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President's Column

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GROUNDWATER RESOURCE EVALUATION OF A COMBINED PRECAMBRIAN AND GONDWANA TERRAIN - A CASE STUDY OF ATHGARH REGION, ORISSA

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ABSTRACT

The complex geological, varied hydrogeological and diverse hydrometeorological factors of the Athgarh area have led to wide variations in groundwater regime. The variations in groundwater are also due to sundry geomorphic and geologic setup, which control the occurrence and yield potential of groundwater reservoirs. Groundwater potential is limited to moderate and is confined to the weathered residuum and fractured rocks below the hard rock terrain comprising of khondalite, gneiss and sandstone whereas in the medium to low lying areas it occurs in the laterite and alluvium. The potential aquifer zone is assessed through the vertical electrical sounding and available bore hole data. The sounding data gives an exhaustive knowledge about the water bearing formations whereas the borehole data in places confirms the lithological set up. The hydrogeological and isopach maps describe the quantity and thickness whereas the cross sections and fence diagram give the details of the aquifer conditions, its extension and quality. The long-term exploitation of groundwater resources requires an in-depth understanding of the aquifer distribution and characteristics under varied hydrogeomorphic and hydrogeologic conditions of the area. The multilayer aquifer in the area gives sufficient knowledge about the occurrence and flow of groundwater management.

Key Words: *Groundwater, Aquifer, Athgarh, Orissa*

INTRODUCTION

The Athgarh and surrounding region (Latitude: $20^0 25$ to $20^0 40$ North and Longitude: $85^0 35$ to $85^0 53$ East) lies in the district of Cuttack of Orissa. The physiography of the area seems to have been controlled by the geological setting of the area. The northern extremity of the area, composed of Precambrian crystalline rocks, is marked by continuous chain of hill ranges of very sharp peaks and steep slope on either side attaining a maximum altitude of about 300m above mean sea level, and exhibits a rugged undulating topography covered largely by laterite & lateritic soil. Further south, the crystalline terrain breaks up into a number of sharp peaked isolated hillocks separated by wide valleys sloping towards south. The southern and central part of the area, composed of early Cretaceous Upper Gondwana sediments (maximum elevation of about 164m above men sea level), has altogether a different topographic expression characterised by widely scattered flat-topped isolated hillocks separated by wide valleys, mainly of laterites, sloping moderately towards south. The bank of river Mahanadi in the extreme south has an altitude of about 20m above mean sea level and forms the floodplain of this river, composed of alluvial sediments. In places, the low-lying areas form large water bodies like one Ansupa lake of 2.0 square km, which is formed by

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change in the original course of river Mahanadi (Fig.1).

DRAINAGE AND GEOMORPHOLOGY

Narrow streamlets originating from highlands and hill ranges form the Ist order drainage. Streams originating from intervening valleys between the hilly terrains on joining the Ist order drainage form the IInd order drainage. These streams are seasonal and receive water from hill ranges during monsoon and dry out during summer and winter. The Sapua and Singlijhor rivers, forming the IIIrd order drainage, are perennial in nature, flow in a southeasterly direction in the central part of the area taking a few sharp bends and ultimately join the Mahanadi river. The river Mahanadi, located in the extreme south flowing from west to east, alone forms the IVth order drainage (Fig.1). Lithological control over the drainages is prominent. The Precambrian crystalline terrain shows dendritic to subdendritic drainage pattern whereas the sedimentary terrain is characterised by subparallel drainage. The area enjoys a humid tropical climate represented by winter, hot summer and wet rainy seasons with an average rainfall of around 1500mm. The humidity ranges from 65% to 86%. Lack of knowledge about the groundwater potential zone and its distribution creates a crisis in all sector of utilization. Proper ground water resources evaluation and its judicious utilization may meet the requirement of the people.

METHOD OF STUDY

In order to get a clear picture of the subsurface geology and aquifer characteristics thirty-one numbers of exploratory borehole data, drilled up to a variable depth of 9.27m to 101.9m, and sixty-two numbers of Vertical Electrical Sounding (VES) data (Schlumberger's Resistivity Method) were obtained. It provided information about the thickness, lateral extension, physical characters and weathering characteristics of various lithologic units and confirmed the sub-surfacial geology & aquifer characteristics. The hydrogeological map is drawn taking the subsurface lithological aspects into consideration. The aquifer thickness map is prepared by projecting the cotours from the existing data whereas the cross sections and fence diagram are drawn from the data available from the sounding and borehole.

HYDROGEOLOGICAL CONDITIONS

The geological formations of the area govern the occurrence and movement of groundwater. Its exploitable quantity depends on the aquifer parameters of the formations, topography, recharge area and precipitation (Basak, 2003). The hydrogeological map (Fig.2) of the area shows the areal distribution of various lithologic types, which hold and yield considerable amount of water to make an aquifer. Four water bearing formations such as weathered and fractured khondalites, weathered sandstones, laterites, clay and alluvium where groundwater occurs under water table condition and circulates freely through fractures, pores and solution channels have been identified. The standing water bodies like lakes, swamps, floodplains and ponds play an important role in recharging the aquifers. The aquifer thickness map, defined as the Isopach map, (Fig.3) was prepared by calculating the thickness of the aquifer from the available borehole and VES data (Ballukraya and Ravi, 1995). A sectional view of the isopach map is shown in Fig.3a. Though the comparison of quantitative layer parameters from the sounding interpretation and borehole particulars reveal that most of the major yielding aquifer zones are in those depths which could not be inferred as aquifer zones from the resistivity data (Muralidharan, 1996) but still drilling and Schlumberger sounding data collected from different locations together give a clear idea about the subsurface lithologic framework and aquifer characteristics of the area. These data were used to draw the cross sections and three dimensional fence diagram to demonstrate the aquifer characteristics along certain profiles. Six regional geological cross sections (Fig.1) three in the E-W and three in the N-S direction have been prepared along profiles to display the sequential position of various hydrogeological formations and aquitards and their relation with available tectonic elements like faults (Jahan and Ahmed, 1997) (Fig.4.a-4.f) whereas the fence diagram (Fig.5) shows a three dimensional configuration of the aquifer, its lithological setup and groundwater occurrence. To measure the groundwater level open wells were inventoried in the course of survey in different topographic situations to infer the occurrence of water table and assess the fluctuation in the ground water level at various locations. The data were used to draw the water table contour map (Fig.6).

RESULTS AND DISCUSSION

The aquifer of the present area is confined to the sloping land, valleys and low-lying areas. The hilly terrain within the area having an altitude of more than 80m above mean sea level is composed of fresh impervious and impermeable crystalline rocks and sandstones which do not hold and yield appreciable quantity of water. The weathered and fractured crystalline rocks, weathered sandstones, laterite and alluvium overlying the fresh, impervious crystalline rocks and sandstones are highly porous, permeable and hold considerable amount of water to form a potential multilayer unconfined aquifer (Fig.2). The weathered and fractured crystalline rocks spreading over an area of 121.19 square km occur at the foot of the Precambrian hills in the north and western part of the area. The weathered sandstones have a wide lateral extent and cover about 115.44 square km of the central region. Alluvial aquifer of about 49.62 square km is found along the bank of the rivers Sapua, Mahanadi and occasionally near minor streams. The subsurface extensions of these potential water-bearing formations (aquifer) have been established from the resistivity (VES) data and borehole logs.

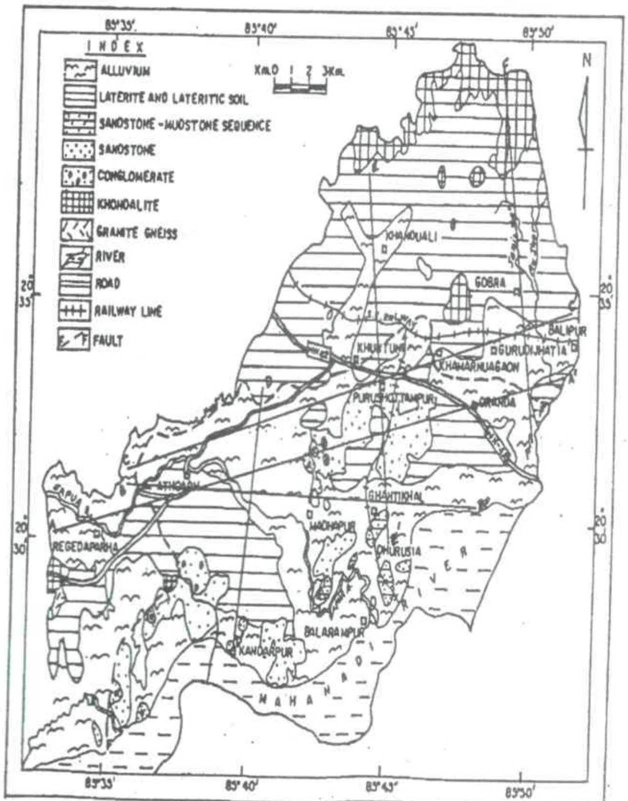


Fig.1. GEOLOGICAL MAP OF THE STUDY AREA.

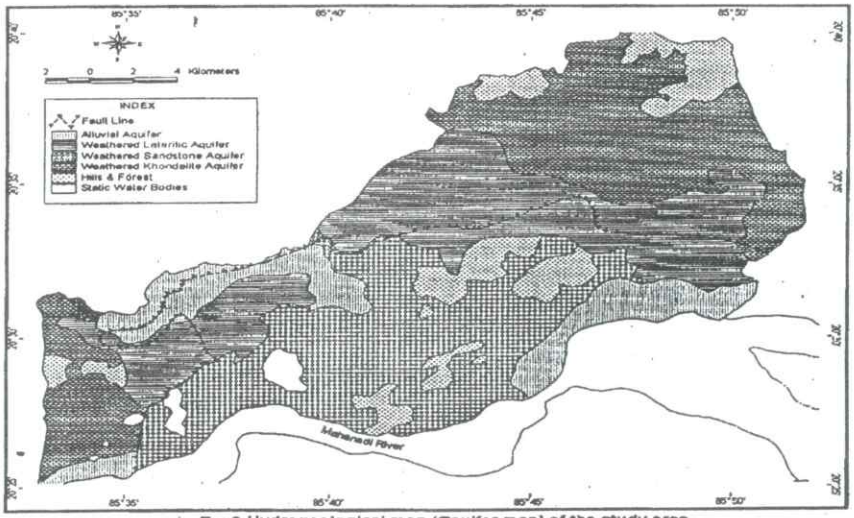
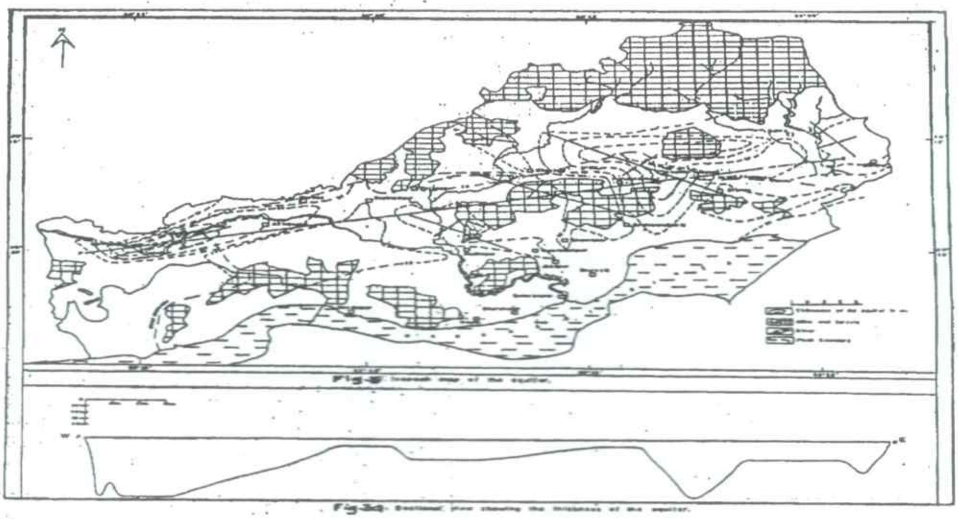


