of viewpoints.	0 = one color, 0.125 = 2-3 colors, 0.25 = more than 3 colors; 0 = only one pattern, 0.125 = two or three patterns clearly distinguishable, 0.25 = more than 3 patterns; 0 = none, 0.25 = 1-2 viewpoints, 0.5 = 3 and more viewpoints

Based on the above-mentioned criteria and weight against each sub-indicators, the incurred scores are summed up to get the geoheritage values for each site. The geoheritage values of each individual sites are then converted into percentage for standardization of estimation. Following this process, all the geoheritage sites have been assessed to find out the Geotourism potential of the study area (Puruliya district).

5. Result and discussion

Following the method of geoheritage sites and Geomorphosites assessment of Kubalikova, it can be inferred that most of the geoheritage sites of Puruliya district are very much potential in response to Geotourism development. The result has been shown in Table 7.

Table 7
Evaluation of geoheritage sites through interpreting scientific, educational, economic, conservation and added values as to measure their Geotourism potential of Puruliya district.

Indicators	Sub indicators	#1	#2	#3	#4	#5	#6	#7	#8	#9
Scientific values	Integrity	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Rarity	0.5	0.5	0.5	0.5	0.5	1	0.5	0.5	0.5
	Diversity	0.5	0.5	0.5	0.5	1	0.5	0.5	1	1
	Scientific Knowledge	1	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5
Educational values	Representativeness and visibility	0.5	0.5	0.5	1	1	0.5	0.5	1	1
	Exemplarity	1	1	0.5	1	1	1	1	1	1
	Existing educational products	0	0	0.5	0.5	0	0	0	0	0.5
	Actual use for educational purposes	0	0	1	1	0	0	0	0	1
Economic values	Accessibility	0.5	0.5	0.5	1	1	0.5	0.5	1	0.5
	Present tourist infrastructure	0	0	1	1	0.5	0.5	0.25	0.75	1
	Local products	0	0	0.5	0.5	0.5	0.5	0.5	0.5	1
Conservation values	Actual threats and risks	0	1	0.5	0.5	0.5	0	1	1	1
	Potential threats and risks	0	1	0.5	0.5	0.5	0.5	1	1	1
	Current status of site	0	1	1	1	0.5	0	0.5	0.5	0.5
	Legislative protection	0	1	1	0	1	0	0	1	1
Added values	Cultural values	0.5	0	0.5	1	0	0	1	1	0
	Ecological values	1	0.5	1	0.5	0.5	0.5	0	0.5	0.5
	Aesthetic values	0.75	0.625	0.75	0.5	1	1	0.5	0.75	0.75
	Total Scientific value (Vtsci)	2.5	2.5	2.5	2	2.5	2.5	2	2.5	2.5
	Total Scientific Value incurred by the particular site in %	62.5	62.5	62.5	50	62.5	62.5	50	62.5	62.5
	Total Educational values (Vtedu)	1.5	1.5	2.5	3.5	2	1.5	1.5	2	3.5
	Total Educational Value incurred by the particular site in %	37.5	37.5	62.5	87.5	50	37.5	37.5	50	87.5
	Total Economic values(Vtecon)	0.5	0.5	2	2.5	2	1.5	1.25	2.25	2.5
	Total Economic Value incurred by the particular site in %	16.67	16.67	66.67	83.3	66.67	50	41.67	75	83.33
	Total Conservation values (Vtcon)	0	4	3	2	2.5	0.5	2.5	3.5	3.5
	Total Conservation Value incurred by the particular site in %	0	100	75	50	62.5	12.5	62.5	87.5	87.5
	Total added values (Vtadd)	2.25	1.125	2.25	2	1.5	1.5	1.5	2.25	1.25
	Total Added Value incurred by the particular site in %	75	37.5	75.5	66.67	50	50	50	75	41.67
	Total value	6.75	9.625	12.25	12	10.50	7.50	8.75	12.50	13.25
	Total Value incurred by the particular site in %	37.5	53.47	68.05	66.67	58.33	41.67	48.61	69.44	73.61

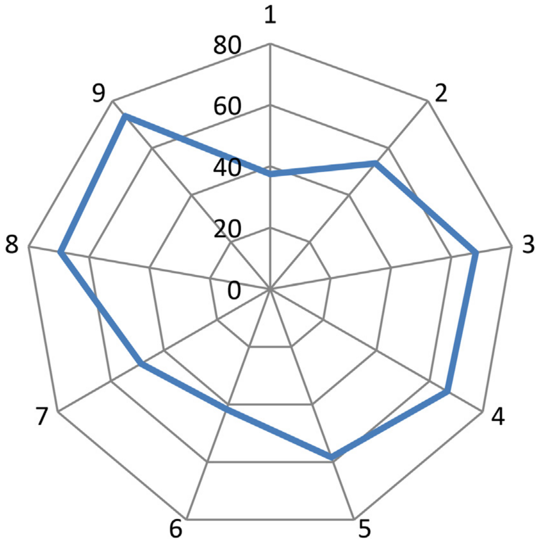

Fig. 11. Disposition of nine geoheritage site according to their total incurred value in percentage.

