GEO-PHYSICAL ATTRIBUTES OF SHUSHUNIA'S AQUIFER, CHHATNA BLOCK, BANKURA DISTRICT, WEST BENGAL, INDIA

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Abstract
Shushunia hill lies in a transitional zone of the South Singbhum Mobile Craton and northern Gondwana formation, India. The Shushunia hill appears like a porcupine peak and it has structural similarity to the Eastern Ghat. The Shushunia hill zone is an example of a contact spring. In the foothill zone, two perennial springs are observed. The study purely deals with its aquifer and water quality. Based on the present rock strata and the nature of the contact aquifer, its early condition has been assumed. The discharge of the confined aquifers occurs by leakage. The water temperature depicts the springs are not of geothermal origin. Shushunia's aquifer is the shallow flow system water table and it is the subdued replica of surface topography. The comparatively high discharge rate during post-monsoon indicates the fractured conduit-water seepage towards the aquifer. Moreover, twin-contact aquifers do not yield water uniformly. The water is slightly alkaline and hard.

Keywords: Shushunia Aquifer, Shushunia Hill, Aquifer's water, landscape

1. Introduction

There are several small and large aquifers in the world. The plateau to undulating plateau-like landform and the occurrences of the aquifer is the most common association. Shushunia hill lies in the northwestern part of district Bankura, West Bengal, India (Fig.1). It (double peak) is a small hill surrounded by a plain (Fig.2 & 3). The area is the transitional zone of South Singbhum Mobile Craton and the northern Gondwana formation (Ghosh, 2010). Shushunia hill appears like a porcupine shape (Fig 3) and it is quite similar to the structure of the Eastern Ghat. Highly metamorphic rocks are observed and those are the living relicts of heat deformation (Ghosh, 2010). The area has experienced polycyclic evolution (Chorley, Beckinsale, & Antany, 1973). The terrain has experienced the Proterozoic ductile shearing (Naik, K, & Wasthi, 2003) and the related deformation (Goswami & Ghosh, 2011). In the foothill zone, two perennial springs are observed (Fig.4). The water temperature depicts the springs are not of geothermal origin. The Guarani aquifer of South America is large and lies in the intracratonic basin and comprises the sedimentary sequences of Silurian – Devonian and the Cretaceous. The main water-bearing rock is sedimentary but the association of metamorphic rock has been observed (Hirata , et al., 2011). The Shushunia aquifer is tiny in comparison to the Guarani aquifer but there are similarities in nature.

2. Objective

Aim to study the Shushunia aquifer and its related geophysical attributes. It includes the location, landscape, rock strata, rock types of the aquifer, water yield by the aquifer, temperature, and hardness of the water. The study covers detail of surficial attributes, water discharge from the aquifer, and the position of twins aquifers. The aquifer lies in the sedimentary rock strata with semi-arid climatic conditions with alternative wet and extremely dry periods. Hence the study also tried to assess the water-yielding potentiality of the perennial aquifer.

3. Study area

The Shushunia hill lies in Chhatna block of Bankura district, West Bengal, India (height 440 m, 23° 22' 30'' N and 86° 58' 20'' E) (Fig.1). A small Paleozoic river named Gandeshwari (Fig.1 & 3) is flowing in southwest edge (Mahapatra & Chakrabarty, 2011) of the hill. The physical appearance of Shushunia is quite similar to the Monadnock (Fig.2 & 4). It appears as an erosional landscape rather