Fig.2 Hydrogeological map (aquifer map) of the study area



Fresh crystalline rocks and sandstones having resistivity value more than 122 m, suggests that they do not hold much water under normal condition (Sikdar et al., 1994). These rocks lie beneath the aquifer, forming impervious and impermeable bedrock zone with a wide variation of resistivity ranging from 97 m to 14,500 m. The variation in the resistivity may be due to change in composition of the rocks from place to place and also change in the intercalated rock types (Dhar et al., 2000). The isopach map pattern indicates that the aquifer close to the Precambrian high lands in the north is less than 20m thick and gradually increases towards south in the Athgarh sedimentary basin between 60m and 180m and further south along the bank of river Mahanadi the thickness reduced to 20m. The aquifer south of the boundary fault in the sedimentary terrain is thicker than that of the crystalline terrain located towards north. Along the E-W profile, the isopach map of the aquifer defines four prominent depressions where the thickness of the aquifer is very high and ranges from 60m to 180m. Out of the four, three depressions have their axes running in NW-SE direction while the axis of western

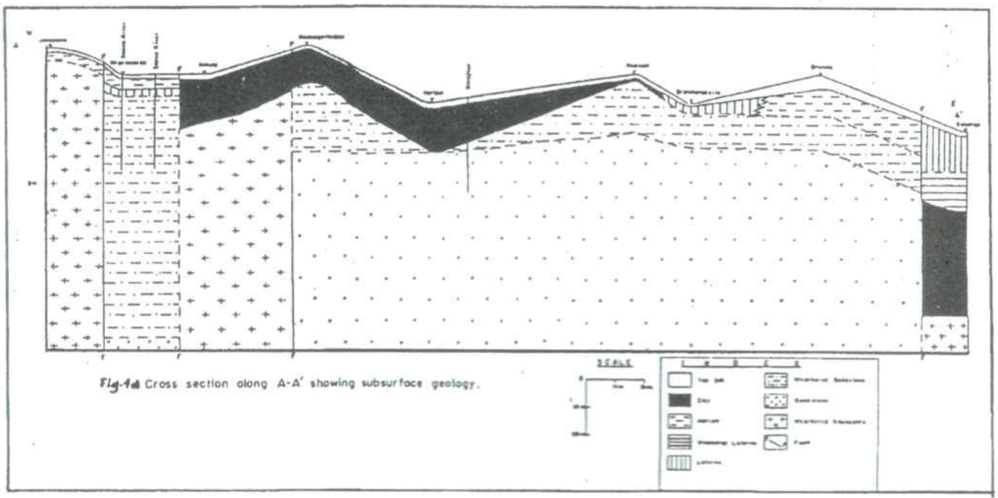


Fig-4a Cross section along A-A' showing subsurface geology.

most depression runs in an ENE-WSW direction. These depressions are separated by highs where the thickness of the aquifer reduces to 20m. Depending on the contrast in lithology, degree of consolidation and porosity, the aquifer system of the study area has been classified into three hydrogeological formations such as consolidated, semiconsolidated and unconsolidated. The consolidated formation includes the Precambrian crystalline rocks (khondalites and granite gneisses) and fresh sandstones covering an area of 253.10 square km.

These formations lack primary porosity and hence they form the bedrock of the aquifer. Occasionally, groundwater occurs in the fractures and fissures of these rocks but do not form a potential aquifer. The consolidated formations occur at a depth of 0.6m to 5.1m below ground level close to the hills whereas their depth of occurrence varies from 16.5m to 200m along the slopes and valleys. The resistivity values of these formations range from 97 m. to 14,500 m., which suggests that, they do not hold much water to form an aquifer

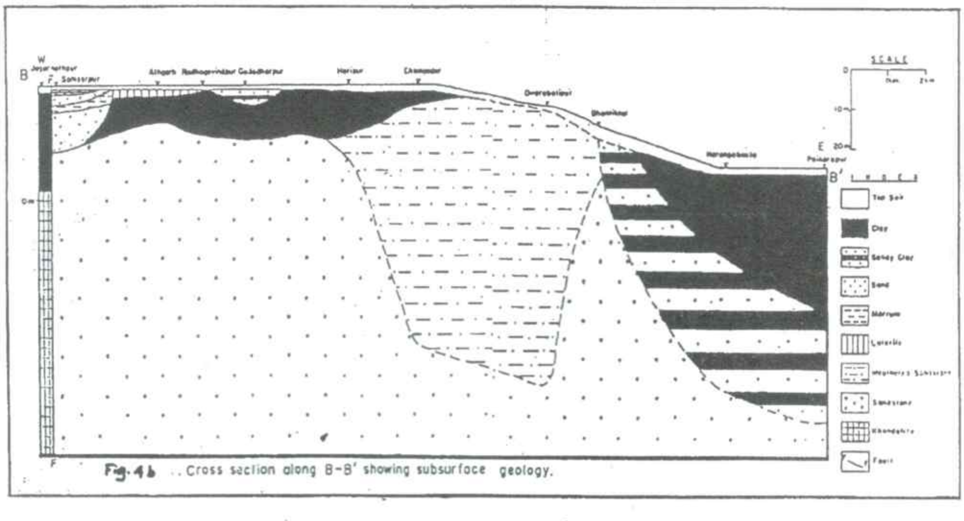


Fig.4b . Cross section along B-B' showing subsurface geology.

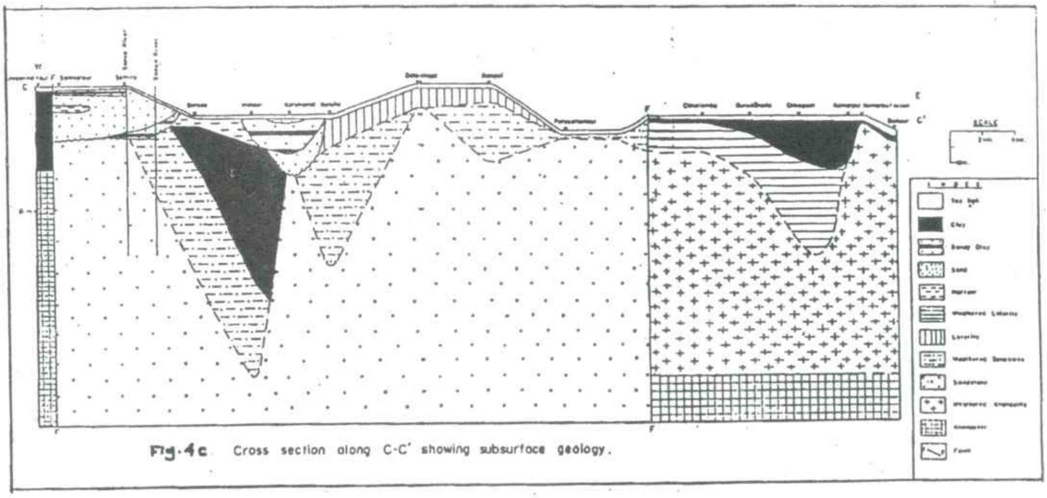


Fig.4c Cross section along C-C' showing subsurface geology.

(Rath et al., 1998). The semi consolidated formation is of three types. These are fractured and weathered khondalites, highly weathered Athgarh sandstones and the laterites extending over an area of 158.34 square km. These are formed due to breaking down of the rocks along closely spaced joints, fractures and cracks and extensive weathering and leaching of Precambrian crystalline as well as the Gondwana sandstones. They occur as a thick blanket capping these rocks.

All these rock types are porous and permeable and ground water occurs under water table condition forming a potential unconfined aquifer system. Weathered khondalites occur at a depth of 7.92m to 18.5m below ground level and their thickness vary from 16.5m to 200m. Weathered sandstones occur at a depth of 1.88m to 12.3m below ground level and their thickness varies from 1.92m to 70.4m. The laterites are found on the ground surface in places and extend upto a depth of 71m

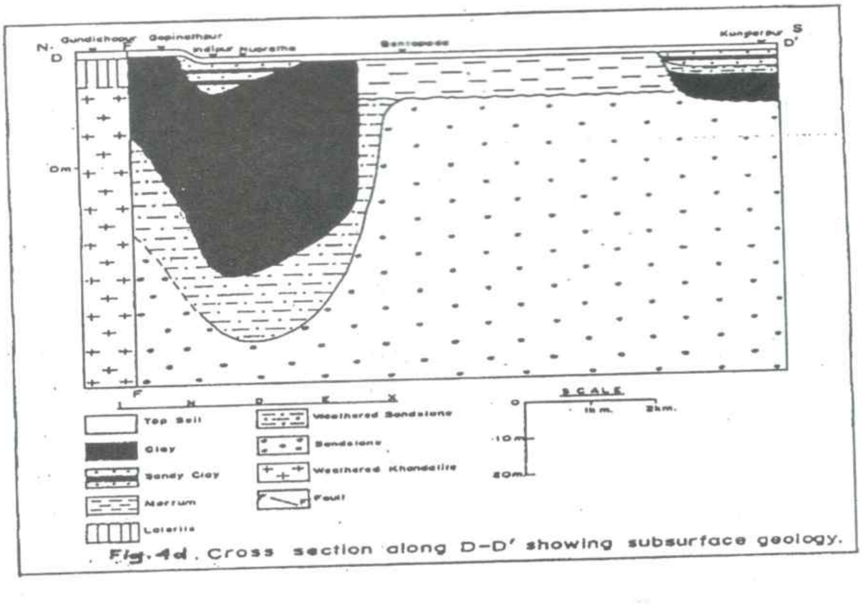


Fig.4d. Cross section along D-D' showing subsurface geology.

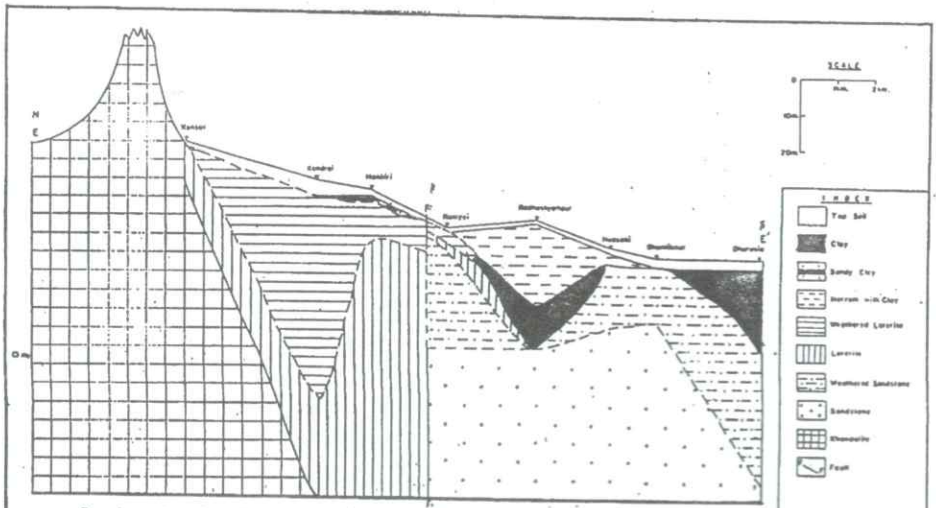


Fig. 4e . Cross section along E-E' showing subsurface geology.

below ground level. This semiconsolidated formation is the potential aquifer zone whose resistivity value ranges from 26 m to 95 m (Rath et al., 1998). The unconsolidated formation includes residual soils formed by the weathering of khondalites, sandstones, laterites and the alluvial soils deposited along the banks of Sapua, Mahanadi and other minor streams. Residual soil occurs as lenses and pockets along the sloping land and valleys of the northern, central and eastern part of the area whereas the alluvial soil occurs as strips along the river courses.