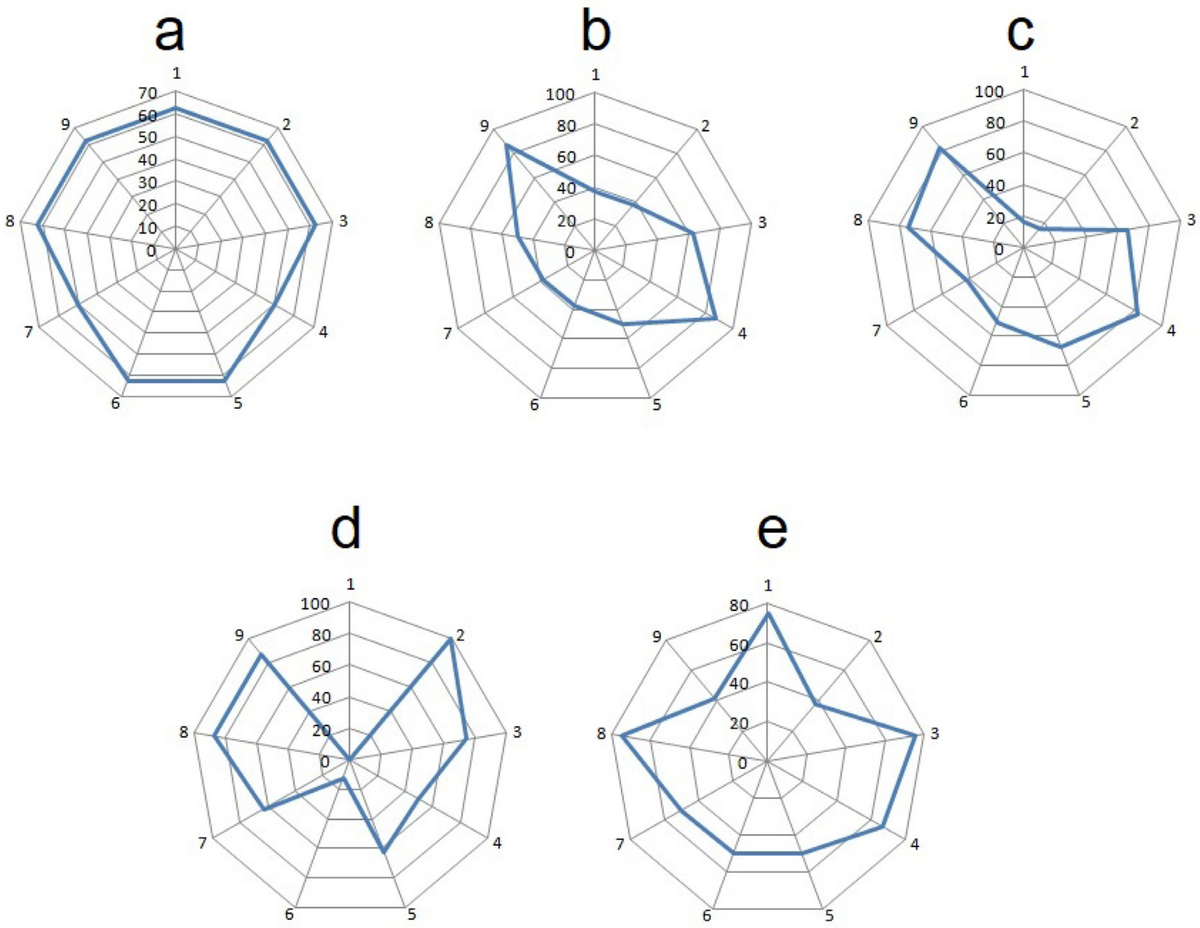

Fig. 12. Position of each geoheritage site according to incurred (a) scientific values, (b) Educational values, (c) Economic values, d) Conservation values, (e) Added values (cultural, ecological and aesthetic).