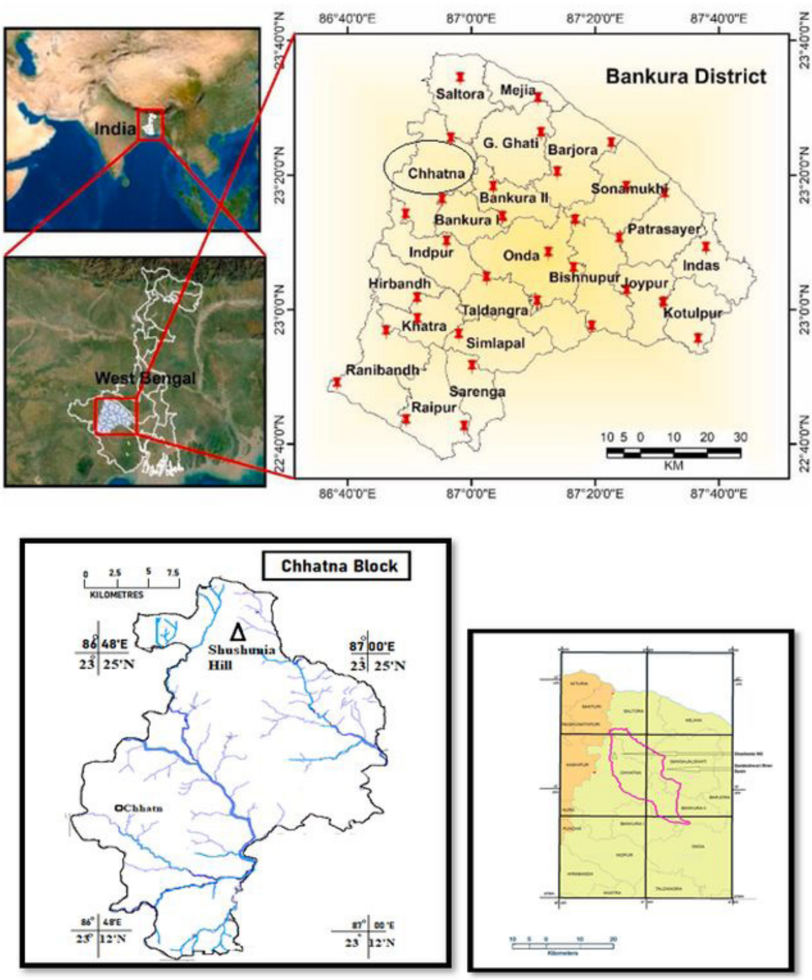

Fig. 1. Study Area

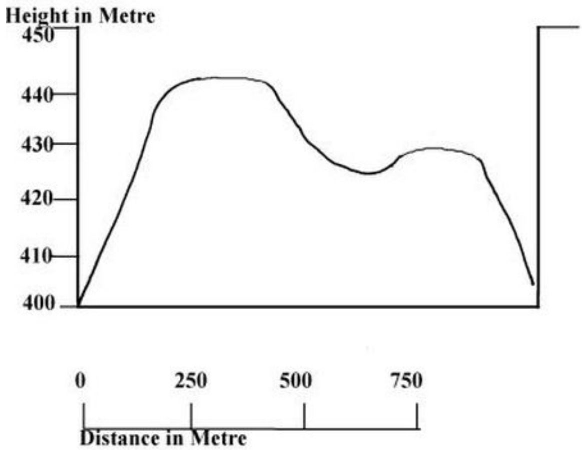

Fig. 2. Shushunia Hill and Porcupine-Peak

than uplifted land (Ghosh, 2010) and it is the result of exogenetic forces of the pre-Tertiary to post-Tertiary era. The height of the peak is 440 m and 426 m simultaneously (Fig. 3 & 4). There is a curvature between the twin peaks (Fig. 2 & 4).

4. Materials and methodology

The relevant information is gathered from the following sources:

1. Information regarding the surface elevation has been collected from the Survey of India topographical sheets (map no. 73I/15, 73I/16, and 73 M/3, R.F. 1:50,000)
2. Geological map of the study area (Bankura District Map by GSI)
3. Satellite Imagery of Indian Remote Sensing (IRS 1C LISS III, path and row 106-55, respectively, on 1:50,000 scale) data to identify the Shushunia hill and its surrounding areas and its lineaments.
4. Initially from geo-referenced topographical sheets, the slope, peaks of Shushunia, and surficial attributes of the hill have been plotted with the help of FOSS QGIS Ver 2.14.9 (ESSEN)
5. The lineament has been identified
6. With the help of a water testing kit (water pH meter, water Turbidity meter) water pH, alkalinity, and total solid dissolve have been measured (aquifer's water) and eighteen soil samples have been collected from the Shushunia hill's surrounding area (86° 58´ 30"E to 87° 00 ´E and 23° 23´ Nto 23° 25´ N). soil texture is identified with the help of the feel method and it has matched to the USDA classification of soil texture.
7. The water samples have been collected from the aquifer. The data covers the first day of December and February (pre-monsoon) and the first day of July, August, and September of 2021 (post-monsoon). The water sample was collected five times in the year 2021. The water sample was collected from the discharge points of the aquifers (both sides). Twenty-five (n=25) separate samples (five samples for each month) have been collected to study the yearly variation of water quality. The sterile plastic bottles with sterile caps (125ml) have been used to collect the water samples and those were kept at 15 to 18 degrees centigrade temperature for eight hours and the quality assessment has been conducted.
8. To measure the electric conductivity (EC), the digital hand EC meter (Hanna H198301, waterproof TDS meter) has been used and it indicated the salt content of water as well as the temperature of the water too.