These formations spread over an area of 44.96 square km and extend to variable depth of 2.9m to 10.10m below ground level and their thickness ranges from 1.1m to 28m. The resistivity value of the unconsolidated formation varies from 2 m to 16 m and therefore, has been considered as good aquifer zone (Sikdar et al., 1994). The subsurface configuration of the aquifer is markedly controlled by its structural setting and lithological behavior (Khan and Sattar, 1994). To configurate the subsurface geology and aquifer distribution the cross sections drawn are studied carefully.

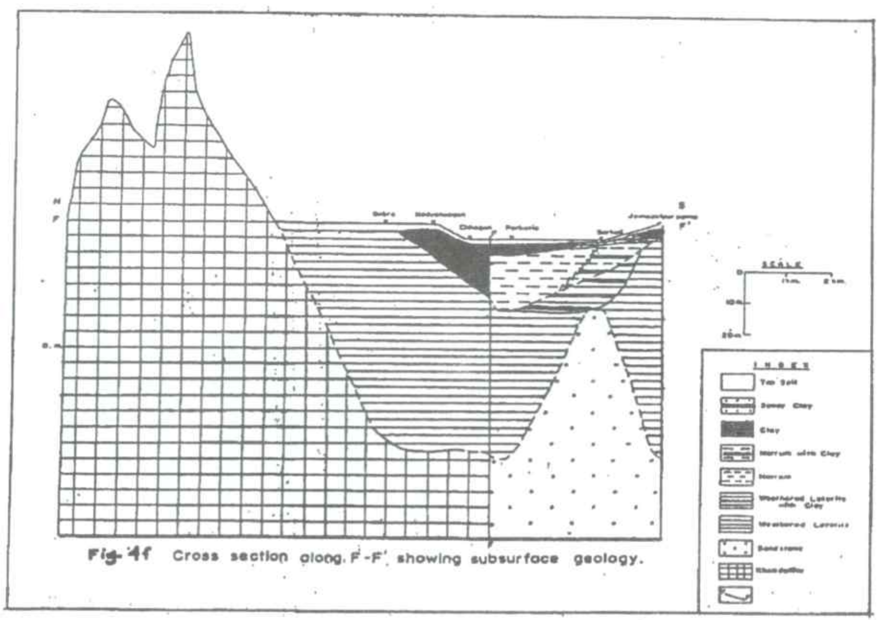


Fig. 4f Cross section along F-F' showing subsurface geology.

Section A-A$^{/}$ (Fig.4a) runs in an E-W direction for 32km. It is bounded by four vertical faults, which correspond to the boundary of the crystalline and sedimentary terrain giving a compositional variation in aquifer lithology. The hydrogeological formations within this profile in ascending order are: weathered and fractured khondalite, weathered sandstone, laterites and thick layer of residual clay. These hydrogeological formations rest on impervious and impermeable bedrock zone of khondalite and fresh sandstone. The weathered khondalites occur in the extreme east and west of the profile. The vertical faults separating the crystalline formations from that of sedimentary rocks act as conduits of groundwater percolation. A thick residual clay layer is produced due to extensive weathering of khondalites and sandstones. Its thickness is 17.5m in the west; gradually decreases to 2.5m towards east and finally disappears near Brahmanabasta village. Grading of laterite is also marked near Oranda.

Section B-B$^{/}$ is an E-W profile (Fig.4b) 21.5km long. A vertical fault in the extreme west separates the crystalline formation from the sedimentary terrain. The hydrogeological formations rest over the bedrock of khondalites and fresh sandstones. The water bearing formations within this profile from bottom to top are weathered sandstone, sandy clay, sand and laterite. Lenticular clay layer 9km long and 17.5m thick extends from Athgarh to Champapur village. Two alluvial aquifers (as pockets around 16m thick) of sand and sandy clay formed by Sapua and Barajhor river are marked near Samsarpur and Gadadharpur village. The Samsarpur aquifer is thicker due to its occurrence close to the fault zone, which allows free percolation of water.

Section C-C$^{/}$ is also an E-W cross section (Fig.4c) extending up to 27km. It has two vertical faults, both in west and east of the section separating the crystalline rocks from the sedimentaries. The east and west of the section is occupied by crystalline rocks

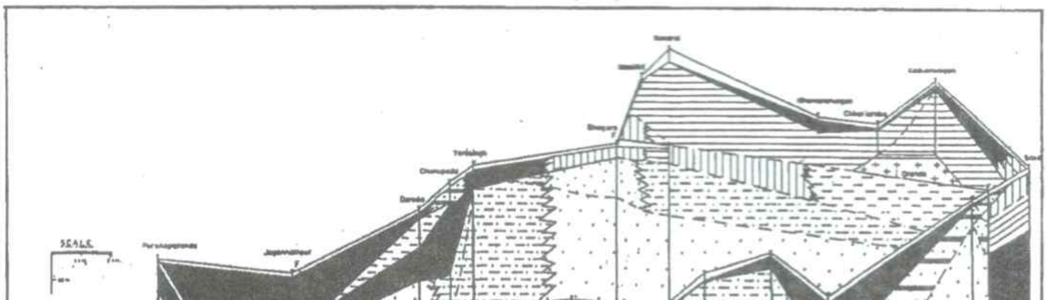


Fig.5 FENCE DIAGRAM OF THE STUDY AREA.

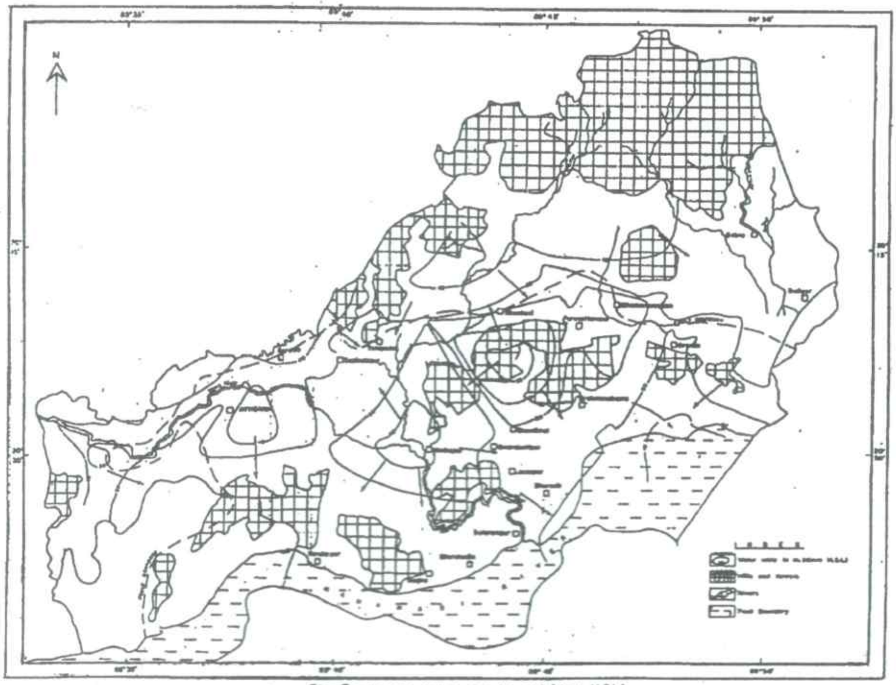


Fig-6 Water table contour map (in mts) (above M.S.L)

while the sedimentary formations occupy the central region. Extensive weathering of khondalites in the extreme west has created 25m thick layer, which forms a poor aquifer. On the other hand 70m thick weathered khondalite resting over impervious bedrock forms a potential aquifer in the extreme east. Free and frequent percolation of surface water through the fault has formed such a thick aquifer. These weathered khondalites are overlain by a thick succession of laterite and clay, ultimately forming a thick hydrogeological unit. Besides, a small alluvial aquifer is also found in the western part of the section near Karakamal village. This is only 20m thick and formed due to lateral migration of Sapua river. The general outflow of groundwater is towards south and mainly southeasterly towards the Mahanadi river.

The N-S trending D-D$'$ cross section (Fig.4d) is 10.5km long. It is dissected by a vertical fault. The fault separates the crystalline rocks from the sedimentaries. The hydrogeological formations in this section from the bottom to top are weathered alluvium. Sapua river alluvium composed of sandy clay and clay forms a 60m thick aquifer due to the sharp bend of the river course along which it has migrated laterally for a considerable distance. This alluvial aquifer has variable water yielding capacity at different locations because of variation in the sand layers within the clay bands. A 10m thick laterite bed forms a conspicuous hydrogeological formation. It extends for nearly 4.5km. A pocket of alluvial aquifer formed by Mahanadi river is also found near Kandarpur village.

The N-S trending E-E$'$ section (Fig.4e) is 19.5km long and displays a clear lithological variation. The section starts from Baniabandha mountain range of 200m altitude located in the north comprising of fresh khondalites. Further south there is a vertical fault separating the crystalline rocks from the sedimentary rocks. A small lenticular alluvial aquifer formed by Barajhor river is also found. Towards north of the section groundwater occurs in the laterite whereas in the south it is restricted to weathered sandstone, laterite and clay. The variable thickness of the aquifer suggests that the trend of groundwater flow is towards south of the section where thickness exceeds more than 60m.

Section F-F$'$ (Fig. 4f) extends in a N-S direction from the Hathiamunda mountain range in the north and composed of fresh and impervious Precambrian khondalites. This Precambrian mountain range is separated from the Gondwana succession near Chhagan village by a vertical fault. The hydrogeological formations, laterite, clay and sandy clay in ascending order rest over the impervious khondalites in the crystalline terrain and fresh sandstones in the sedimentary terrain. Depth of occurrence of these hydrogeological formations ranges up to 70m. A small alluvial aquifer formed by Barakatiajhor stream is marked near Sarakoli village. The general trend of groundwater flow is towards river valleys. Fence diagram shown in Fig.5 is based on interpreted layer parameters (Dasgupta and Ghose, 1987 and Dhar et al. 2000) and derived from twenty-three sounding and drilling data. Four sets of hydrogeological formations lie over the impervious and impermeable bedrock of khondalite and fresh sandstone. These hydrogeological formations are weathered khondalite, weathered sandstone, laterite and alluvium including clay in ascending order. Two prominent vertical faults have been demarcated, one extending from Jagannathpur to Mahidharpur in a SE direction and the other from Bhogra to Sarkoli in a NW direction. These two vertical faults separate the Precambrian crystalline terrain from the Gondwana sedimentary terrain. The upper boundary of the aquifer has been fixed at water table whereas the lower limit is defined on the resistivity values of different lithlogic units. Weathered and fractured khondalites whose resistivity value ranges from 54.6 m to 90 m, weathered sandstone and laterite (26 m to 95 m) and clayey alluvium (2 m to 15 m) have been considered as the potential aquifer zone (Sikdar et al. 1994; Rath et al. 1998 and Dhar et al. 2000). Any resistivity value exceeding these given values defines the impervious bedrock zone. A complete analysis of the fence diagram shows that the aquifer thickness in different locations varies from 2.5m to 84m. The nature and distribution of aquifer in different geologic cross sections and fence diagram of the study area are markedly controlled by the lithology and structure of the geological formations. There exists a considerable diversity in the nature and thickness of aquifer material, which depends on the relief, topography and relative movement along the fault lines. The lateral continuity of the weathered and fractured crystalline rocks, sedimentary layers and alluvial deposits is an important factor affecting groundwater storage, yield and flow. The surface separating the weathered zone from that of the bedrock zone has been regarded as the lower boundary of the aquifer, while the water table defines the upper boundary of the aquifer. The depth of occurrence of lower boundary varies from 20m to more than 180m. The water table that defines the upper boundary of the aquifer rises from 8.7m to 58.5m above mean sea level of the region. The water level contours follow the topography and drainage of the area and suggests that the geomorphology has largely controlled the groundwater regime. The contour map of water table orienting in an ENE-WSW direction running parallel to Mahanadi gives an idea about the concentration of groundwater in the aquifer and the directions of groundwater flow. The map shows four sets of concentric patterns with closely spaced contours moving from elevated regions to low lying areas finally tending towards river Mahanadi. The flow lines perpendicular to the contours indicate the direction of movement of groundwater. The thickness of the aquifer is uneven and ranges from less than 20m to more than 180m.