The figure 11 clearly depicts that four sites have incurred a 'total value' of more than 60% out of its total assigned value. The 'total value' of two sites ranges between 50% and 60% and for rest of the sites the 'total value' is less than 50%. Garhpanchakot hill, Jaichandi hill, Bhanratongri hill and Durgabera dam (Marble Lake) are categorized as high potential geoheritage sites. Belamu hill and Paharpur-Dhanardih hills have scored between 50% and 60% out of its total assigned value, and have included within medium-class potential geoheritage sites.

It can be noted that all the sites have attained almost the same score in accordance to 'scientific values' except two geoheritage sites i.e. Jaichandi and Tamakhun (fig. 12.a). The noted variation in the total score of each site is primarily due to the scoring variation in 'educational values' and 'conservation values'. However 'economic values' and 'added values' also have some contribution in response to such variation in total value of geoheritage sites. From the site-specific value analysis, it can be inferred that Jaichandi and Durgabera dam (Marble lake) have attained the maximum 'educational values' (87.5%), followed by Garhpanchakot hill. For rest of the sites, educational value (Vtedu) varies between 37.5% and 50% (fig. 12.b). The reason for such low 'educational values' for rest of the sites is because, in most of them either do not have any provision of 'info panel' or have lacuna in obtaining information about the site through websites, maps and leaflets. Another reason of achieving low 'educational values' for most of the sites is the inadequacy of specialized excursions or guided tour to attain the basic knowledge about geological and geomorphological features. Specialized tours for the students are conducted by different educational institutions only to the geosites like Garhpanchakot, Jaichandi and Durgabera dam (marble lake).

Most of the geosites (geological sites) belong to old rock quarrying site, which have been strictly banned by the government. As a result, the present status and future potential of degradation risks of the sites are relatively less, which helps to acquire high score in 'conservation values' (Vtcon) (fig. 12.d). The reason for obtaining medium value by Poradih and Paharpur-Dhanardih hills in response to 'actual and potential threats' is illegal mining by the poor local villagers for earning the money. Whereas, sites like Garhpanchakot and Jaichandi have achieved medium score in response to 'actual and potential threats' due to influx of huge number of visitors and their irresponsible behaviour as well as unplanned construction of hotels and lodges near the sites. In the case of Jaichandi hill, a concrete made ecotourism lodge has been constructed over a small dome which actually violates the principle of ecotourism. In the case of Garhpanchakot hill, a sponge iron factory has established which is very much responsible for polluting the surrounding environment as well as has disturbed the flora and fauna of the area. Engraving the name of individuals on the wall of the heritage buildings situated near the geoheritage sites, haphazard dumping of plastics are some common behavioural problems of the tourists that might increase the risk of degradation of the sites like Garhpanchakot and Jaichandi hill. Jabar hill has not secured a single score against the 'conservation values', as the site shares the border with neighbouring state Jharkhand and is very much sensitive to Maoist activity and illegal rock mining.

The 'economic values' consider all the criteria that are indirectly related to the development of a specific site as Geotourism destination. 'Accessibility' infers to road connectivity primarily, the availability of parking lots, metalled road connections and distance to nearby bus stops. Field observations have supported the fact that most of the sites are more or less located near the vicinity of metalled road connections and parking lots. Three sites i.e. Jaichandi, Paharpur-Dhanardih, and Bhanrotongri hill are located just along the side of the main road with the frequent bus service facility. Thus these sites have achieved the maximum score in 'economic value' criteria (Fig. 12.c). From the point of view of 'tourist infrastructure' and 'availability of local products', two sites i.e. Jabar and Belamu are significantly lagging behind, as the sites are located at the interior parts of the district. On the other hand, Durgabera dam has obtained maximum score in 'availability of local products', as the site is located near the Chorida (famous for Chau mask making) village. This artificial lake is situated near the Ajodhya hilltop and Bagmundi market. Therefore, the site has able to achieve the maximum value in 'tourist infrastructure' compared to other geoheritage sites. The last criteria 'added values' comprises three additional values regarding the Geotourism development i.e. cultural values, ecological values and aesthetic values. Garhpanchakot, Jaichandi, and Tamakhun have scored maximum 'cultural values' as all these sites bear historical background from different perspectives (Fig. 12.e). Garhpanchakot was the capital of Garhpanchakot kingdom during 926 A.D. to 1750 A.D (Goswami, 2016). The Raghunath temple situated over the hill (Fig. 13.b), the ruins of Ranimahal (Queen's chamber) (Fig. 13.a), the dilapidated watchtower, the relics of Maa Kalyaneshwari temple, and recently renovated Vishnu temple (Fig. 13.c) at the pedestal of the giant hill bear the history of old civilization which can pull the touristlarge in number (Goswami, 2016). The oldJaichandi temple (Fig. 13.d) and the ancient watchtower (Fig. 13.e) act as additional attractions for the Jaichandi hill. The site (Jaichandi hill) is also famous as the shooting place of classic Bengali film "Hirok Rajar Deshe", directed by Oscar winner Satyajit Ray (https://www.getbengal.com/details/film-tourism-in-bengal-follows-the-shooting-trail-to-iconic-locations). All these historical facts helps to increase the cultural value of the above mentioned geosites. Tamakhun, an abandoned copper quarrying site bears the imprint of mining activities during the British period of India. This place was also the centre of copper mining activities by Jain merchants during 8th to 12th century (Roy, 2007; Roy, 2010). From the perspectives of'ecological value', Jabar and Garhpanchakot hill have attained the maximum score, as these sites belong to the forest area and are rich in so many species of flora and fauna that differentiates it from the other geosites. 'Aesthetic value' judges the picturesqueness of landscape through evaluating its colour, pattern and number of viewpoints. Considering all the sub-indicators under 'aesthetic value', a little variation is found in the scoring of each site. Paharpur-Dhanardih and Poradih hill have scored maximum value, followed by Jabar, Garhpanchakot, Bhanratongri and Durgabera dam. Jaichandi hill and Tamakhun have achieved the lowest value from the aesthetic point of view, as the landscape of these two sites does not possess such typical colour contrast like the others have. Therefore, considering all kinds of additional values i.e. cultural value, ecological value and the aesthetic value, it can be concluded that three geoheritage sites Jabar, Garhpanchakot and Bhanratongri have secured maximum added values (75%), whereas Belamu hill and Durgabera dam have achieved the lowest added values (37.50%) especially due to inadequacy of cultural values.