9. The rate of water discharge per second has been measured with the help of a bucket (containing 5 gallons of water) and a stopwatch. The container has been placed directly into the vent of discharge and the stopwatch has been used to measure how long it takes to fill the bucket. The process has been practiced thrice and later an average has been taken. The average time, average discharge, and water flow discharge per second have been calculated.
10. The six Paleolithic sites have been depicted and those sites depended on perennial aquifers for fresh water.

The study is purely empirical (intensive fieldwork and observation) and it is solely based on an intensive survey of the rock strata of the structural hill. Rock strata surveys include geographical appearances, such as the pattern of rock texture, colour, gesture, grain size, and their association. The rock details have been identified with the help of a mineral microscope but have not been done by any chemical analysis in the laboratory. The study deals with types of strata, the gesture of the aquifer, and the water quality of the aquifer.

5. Discussion and result

Shushunia is a small double peak-elongated-isolated hill (440m) (Fig.2 & 3). Its surrounding contour value varies from 100-110 m (Fig.2). Shushunia appears like a two-domical inselberg and it's a massive fractured rock structure (Mandal & Ray, 2009). The hill Shushunia (440m) is abruptly high from its surrounding plain (Fig.2). It is just like an isolated hill of bedrock and it is standing conspicuously above the general level of the surrounding area (Fig 2). It remains the relict of erosion (Dassarma, Biswas, & Nandi, 1982). The physical appearance, geological structure, and climatic situation depict that Shushunia hill is the relict of erosional upland and therefore, it is very relevant to define it as 'Monadnock' (Sinha, 2016). Moreover, the geophysical appearance of Shushunia hill is quite similar to Mt. Monadnock (Chorley, Beckinsale, & Antany, 1973). The Shushunia hill is an example of erosional remnants and it stands like Monadnock (Sinha, 2016).