CONCLUSIONS

The groundwater in Athgarh region occurs under water table condition in fractured and weathered khondalite of crystalline terrain, weathered sandstone of sedimentary succession, Tertiary laterite and Holocene alluvium. These lithounits form the hydrogeological formations (aquifer) of the region. Depending on the contrast in lithology, degree of consolidation and porosity, the aquifer system of the study area has been classified into three hydrogeological units viz. consolidated, semiconsolidated and unconsolidated formations. Consolidated formation comprises of nonporous and impervious khondalite and fresh sandstone whose resistivity value ranges from 97 m to 14,500 m suggesting that they do not hold much water to form an aquifer and hence forms the bedrock. Weathered khondalite, weathered sandstone and laterite together form the semiconsolidated formations with the resistivity value of ranging from 26 m to 95 m suggesting a permanent source of groundwater storage. The alluvium comprising of sand and sandy clay forms the unconsolidated formation whose resistivity value ranges from 2 m to 16 m suggests an excellent aquifer. The depth of occurrence of consolidated formation ranges from 0.6m to 200m below ground level and their thickness varies from 16.5m to 200m below ground level whereas the semiconsolidated formation occurs within 1.8m to 18.5m below ground level and its thickness ranges from 1.92m to 71m. In unconsolidated formation depth of occurrence is recorded at 2.9m to 10m below ground level and thickness extends upto 28m. The upper limit of the aquifer has been defined by the existing water table of the aquifer whereas the lower limit of the aquifer is fixed on the basis of the resistivity values of the aquifer material. The nature and distribution of aquifer are markedly controlled by the lithology and structure of the geological formations. The groundwater potential, which depends on the thickness and discharge of the aquifer, shows that the area adjacent to Mahanadi and Sapua river are rich in groundwater yield. This is due to the thick deposit of alluvium supported by considerable thicker weathered sandstone aquifer. The northern and western fringe comprising of weathered khondalite aquifer is poor in groundwater potential either due to less thicker aquifer material or abundance of thick clay obstructing the frequent flow of groundwater movement. The central zone has a moderate potentiality of groundwater. The Athgarh and surrounding area, therefore, has been considered as a well documented example of a multilayer unconfined aquifer with significant groundwater potential, which can cater to the need of people.

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CRITICAL HYDROGEOLOGICAL CONDITION IN URBAN AREA OF BALASORE, ORISSA

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ABSTRACT

Balasore, an important coastal town in Orissa State, is underlain by the Tertiaries and Quaternaries. The area has an average slope of 0.8 m/km. from west to east. Two to five nos. of aquifers have been encountered at different places in the subsurface up to a depth of 100m with a total thickness ranging between 12 and 42 m. The hydraulic conductivity (K) of aquifers ranges from 8.7 m/day to 47m/day. The average gradient of phreatic water table is 1.20m/km. towards southeast. Due to heavy withdrawal of groundwater by accentuated pumping of a large number of deep tube wells a ground water trough with lowest elevation of -1m. from the mean sea level has been created. This trough, along with reversal of natural hydraulic gradient, unproductive nature of shallow aquifers, diminishing yields of deeper aquifers, maximum draw down and defunctness of deep tube wells before the expiry of total life of these abstraction structures are indicative of over-exploitation of aquifers beneath this urban area.

Keywords : Potentiometric surface, Groundwater trough, Over-exploitation.

INTRODUCTION

Balasore (21°30'08" N; 86°55'21"E) town is situated on a vast gently sloping alluvial plain. The area is almost flat with an average slope of 0.8 m/km from west to east and altitude ranging between 10 and 20.5 m above mean sea level. Total area of this eastern coastal town (Fig.1) of Orissa State is 19.43 sq. km and is located 15 km onshore from the sea, Bay of Bengal. Town water supply for its entire population of 1,30,000 (approx) is met by ground water and for this purpose high discharge production tube wells have been constructed. The gross present water demand @100 l.p.c.d. +15% U.F.W (Unaccounted for Water) amounts to 14.95 MLD. Total water supply in the town by means of deep tube wells has been estimated to be 17.85 MLD. Such large scale abstraction has resulted failure of a number of deep tube wells and the discharge of many of these tube wells have been reduced to a large extent. Contemplating the sewerage system to be implemented in Balasore town by the year 2020, the demand of water is 135 l.p.c.d (Central Public Health and Environmental Organisation, 1999) and at this rate total water requirement for the estimated population of 1,86,000 of this town at year 2020 would be 28.88 MLD. To know the effect of this massive withdrawal of ground water by accentuated pumping of large number of deep tube wells and its cumulative environmental impact on the ground water regime occurring in the multi-aquifers of Balasore town area, detail hydrogeological investigations have been carried out and analysis of collected data have been made. Some remarkable facts have been brought to light and useful conclusions have been drawn.

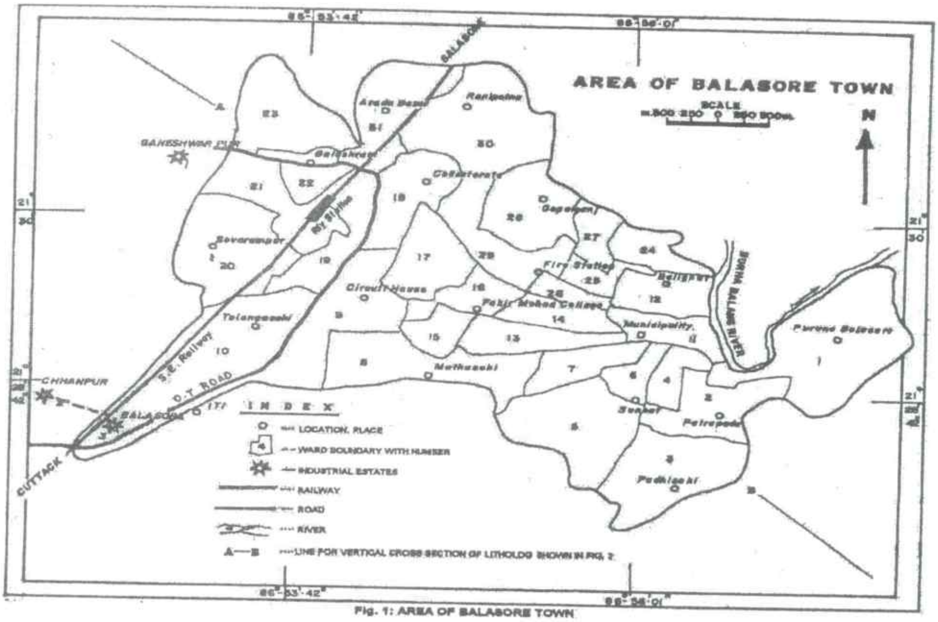


Fig. 1: AREA OF BALASORE TOWN

GEOLOGY

The coastal tract of Orissa is underlain by Tertiary and Quaternary Formations, the latter covers the entire study area.

Exploratory drilling by Geological survey of India in late fifties shows the presence of Miocene (?) marine sediments comprising grey clay with fine sand, molluscan shells and fish teeth at Remuna at a depth of 69.48m below ground level and at Balasore, the Miocene deposits consisting of fine to coarse sand with calcareous clay containing shell fragments occur at a depth of 272.79 m below ground level (Bhatnagar et al., 1970).

The data of exploratory drilling by Central Ground Water Board at Remuna and Bhimpura, which are located within 1-3 km from the western periphery of Balasore town, show the presence of grey to greyish black and greenish grey clay-sand-gravel sequence along with fossil fragments and limestone at reported depths of 68.5m and 302.2m below ground surface respectively. Limestone has also been struck very recently at 60.30m depth in an exploratory borehole at Mitrapur, 12km WNW of Balasore town. The Mio-Pliocene unfossiliferous sediments lie conformably over the Miocene sediments. This unfossiliferous sequence comprises yellowish, brownish and greyish clays, sands and gravel, and is encountered in different boreholes in Balasore town area at depths within 16.50-40.00m. Clays in this unfossiliferous sequence is micaceous and sands are quartzo-feldspathic in composition.

Older alluvium consists of sediments, which are grey to brown in colour, unfossiliferous, and quartz enriched but possesses plenty of calcareous concretions. Thickness of this formation in Balasore town ranges up to the maximum of 40m. Younger alluvium of recent age consists of clays, sands, gravels, pebbles and it has been deposited as discontinuous pockets in the flood plains of Burhabalang river.

An attempt has been made to study the sub-surface disposition of different conspicuous litho-units of the Tertiaries and Quarternaries by correlation and subsequently drawing a vertical section along a line trending E 25° S – W 25° N from Sunhat in Balasore town to Remuna. This section (Fig.2) has been drawn on the basis of litho-logs of different boreholes drilled by the Central Ground Water Board in the period 1980-2002. An apparent south-eastern dip of different litho-units within 3-6° has been envisaged. The fossiliferous horizons occurring at a depth

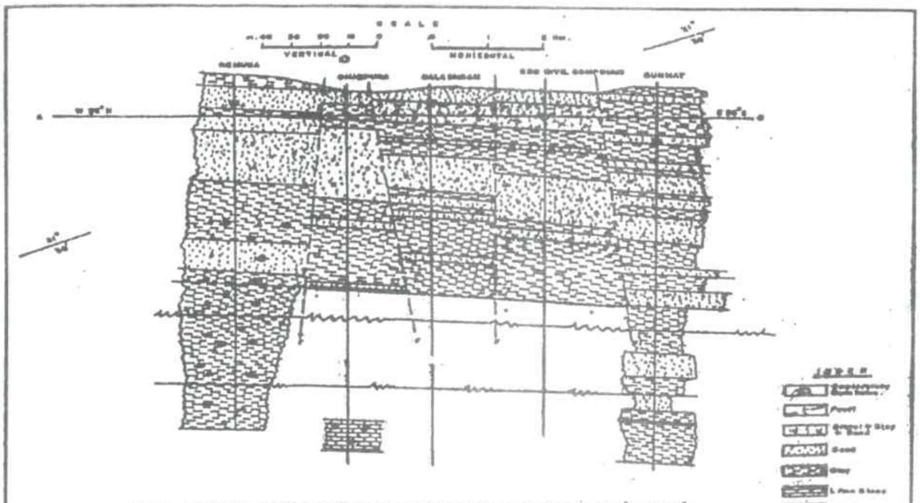


Fig. 2 VERTICAL CROSS SECTION ALONG THE LINE AB TRENDING E 25°S - W 25°N SHOWING LITHOLOGICAL SUCCESSION ENCOUNTERED IN DIFFERENT EXPLORATORY BOREHOLES.

of 69.88m at Remuna and at a depth of 272.78m at Balasore seem to dip at an angle about 56.38 m in 1.6 km (Bhatnagar et al., 1970) At the top, the clay layers distinctly show "pinch and swell" structure. Also, this geological section shows that the formations have been affected by block faulting.

URBAN HYDROGEOLOGY

The Mio-Pliocene and alluvial sections contain the principal ground water reservoirs, the Miocene marine sediments being dominantly composed of finer clastics and non-clastics (Bhatnagar et al., 1970). Quaternaries are most prevalent in the phreatic aquifer, which exists within 20m depth and ground water in this zone occurs under water-table condition. This phreatic aquifer is tapped by open wells and filter point tube wells. The yield of these open wells ranges between 50 and 100 m^3/day (CGWB, 1999). Open wells in Balasore town are under-used owing to the presence of large number of hand pumps and deep tube wells, the latter are used for pipe water supply.