Fig. 13. (a) Raghunath temple situated over the Garhpanchakot hill, (b) Queen's chamber in ruin condition, at the pedestal of the Garhpanchakot hill, (c) Vishnu temple at the pedestal of the Garhpanchakot hill, (d) Maa Jaichandi temple situated over the Jaichandi hill, (e) Watchtower over the Jaichandi hill representing added values for the respective Geoheritage sites.

Thus, some sort of management strategies should be taken to conserve and popularize these geoheritage sites and for the beneficial of the local people.

- Strict prohibition on illegal mining in endangered site i.e. Poradih, Jabar, and Paharpur-Dhanardih hill; penalty and punishment should be implemented for those who influence this kind of illegal works. Geopark should be formed to protect the geoheritage resources of Puruliya.
- Placing boards at the turn of the main road from where the site can be directly reached, giving detail information about how to reach, the distance of the site and a small highlight about spectacular characteristics of the geoheritage site.
- Installing hanging placards and boards as info-panel giving detail information about the geological and geomorphological explanation (history of origin, special features) at the particular geoheritage site.
- Organizing guided tour through tourism department of West Bengal, especially to show the potential geoheritage sites of the district; encouraging private tour agencies to offer exciting packages for Puruliya tour.
- Approaching different schools and colleges by education department to organize tour to the geoheritage sites of Puruliya district. It will help the students to learn (geoeducation) about the various geological and geomorphological features and at the same time Geotourism will be possible to develop in Puruliya district.
- Awareness should be built among the local people about their local natural tourism resources. Therefore, various seminar and conferences should be organized at the local level in aim to aware the public about the conservation value and tourism value of the geoheritage resources.
- Various workshops and training programmes should be conducted in aim to train the local residents as tour guide and inculcate the scientific and educational values of the local geoheritage resources among them.
- Trekking routes should be identified with the help of forest department so that more visitors will come who loves to trek a lot.
- Annual competition can be arranged for encouraging rock climbing, paragliding etc. where ever (especially at Jabar hill, Ajodhya hill, Garhpanchakot hill) it is possible. This type of sports activities will help to popularise the potential geoheritage sites of the district.
- Encouragement should be given to the locals for making provision of homestays/geolodges which will help to gain some profit to them and eradicate their poverty level as well as environmentally sustainable.
- Publicity about the geoheritage sites should be done using various media platforms i.e. television, newspapers and websites.

6. Conclusion

Identification of rocks, analysis of special features of geology and geomorphology has now become the integral part of tourism studies. This type of empirical study is not only helpful for students and learners but also has opened up a window for the economic prospering for the people who live in remote places. Being an area with huge natural resources, Puruliya has a great opportunity to show its Geoheritage to the world and take benefit the chances for the economic development of the local inhabitants. In accordance to that, a collaborative attitude should be built within the local people, NGO's and local administrative body and should implement all the necessary steps to conserve the geoheritage as well as develop Geotourism which will foster the economic development of Puruliya district.

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