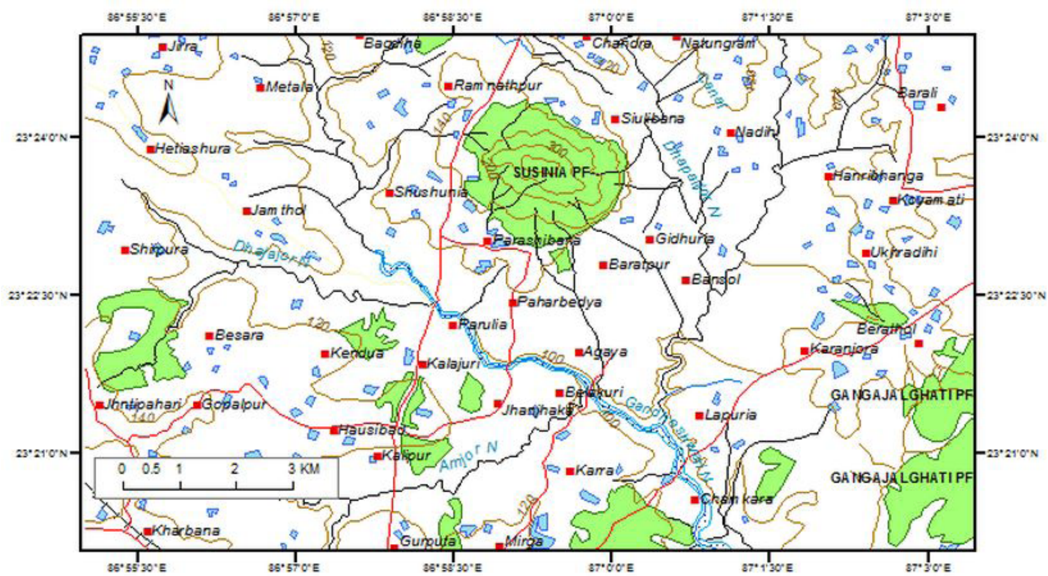

Fig. 3. Shushunia Hill and Surface Runoff

Shushunia and its Connotation

The adjacent area of Shushunia hill is dominated by the Santhal and Munda communities. In the Munda language (Austric Language group, the main group is Indo-Austric), the word Shushun means a place where dancing and singing goes in hand in hand. According to the Santhali language, the word meaning of Shun Shun is nearby or side by side and nia means this. In the Munda language (dialect), the literal meaning of Shushunia is a place for a social gathering (accompanied by dance and song). According to the Santhali language, the word Shushunia means lying side by side. Twin peaks or porcupine-shaped peaks which lie side by side are described as Shushunia. Another word of the Santhali language is Shur Shur, which indicates the 'sound of whistling bird' and nia means 'this'. Therefore, Shushunia may have been derived from the Santhali language, meaning 'the place of whistling bird'.

Geological Set-up of Shushunia hill and its Adjacent Area

The small hill reveals the geological history since Proterozoic orogeny (Meert & Pandit, 2014). Most of the sedimentary layers and schist layers are intensively fractured by prolonged weathering (Kaila et al. 1996). The surface layer of Shushunia is the reflection of mechanical weathering too. The sandstones constitute a few impurities of iron oxide and it provides the outer surface of the sandstone with a ferric appearance (Talukdar et al. 2012). The fractured sandstone and shale layer are highly permeable (Fig.5) and shale has a high retentivity of fluid. The sandstone is very coarse and dominated by the massive sand, kyanite-quartzite (Mazumder, 2005). Sillimanite, kyanite, quartz, dumortierite, anorthosite, shale, sandstone, and arenites (Mishra & Kumar, 2014) are common associations. Shushunia hill zone is covered by the gneiss which is composed of sillimanite and kyanite-bearing quartzite (Pal & Nandi, 2014). It covers the per-aluminous sedimentary rock of the Proterozoic formation (Mahapatra & Chakrabarty, 2011). Shushunia's quartzite and sandstone (arenites) are banded in nature and it is clear evidence of high heat metamorphism (Kumar & Ahmad, 2007) and tectonic compression (Ghosh, 2010). These sandstones are clastic and detrimental origin. The sandstones are cross-bedded in nature and highly fractured. In top most layers, the inter-granular porous sandstone and the fractured quartzite are prominent. Just beneath the zone, the metamorphosed and granite rock strata have been observed, but the southern part is dominated by the fracture sedimentary layers. In between the sedimentary layers, the palaeo-Mesozoic dextral motion has been observed. The porous rock layer of Sandstone and Quartzite covers the surface layer and the layer extends up to a depth of 26 cm (Fig.5). Despite monsoonal climatic and steep gradient (Fig.3 and 4), the number of the first-order stream is insignificant in the count. The fractured sedimentary rock is highly permeable which prevents surface runoff. It retains the meteorological water and forms good storage of groundwater table (Fig 4,5) and provides impetus to the perennial aquifer of fresh water.

The Shushunia hill has an association with the origin of the Eastern Ghat Mobile belt. The Eastern Ghat Mobile Belt relates to the formation of the Columbia and Rodinia supercontinent. The entire Eastern Ghat evolved from Palaeo to the Neo-Proterozoic era (Yoshida et al. 1992) but evidence of Archaean metamorphic signature (Mishra & Kumar, 2014) is absent. Shushunia hill lies in the zone of the Gondwana formation (Chattopadhyay et al. 2016) as well as the north Indian shield (Nag & Ghosh, 2013). Shushunia's formation relates to the breaking and making of the supercontinent Columbia (Yoshida et al. 1992). There is a similarity in the configuration of the eastern margin of the Gondwana supercontinent and the west coast of Australia (Crawford, 1974). There is also a matching of the coastline configuration of India and East Antarctica