In Fig.3, pre-monsoon and post-monsoon depth to water level in dug well zone have been shown. During pre-monsoon, depth to water level in open wells ranges between 0.98 and 15.04m below ground level, while the same varies from 0.07 to 4.67m below ground level in post-monsoon; during pre-monsoon the

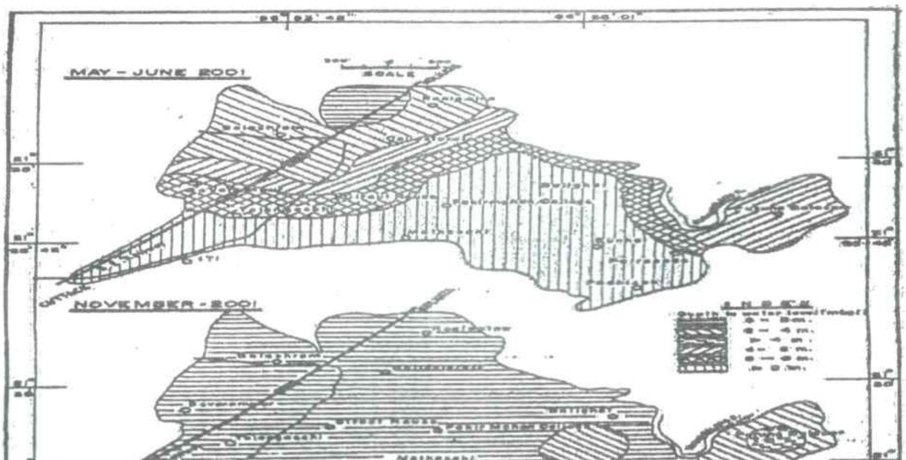


Fig. 3 DEPTH TO WATER LEVEL , BALASORE TOWN (PHREATIC AQUIFER)

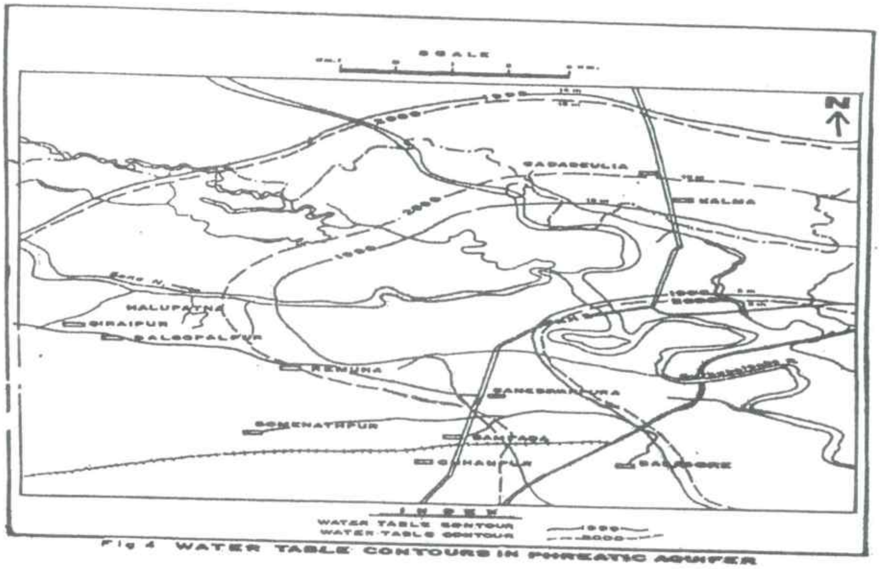


Fig 4 WATER TABLE CONTOURS IN PHREATIC AQUIFER

presence of shallow water level of less than 4m and moderate level of less than 8m occurs in the extreme north-west of Balasore town, i.e. Railway Station - Aradabazar sector and in the east around Puruna Balasore respectively, while in other areas water level is very deep and the maximum water level of 15.04m has been recorded just at the proximity to Balasore Industrial Estate. Post-monsoon data depict a general shallow water level during Nov.2001. Water level below 2m has been recorded all over this urban area excepting at Municipality Office (2.55m), Puruna Balasore (4.63m) and south west of Balasore Industrial Estate. In Fig.4, phreatic water table contours of a large area including Balasore town has been shown, the average gradient of water table is 1.20 m/km towards south-east.

Deeper aquifers of the present area are restricted within a depth range between 25 and 100 m, because beyond this depth finer clastics are encountered as mentioned earlier. These aquifers are tapped by hand pump fitted tube wells and deep tube wells run by submersible pumps for town water supply. Transmissivity (T) values of these aquifers together ranged from 188 to 1504.26 m^2/day and Hydraulic Conductivity (K) varies from 8.7 m/day to 47 m/day. Post-monsoon (Nov.2001) depth to water level in deeper aquifers

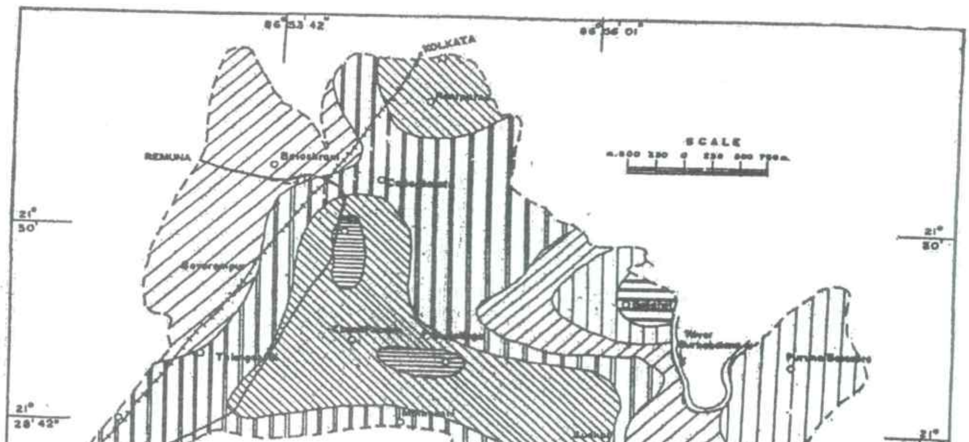


Fig-5 DEPTH TO WATER LEVEL IN HAND PUMP FITTED TUBEWELLS TAPPING AQUIFER ZONES FROM 25 TO 60m. IN BALASORE TOWN AREA (NOV.2001) tapped by hand pump fitted tube wells has been depicted in Fig.5. It shows deep water level of 8m and more excepting at south-eastern part of Patrapada-Puruna Balasore, northern part of Balighat and western part of Balashram area, where water level ranges between 3.09m and 6.55 mbgl. In the central part of Balasore town, i.e. Sunhat-Circuit House-Collectorate area, the water level is very deep and it ranged between 10.83 and 12.15 m bgl.

Deep tube wells for pipe water supply are run by pumps for 12 hours daily from 4 AM to 5 PM with a brief rest of 1 hour from 10 AM to 11 AM. Water level in February 2002 in these deep tube wells has been shown in Fig. As per the measurement taken between 2030 hrs. and 2300 hrs. This depicts a very deep water level ranging between 12.83 and 15.84m below ground level excluding the south-eastern part of Puruna Balasore (4.90 mbgl) and western part of Balashram(6.10 mgbl).

Critical Hydrogeological Situation

The fence diagram (Fig.6) shows 2 to 5 aquifers in the sub-surface of Balasore town. The cumulative thickness of aquifers varies from 12 to 42m. The maximum depth of deep tube wells could not be extended below 100m, as finer clastics are encountered. below this depth (Bhatnagar et. al., 1970), which are mostly unproductive for ground water.

Long term trend analysis of water level data of one open well at Sunhat and one piezometer at Balia show declining trends in all seasons (Fig.7 & 8). Both this open well and piezometer are now dry and abandoned.

Depth to cumulative water level in deeper aquifers is alarmingly declining. In the central part of Balasore town, this level in deeper aquifers has gone down to the tune of 5 to 6m within a period of 22 years from 1980 to 2002.

The yield of a large number of tube wells has been reduced over the years. Fig.9 depicts the initial potentialities versus present discharges of some of these deep tube wells. Most of the tube wells suffered reduction in its yield values and a few of them showed more than half reduction of its original yield potentialities. Also, some tube wells are characterized by heavy draw-down and they need frequent lowering of pumps in successive summer

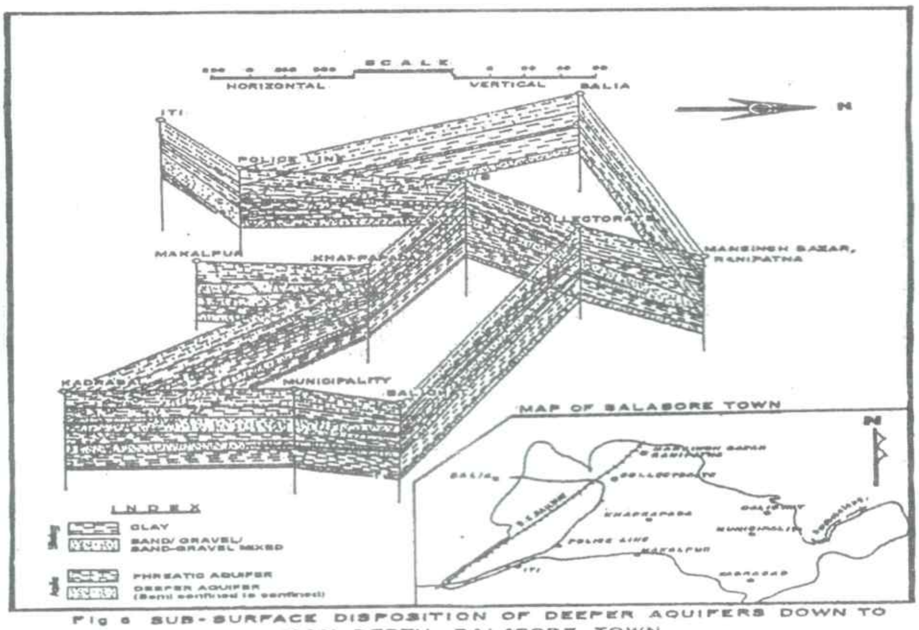
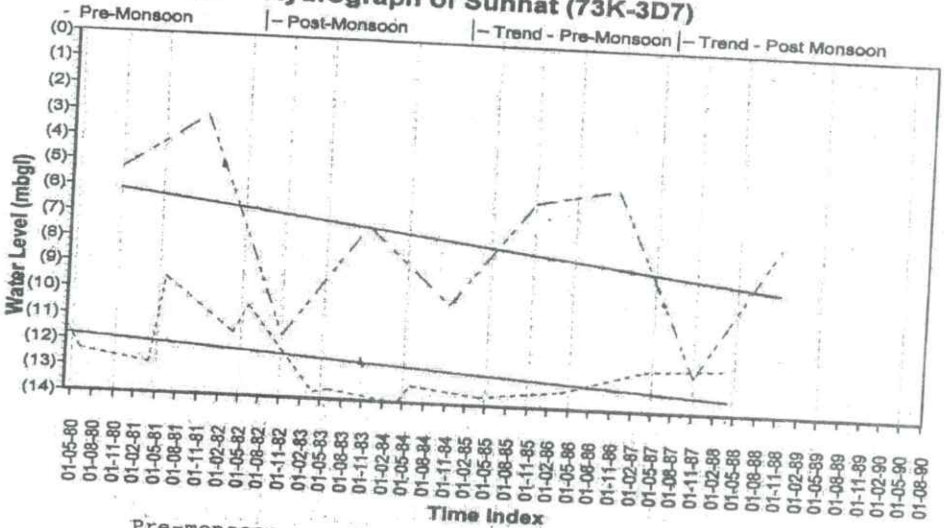


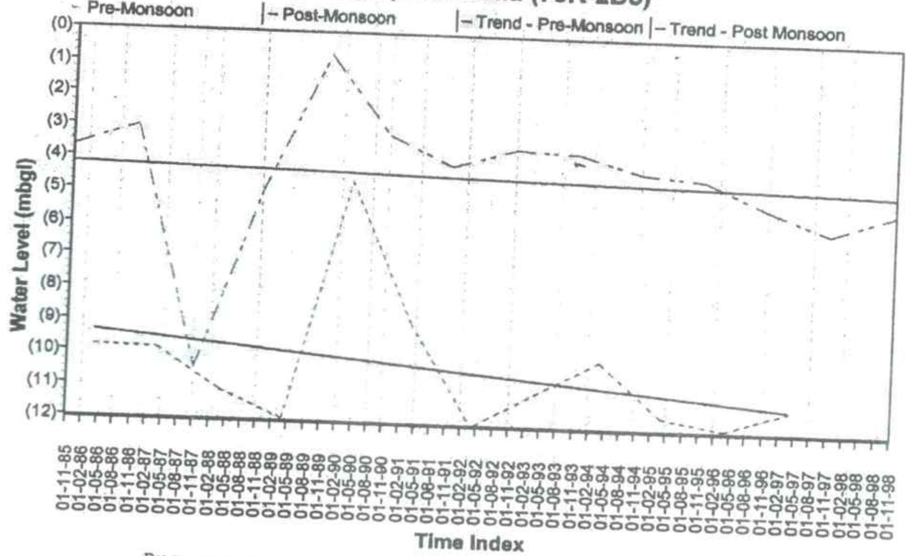
Fig 6 SUB-SURFACE DISPOSITION OF DEEPER AQUIFERS DOWN TO 100M. DEPTH, BALASORE TOWN

Fig. 7 Hydrograph of Sunhat (73K-3D7)



Pre-monsoon : Slope= -0.214 Intercept= -11.76
Post-monsoon : Slope= -0.392 Intercept= -5.86

Fig. 8 Hydrograph of Balia (73K-2D5)



Pre-monsoon : Slope= -0.176 Intercept= -9.22
Post-monsoon : Slope= -0.034 Intercept= -4.17

seasons. Some deep tube wells have become defunct mostly in the central part of Balasore town because of diminishing potentialities. Potentiometric surface contours in Fig.10 exhibit that a ground water trough has already been created due to massive withdrawal of ground water by the accentuated pumping of a large number of deep tube wells in Balasore town. The centre of this trough coincides with the central part of the town and is elongated elliptical in plan trending NNW – SSE. On the western part of the trough the gradient of these potentiometric contours is in the same direction as that of the ground slope; it is steeper (4.13m/km) in the north-western part than that in the southern part (1:82m/km). The average gradient of these potentiometric contours on the eastern part is opposite to the ground slope and is 2.77m/km towards west. The lowest elevation is <-1m from mean sea level. As a result, the natural hydraulic gradient has been reversed. It has been observed that the draw-down in water level by pumping these deep tube wells ranges between 2.10 to 18.35m; lower values of the order of 2.10 to 3.80m are obtained in the newly constructed tube wells and higher values of the order of 11 to 18m have been encountered in the old ones located at the central part of the

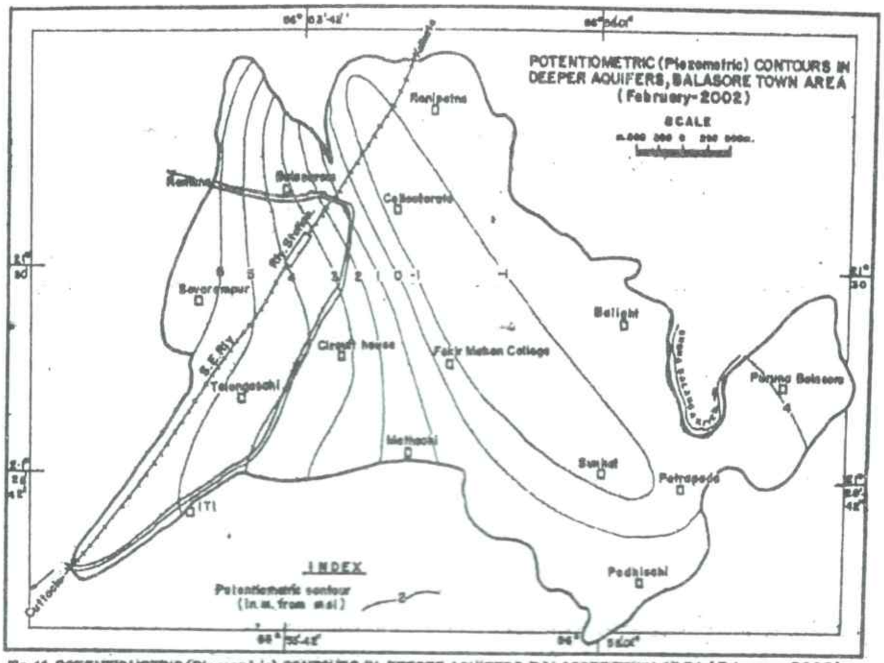


Fig. 10 POTENTIOMETRIC (Piezometric) CONTOURS IN DEEPER AQUIFERS, BALASORE TOWN AREA (February-2002)

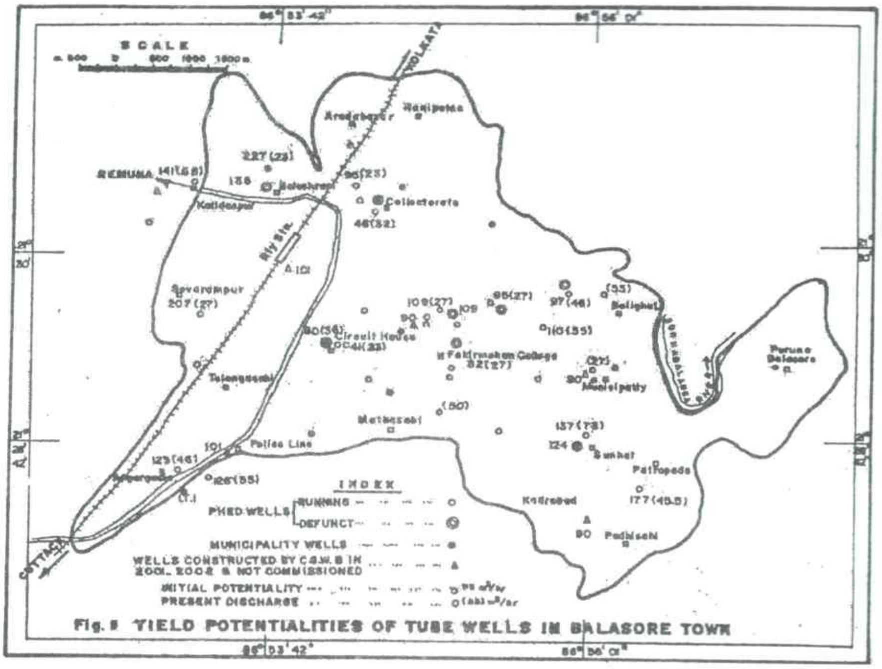


Fig. 9 YIELD POTENTIALITIES OF TUBE WELLS IN BALASORE TOWN

ground water trough. The effect of this ground water trough has been severe: (i) eight (8) nos. of tube wells have been reported to be defunct and these are mostly located in the central part of the trough, (ii) sand pumping has taken place in a few tube wells and as a result these wells are being filled up and (iii) many tube wells are getting abandoned because of diminishing yield.

Over Exploitation of Ground Water

The large scale abstraction of ground water in Balasore town area is an established fact. But, it is worth mentioning to what constitutes an over-exploited area and the characteristic parameters of such zones. The report on GWREC (1997) recommends that areas can be categorized based on the level of ground water development, using the ratio of net draft to total utilizable ground water resources. Areas having more than 100% level of development are designated as over-exploited. The report further adds that over-exploited areas show significant long-term decline in both pre- and post-monsoon ground water levels. An area may be classified as over-exploited :

(i) When groundwater levels do not recover to their original level on a long term basis.

(ii) When discharge exceeds recharge by an appreciable volume.

(iii) When shallow aquifers progressively become unproductive.

(iv) When the natural hydraulic gradient is reversed and stays so through out the year.

Any one or several of these hydrogeological features may characterize an over-exploited region (Ballukraya, 2000). In the study area, the only source of pipe water supply is the deep tube wells and these wells are run from early morning to 5pm in the evening. Measurement taken between 2030 hrs. and 2300 hrs showed formation of groundwater trough. Eventually, the hydraulic conductivity of these aquifers range between 8.7 and 47 m/day. Presently, an estimated 17.85 MLD of water is being withdrawn from the aquifers of this town area. Shallow aquifers have definitely become unproductive which has been shown in Fig.7 drawn with the help of historical water level data of hydrograph station at Sunhat. This open well has gone dry and has been abandoned. The natural hydraulic gradient has definitely become reversed which can be visualized on the eastern part of the trough in Fig.10.

CONCLUSIONS

It is evident from the foregoing discussion that serious geo-environmental impact has already been done by massive withdrawal of groundwater by accentuated pumping of a large number of deep tube wells in the area. The problem is further aggravated due to the presence of unproductive finer clastics below 100m depth. Massive withdrawal of ground water to the extent of 17.85 MLD from this town area of 19.43 sq. km by 41 nos. of deep tube wells, deep water level up to the extent of −1m from the mean sea level, creation of ground water trough and heavy draw-down of water level of more than 18m, diminishing yield characteristic of tube wells over years, sand pumping and defunctness of production tube wells indicate over-exploitation of groundwater aquifers in Balasore town. Regular monitoring of the already created ground water trough is urgently needed. Ground water development may be substantiated by means of artificial recharge to deeper aquifers in town area by tube wells and in the west of Balasore in the intake area of deeper aquifer by means of percolation tank and pit and/or shafts.

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Troubleshooting Shivaganga graphite beneficiation plant of TAMIN

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ABSTRACT

Graphite beneficiation plant of 200 tpd capacity at Shivaganga in Tamilnadu was set up to produce 28 tonnes of graphite concentrate per day containing 96% F.C. at ~ 92% recovery from a feed grade of 13-15% F.C. by TAMIN. Despite the fact that the circuit has four imported columns of various diameters and being equipped with modern infrastructure and adequate instrumentation the plant hardly achieved 70% recovery while the product grade varied between 89 to 94% F.C.. After auditing the available data as well as by collecting the fresh data, the plant recovery has been augmented to around 80% at a grade of 96% F.C. by incorporating the needed modification in the circuit configuration. This paper highlights the drawbacks in the current circuit and the changes made in the circuit to augment the performance of the plant with supportive data and logic.

INTRODUCTION

TAMIN (Tamil nadu mineral limited) has over 600 acres of flaky graphite bearing land in the Shivaganga district of Tamilnadu. The estimated reserve of graphite ore is around 3 million tonnes with recoverable graphite of 3 lakh tonnes with an average feed grade of 14% F.C.. The ore contains 13-16% F.C; 60-70 % SiO_2,;~3 % Fe_2O_3 ; ~4% Al_2O_3 , and 1.6% CaO with a total ash amounting to ~ 76% and ~6% moisture [1,2,3,4]. The beneficiation plant was initially set up with an objective of producing graphite with 96% F.C. at around 92% recovery from an ore containing 13-15% F.C.. The plant circuit consists of crushing of ore in jaw and impact crushers, grinding the –10 mm size crusher product in rod mill, rougher and scavenger flotation in mechanical flotation cells of the rod mill product followed by cleaning of the rougher concentrate in four flotation columns as per the flow sheet given in **Figure.1**. However the best recovery achieved at 96% F.C. product was only around 56% during the performance guarantee (P.G) tests as indicated by TAMIN. It is observed that the annual plant performance during the last 5 years was far below the targeted results [**Figure. 2**]. As per this annual plant production data of TAMIN, it is observed that the plant is able to produce concentrate containing 88-93% F.C. at only 65 to 70 % recoveries, thereby an estimated loss of around 6 crore rupees worth of graphite due to certain flaws. Despite the fact the circuit has been modified [**Figure.3**] as per the advise of the agencies who have earlier audited the plant and suggested the remedial measures to enhance the plant performance, the plant performance could not be improved.