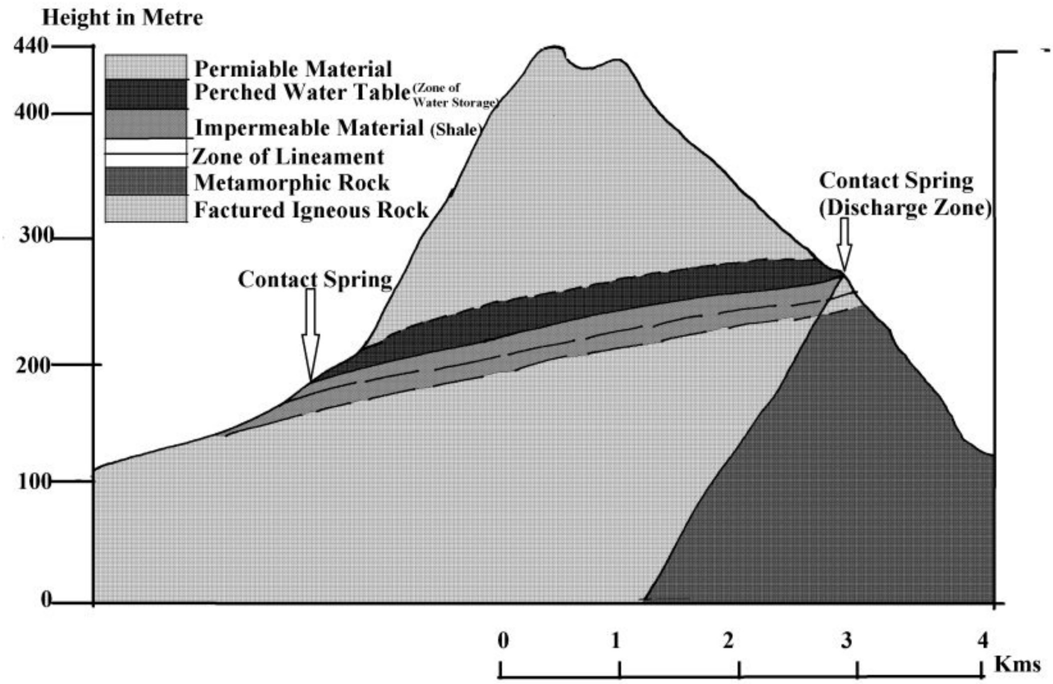

Fig. 4. Sushunia Hill and Contact Aquifers

(Crawford, 1974) and it is showing that EGM evolved from Columbia Super Continent (Yoshida et al. 1992). However, analysis of the palaeo-magnetic (Mukhopadhyay et al. 2013) and Spatio-temporal data (Palaeo-proterozoic age) indicates that the formation of Eastern Ghat or the Eastern Ghat mobile orogeny, the Columbia supercontinent and the Napier Complex are closely related. The hill and its adjacent area belong to the same isotopic provinces and later the Shushunia hill and adjacent area have been dissected by the Mahanadi graben formation and separated from the Eastern Ghat Mobile belt (Mahapatra & Chakrabarty, 2011). The northern boundary of Eastern Ghat extends up to the Munger zone (Mishra & Kumar, 2014) and Shushunia hill lies in the linear track. Later the region is eroded by the Silurian surface runoff.

The river Gandeshwari (a tributary of river Dwarakeshwar) is flowing and it holds the records of palaeontological evidence (Table 2) of phases of arid to humid climate (Pal & Nandi, 2014). Moreover, this Silurian origin (Mandal & Ray, 2009) small surface runoff (river Gandeshwari) depicts the uneven river terrace and it signifies the zone has crossed the phases of poly-cyclic erosion of landscape evolution.

Shushunia Hill and Perennial Aquifer

Shushunia as a structural hill has every possibility to provide high surface runoff but in reality, it is quite different. The topmost layer and rock composition prevented its runoff rather and acts as a permeable layer of an effective recharge zone. The discharge of the confined aquifers occurs usually by leakage. The gradient of the hill slope is the potential to produce first-order steam (Fig.2 & 3) but the number of the first-order stream is insignificant in number (Fig.3). The topmost layers comprise sandstone, quartzite, and a few fractured conglomerates which are highly permeable and retain meteorological water (Fig.5). The similarity is observed between the surface curvature of landscape and the curvature of the water table (Fig.4). Just below the perched water table, the shale