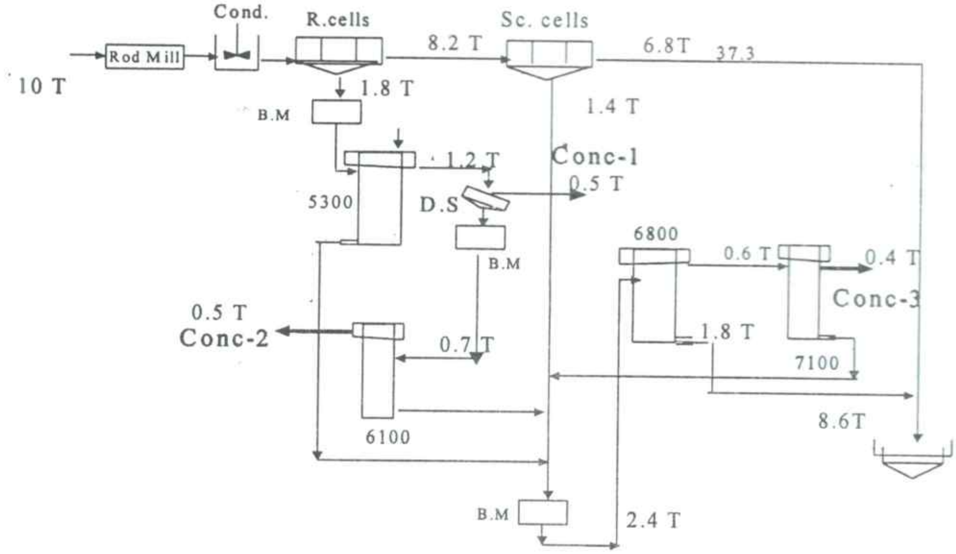

Fig.1: Flowsheet of the Shivaganga graphite beneficiation plant as per L&T and Sala International

Subsequently, at the instance of TAMIN, joint efforts were initiated by Regional Research Laboratory, Bhubaneswar and Shivaganga plant officials during August 2002 to improve the grade to ~ 96% F.C. at an appreciable recovery without any further investment in the circuit i.e., by incorporating only the needed circuit changes to obtain a consistent plant performance at 96% F.C. .

This paper describes the efforts made to diagnose reasons for the inconsistency in plant results with the help of the previous audited reports available on the plant as well as by collecting fresh data. By introducing the minor rearrangements in the circuit, the grade could be improved to 96% F.C. at varied recovery of 72 to 82%. Since the plant produces graphite concentrate grade as per the clients requirement, which are often

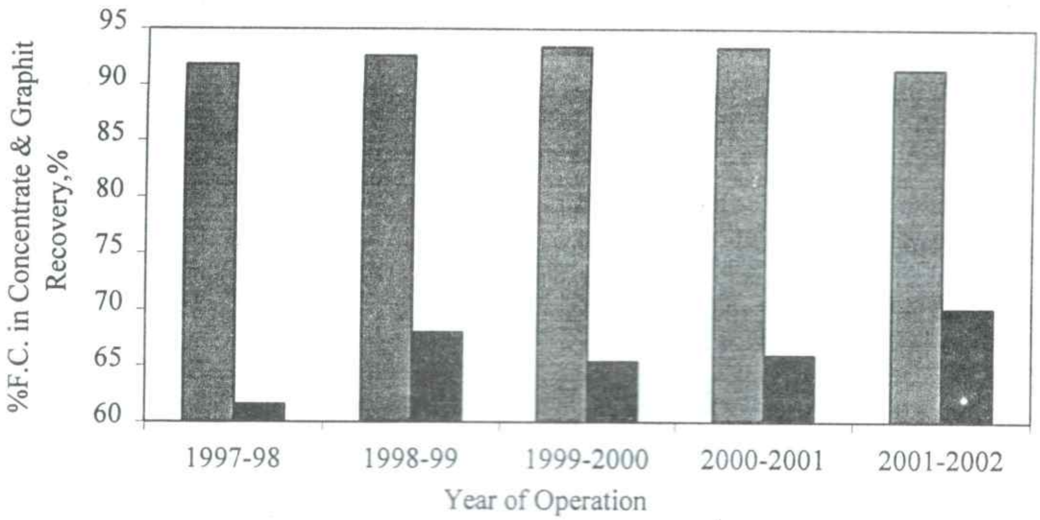

Fig.2 : Graphite beneficiation Plant Performance during 1997-2002

F.C in the Concentrate   Graphite Recovery,%

in the range of 90-92%, the circuit modifications introduced, however, were retained while producing the desired grade concentrate. It was observed that the recovery remained constant at around 78% for three months.

Mineralogical details of Shivaganga ore

The F.C. content in the Shivaganga ore is observed to vary between 13 to16% .The only important constituent mineral of the ore present in subordinate amount is graphite. Quartz is the main associated gangue present in predominant amounts where as feldspar is in subordinate amounts. Other minerals are the iron oxides (hematite, goethite intermixed with limonitic material), carbonate (calcite) and mica (muscovite) present in very minor amounts. Graphite reported to be present as crystalline grains, which are flaky, tabular, and lath shaped in nature [1,3]. In general graphite is present as fine to very coarse grained and mostly associated or observed as interlocked with silicate gangue minerals. Graphite was also quartz, feldspar, clay and goethite/limonite. As per the earlier test reports the graphite grains are fairly liberated at 210 micron size.

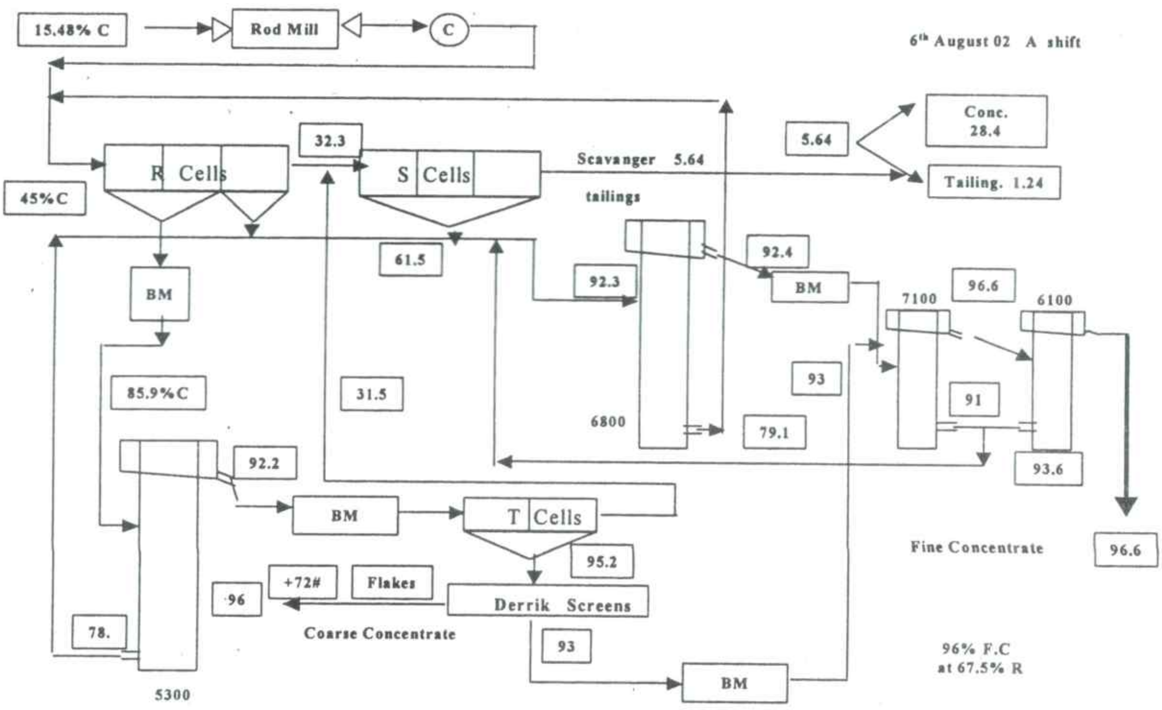

Fig. 3a: Flowsheet of Shivaganga graphite beneficiation plant at the time of plant auditing on 6th August 2002.[scavenger tailings flotation results in laboratory flotation cell are shown at scavenger tailings stream of the circuit].

R.Cells: rougher flotation cells: S.Cells: scavenger flotation cells; B.M: ball mill; T.cells: twin flotation cells; 5300: 1 M dia. column; 6800: 1.2 M dia. column; 6100 &7100: 0.6 M dia. columns]
Numerical values : F.C. content at the stream shown

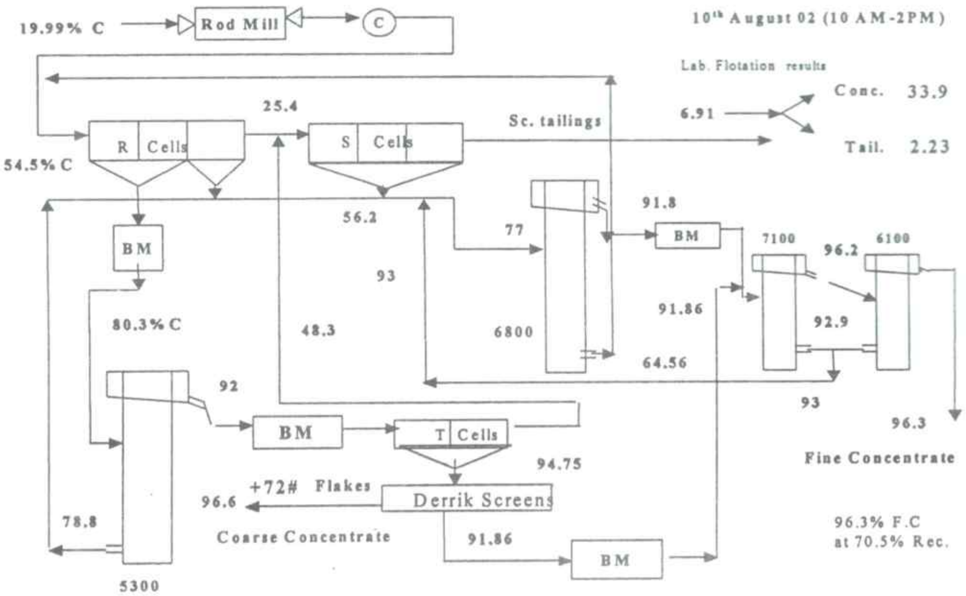

Fig. 3b: Flowsheet of Shivaganga graphite beneficiation plant at the time of plant auditing on 10th August 2002.[scavenger tailings flotation results in laboratory flotation cell are shown at scavenger tailings stream of the circuit].

Beneficiation Circuit of the plant

As per the original plant flowsheet **[Figure.1]** set up jointly by L&T, Kolkata, India and Sala International, Sweden, the crushed ore of < 10 mm size was fed to rod mill followed by rougher flotation of the rod mill product in 3 twin cells. The rougher tailings were subjected to scavenging flotation in another battery of 3 twin cells. The rougher concentrate was treated in 1 M diameter column [coded as 5300] preceded by grinding to obtain column concentrate 1. The column concentrate 1 gets screened on Derrik screen to obtain coarse product as product-I while the Derric screen underflow was treated in 0.6 M diameter column [coded as 6100] to obtain the column concentrate 2 as product-II. The tailings of the 1 M dia and the 0.6 M dia columns were mixed with the scavenger concentrate and treated in two columns of 1.2 M dia [coded as 6800] and 0.6 M dia [coded as 7100] preceded by grinding to obtain product-III from the 0.6 M dia column. Thus three products of beneficiated graphite concentrate has to be produced containing ~96% F.C. at an overall recovery of ~92%. However, the plant hardly achieved around 60% recovery when attempted to produce higher grade graphite of 96% F.C. as reported by TAMIN.

All the four columns were fitted with external air spargers of air-water mixture type and are of 10 M height. The rougher and scavenger flotation in mechanical cells and column froth interface is being controlled by the instrumentation provided.