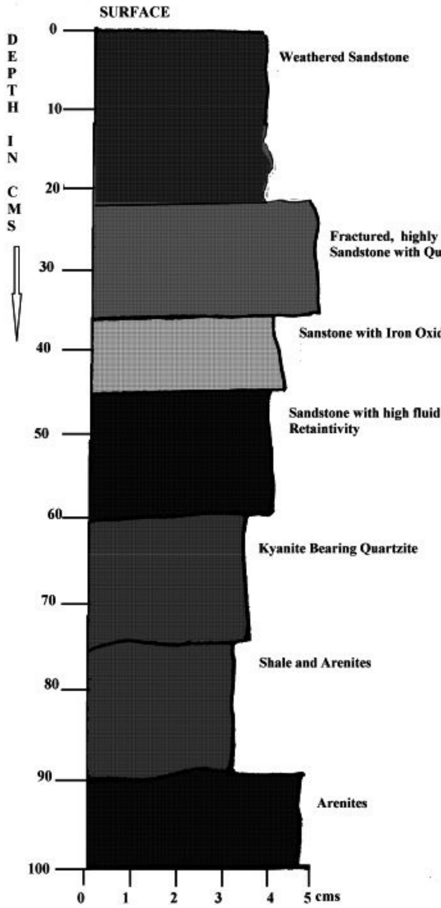

Fig. 5. Cross Section of foothill zone of Shushunia Hill

layer is found and an inclined lineament intersects the water table near the surface (Fig.4). The bottom of the perched layer is highly metamorphosed (Fig.4). The shape of hill, mound and water table both are convex and that intersects within the 120 to130 m elevation. It'sa perfect example of twin contact springs (Figs. 2 & 4). In the foothill zone, two perennial springs are observed and but their rate of discharge is not uniform. The average water temperature of an aquifer is uniform throughout the year and on average, it varies from 28.02˚C to 32.01˚C (Table 1). It depicts that the aquifer is not of geothermal origin. The permeable sandstone and quartz layers have good retentivity of fluid. The aquifer is perennial and the water is slightly alkaline (with a combination of sulfur) in nature. The range of pH varies from 8.2 to 8.7 and there is a variation in pre and post-monsoon periods (Table 1).

Water Potentiality of Shushunia's Aquifer

On average, each five-second aquifer yields 1.32086 gallons of fresh water and within twenty-four hours it yields 22824.4608 gallons of pure water. The average demand for the freshwater of Chhatna block is 5152358.8747 gallons (the total population of Chatna is 195038 (2021) and it is considered that per capita water demand is 100 liter). This aquifer is the potential to mitigate 22.57% of the daily water demand of the Chhatna block without rigorous water treatment. Water storage is essential for the optimum use of Shushunia's flowage. The

Fig. 6. Soil Texture of Shushunia Hill's Surrounding Area (Sandy Loam)

storage option may serve both purposes; it will mitigate the 22% demand for fresh water and it will enhance the scope of pisci culture. A commercial mineral water project was launched by a private organization twenty years back, but that project could not survive. From an Indian rural perspective of water sustainability, creating water storage by the prevention of seepage in a natural way will be more effective rather than the commercialization of water in the drought-prone pocket of the western part of West Bengal.

The surrounding area of Shushunia hill composes mainly of fractured sandstone and yellowish quartzite. Therefore, Shushunis's water easily percolates through the fractured permeable layer and the surrounding area remains dry throughout the year. Govt is trying to ensure pure and safe water for all and at the village level, the Sajaldhara project has already started in rural India. Archaean basement has a high probability of fluoride contamination in groundwater, and the Chhatna block is no exception. The fluoride in groundwater is slightly above the permissible level (1.9 to 2.2 mg/l) (Roy, 2009). Storage of water will meet 22% of local water demand.

Moreover, existing silt, gravel, and sand have dominant influences on water loss due to evaporation and loss due to deep percolation (Fig. 6). The aquifer's flowage storage in nearby lowlands with the clay carpet method can reduce the loss of water due to seepage. The clay layer will be compacted to its optimum moisture content and it prevents percolation. The 160 cm thick clay layer over fractured sandstone will decrease the seepage rate. The clay layer will act like a polythene lining over the surface. The clay layer will act like a clay carpet and low land can hold a large volume of aquifer flowage and it will preserve for future use. The clay is cheap, environment-friendly, the easily available from the nearby location.

EC is the reciprocal of electrical resistivity which is measured as the electric current that passes through a 1-centimeter-long liquid

Table 1. Shushunia's Contact Aquifer and Water Quality

Period	Water Discharge Rate	Water Temperature (Average)		Water pH		Turbidity (ppm)		Odor	Colour
Pre-monsoon	260 ml /Sec	30.2°C	Normal	8.2	Slightly Alkaline	Almost clear	700	Odorless	Transparent
Post Monsoon	274ml/Sec	28.5°C		8.6			800		Transparent

Reading of EC Meter

Sample No.(2021)	Temperature (degree centigrade)	EC (µS/cm)(micro Siemen/cm)	TDS (ppm)
December (n=5)	28.5	1122	785.40
January(n=5)	28.3	1128	789.60
July(n=5)	27.3	1200	840.00
August(n=5)	27.8	1245	871.50
September(n=5)	27.6	1275	892.50

column with a cross-sectional area of one square cm. The water of the aquifer is hard (Table 1) and the turbidity varies from 700 to 800 ppm (Table 1) and it's the variation of pre and post-monsoon periods.

Shushunia's Aquifer and Paleolithic Industry of Early Hominoids

The six lithic sites have been recorded along this area. Those six sites are the Jamthol, Panchasimula, Purulia, Paharbedia, Suyabasa, Gidhuria, and Dhankararjor of Chhatna Block (Table 2).

The six archaeological sites of Acheulian culture are found in Chhatna Block ((Mookerji, 1932), district Bankura, West Bengal and there was a probability to spread the stone tool industry from a single unit to the whole area (Table 2). The rock composition of stone tools was mainly grayish and fine-grained quartzite, which are very common in Shushunia hill. The remnants of bone tools and hammer-like stone tools are found between the elevation of 100 to 120 feet (Pal, 2014). The villages Aduri, and Kherbani of Chhatna Block are the living sites of early hominoids. Just before 1.76 million years (Holocene period), the stone tools technologies are observed in the Bankura area by the homo-habilis and homo-Erectus in the surroundings of the Shushunia hill region (23° 22' 30'' N & 86° 58'20'' E) (Neogi 2011). That fact reveals the association between the Shushunis' aquifer and Paleolithic culture.

It appears from various pieces of evidence that Shushunia was a suitable habitat area for early hominoids for its aquifers (for safe yielding drinking water). On the northwestern corner of the hill, there is a famous Shushunia rock inscription of King Chandrabarman observed (on the hill terrace). The script of the lithic inscription is Brahmi and it was from the fact of 4th century AD (Dassarma, 1982). The ancient lithic inscription is not the inscription of victory rather it identified the location of the safe water zone too. That signifies the freshwater aquifer, a small hill with quartzite stone was the association to develop the Paleolithic industry of early hominids.

Result

The perennial spring of Shushunia is the contact aquifer and Shushunia is the relict of the EGM belt. The aquifer is not of geothermal origin and it retains meteorological water through the porous sedimentary strata. The Shushunia's perched water table does not far beneath the surface or subsurface layer. Shushunia's aquifer is the shallow flow system water table and it is the subdued replica of surface topography (Fig.4). The comparatively high discharge rate during

Table 2. Palaeolithic Sites

Name of Villages	Geographical Location	
Jamthol	23°26’55” N	86°52’15”E
Panchasimula	23°23’15”N	86°52’15”E
Parulia	23°22’15”N	87°57’30”E
Paharbedia	23°22’55” N	86°58”E
Suyabasa	23°23’10’’N	86°58’30’’E
Gidhuria	23°23’ N	87°0’30”E
Dhankorarjor	23°24’20” N	87°0’15”E

Source: Field Survey

post-monsoon indicates the fractured conduit-water seepage towards the aquifer. Moreover, twin-contact aquifers do not yield water uniformly. The water of the aquifer is alkane in nature and it appears as perfectly transparent. It yields a vast volume of water in drought-prone areas and areas where the provision of surface and groundwater is limited during the summer period. The construction of an earthen clay-carpet pond in nearby low areas will be a very positive impetus towards water sustainability (local level). The association between with paleolithic stone tools industry of early hominoids and the perennial aquifer is very ancient. The uppermost layer of fractured sedimentary strata has high retentivity to meteorological water and it provides impetus to the perennial aquifer of Shushunia hill.

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