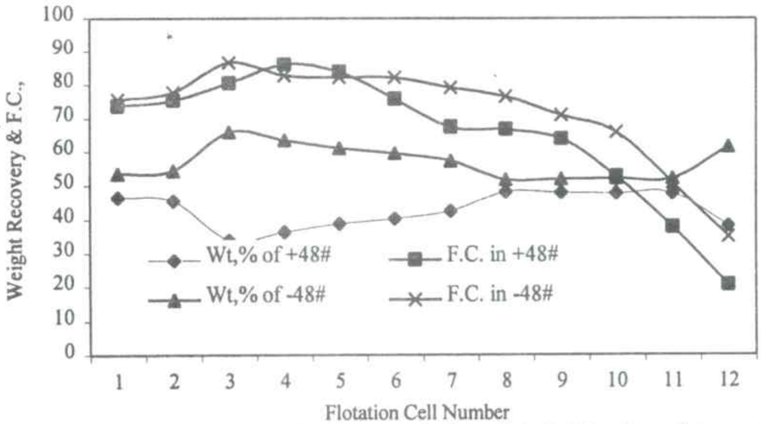

Fig. 4a : Wt. distribution and F.C content in the + 48&-48 # fractions of the graphite concentrate obtained from each cell

Beneficiation circuit of the plant at the time of plant audit.

The ore after crushing to < 10 mm size is being ground in an open circuit rod mill to produce a product size of d_{80} ~ 600 micron. Due to significant demand of flaky variety of graphite concentrate, the rod mill grind size is being maintained at d_{80} of 600 microns. The rougher concentrate from the first 2 twin cells is collected and subjected to secondary grinding in ball mill combination with hydro cyclone (desliming) and the ground rougher concentrate is further subjected to flotation in 1 M X 10 M column flotation unit. The column concentrate is subjected to one more stage of grinding in ball mill after hydro cycloning of the column concentrate and subjected to flotation in a twin mechanical cell. The concentrate of the twin cell is screened on the Derrik screens to collect +72 # [i.e., + 210 microns] product as flaky variety of graphite concentrate. The –72# size of the Derric screen is subjected to further grinding followed by flotation in columns. The

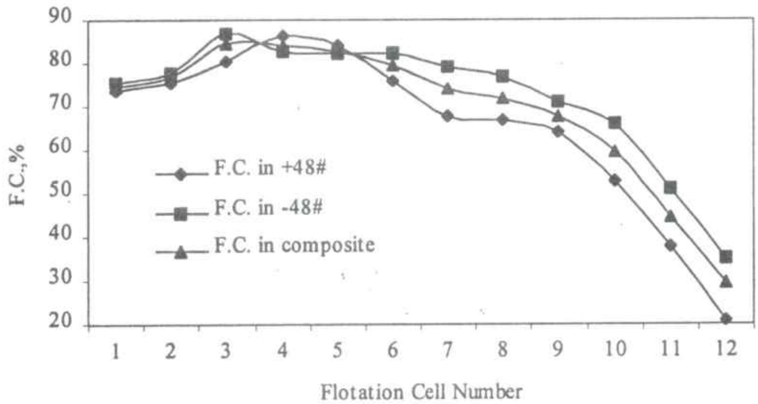

Fig.4b : F.C. content in the +48 & -48 # size fractions of the product from each flotation cell

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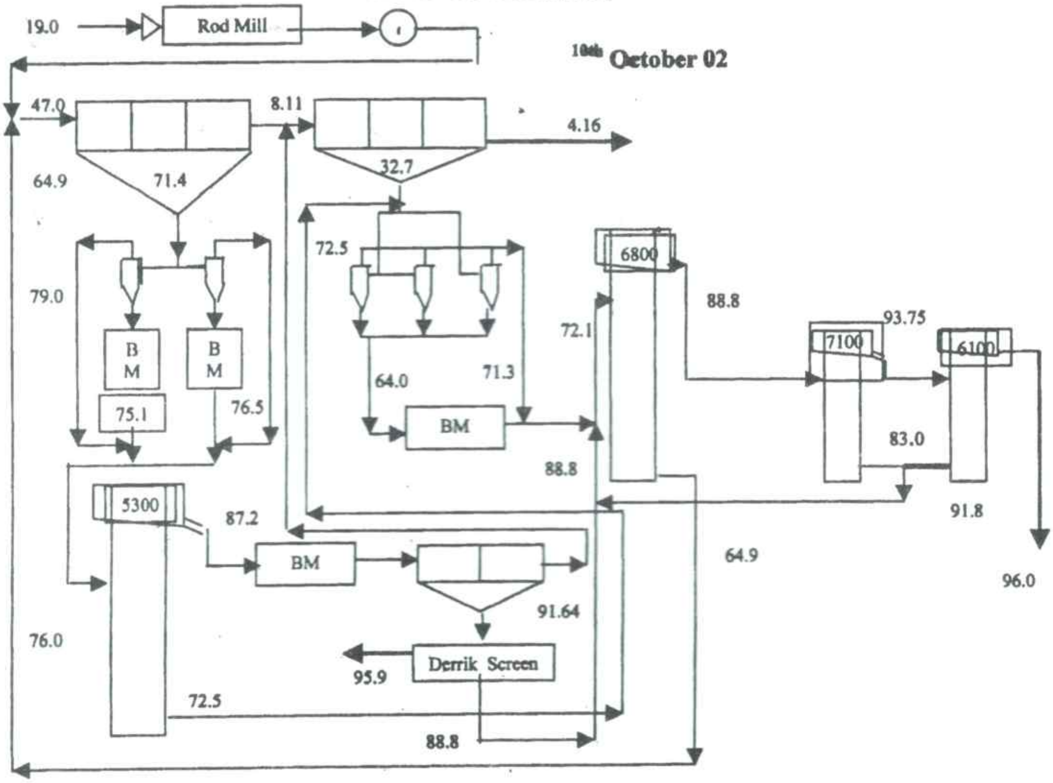

Fig.5 : Flowsheet of Shivaganga graphite beneficiation plant after incorporating needed modifications in the circuit.

tailings obtained from the twin cell are being mixed with the tailings stream of the rougher flotation cells to form a combined feed to the scavenger cells **[Figure.3]**.

The scavenger concentrate, in combination with the 3rd twin cell product and tailings of the 1st column [1 Mx10 M] is subjected to flotation in the 1.2 M dia 2nd column. The tailings of this column are joined to the rod mill product i.e., feed to the rougher cells. The 1.2 M dia column concentrate is subjected to grinding followed by flotation in two successive 0.6 M dia X 10 M size columns to obtain the second graphite concentrate product. The tailings from the last two columns [0.6 M X 10M] are recycled to the 1.2 M dia X10M size column. The tailings of this column are being fed to the rougher cells feed along with the rod mill discharge. The eventual tailings of the plant are the scavenger cell discharge. The grade of carbon in this scavenger tailings eventually dictates the overall recovery of the plant.

Reagents

Sodium carbonate is being used as pH regulator and sodium silicate as gangue depressant. Kerosene oil and MIBC mixture is being used as collector and frother. The reagent consumption noticed at the time of the inspection by RRL is ; sodium carbonate 5 kg/t, sodium silicate 4.75 kg/t, mixture of LDO and MIBC (9:1) 1 kg/t and no changes are made in the dosage of the reagents during the entire work reported in the paper.

Data Collection

In order to evaluate the drawbacks of the circuit, samples from the rod mill feed, rod mill product, and the scavenger tailings were collected along with the timed samples from 30 selected locations of the plant circuit **[Figure.3]**on two occasions. The rod mill feed, product, and the scavenger tailings were subjected to size analyses. All the size fractions as well as the samples collected from 30 locations of the circuit on two occasions were analysed for the F.C. content. The F.C. content and its distribution in the rod mill feed, rod mill product are given in **Tables 1 and 2.** Laboratory flotation results on three rod mill discharges collected during this period are given in **Table 3**. It is seen that the gangue is predominant in the finer fraction of the rougher concentrate in all the cases

The typical data at 30 various sampling points are shown in **Figure.3a** in terms of the grade of graphite at each location of the plant. Similar data was also collected at a gap of three days to check the expected variation **[Figure.3b]**. It was observed during this sample collection campaign, the grades of the concentrate achieved were around 96% F.C. but the recoveries varied between 67.5% and 70%. The corresponding scavenger tailing samples of the plant containing 5.64% F.C. and 6.91% F.C. respectively were subjected to flotation in the laboratory flotation cell at the R&D unit of the plant. These studies were made in order to assess the possible extent of carbon recovery further and the corresponding grade achievable from such scavenger tailings of the plant and the results are given in **Table 4**. The flotation concentrate obtained from three plant scavenger tailing samples revealed the possibility of obtaining significant froth product containing 28 to 34% F.C.. Such low-grade concentrate generally requires adequate grinding to liberate the locked carbon values from the gangue.

Table.1: Typical size and F.C. content distribution in the rod mill feed

	Sample-A			Sample-B		
SIZE,	Wt., %	F.C.,%	Rec., %	Wt., %	F.C., %	Rec., %
+7.5 mm	1.60	19.4	1.66	12.8	22.2	16.4
-7.5 mm+4 mm	12.0	20.3	13.0	17.6	14.3	14.5
-4 mm+3 mm	6.80	18.0	6.54	8.00	16.5	7.63
-3 mm+ 2.5 mm	5.20	15.4	4.28	5.60	14.8	4.79
-2.5mm+600 μm	27.2	17.2	25.0	20.8	14.3	17.2
-600 μm+420 μm	8.80	21.4	10.0	6.40	20.8	7.69
-420 μm+340 μm	5.60	20.9	6.26	3.20	21.9	4.05
-340 μm+240 μm	3.20	21.4	3.66	1.60	20.4	1.88
-240 μm	29.6	18.9	29.9	24.0	18.6	25.8
Head (calc)	100	18.7	100	100	17.3	100

Table.2 : Typical size and F.C. content distribution in the rod mill product

Size, µm	Sample-1 Wt.,%	F.C.,%	Rec.,%	Sample-2 Wt.,%	F.C.,%	Rec.,%	Sample-3 Wt.,%	F..C,%	Rec.,%
+340	19.7	46.6	22.1	23.1	54.2	27.3	20.7	47.8	20.9
+250	14.4	46.2	16.1	13.8	52.9	15.9	13.1	55.9	15.5
+150	25.7	44.1	27.4	25.4	51.3	28.4	24.7	54.9	28.8
+75	20.2	45.1	21.9	17.4	49.9	19.0	19.3	50.3	20.6
-75	19.9	25.9	12.5	20.2	32.2	14.2	22.2	30.0	14.1
Head	100	41.4	100	100	45.9	100	100	47.13	100

Table.3: Typical size, F.C. content distribution in the rougher concentrate obtained from the rod mill discharge with laboratory flotation cell

Size, µm	Sample-1 Wt.,%	F.C.,%	Rec.,%	Sample-2 Wt.,%	F.C.,%	Rec.,%	Sample-3 Wt.,%	F.C.,%	Rec.,%
+340	14.4	27.3	14.1	2.33	30.1	2.36	14.0	34.3	14.1
+250	9.84	21.4	7.91	5.83	33.3	5.17	8.72	26.9	6.88
+150	28.7	20.1	5.79	14.6	36.1	14.1	24.7	30.8	22.4
+75	19.8	24.1	17.9	17.1	35.5	16.2	20.7	32.2	19.6
-75	27.1	37.0	37.0	60.0	38.9	62.1	31.7	39.4	36.8
Head	100	26.7		100	37.5		100	33.9	

Table.4: Typical size, F.C. content distribution in the flotation concentrate obtained from the scavenger tailing samples [Laboratory flotation results]

+ 340	15.1	24.4	37.4
-340 + 250	11.1	19.6	37.4
-250+150	27.3	15.5	27.0
-150+75	22.0	15.2	21.4
-75	24.5	9.00	14.2
Head(calc)	100	15.67	100

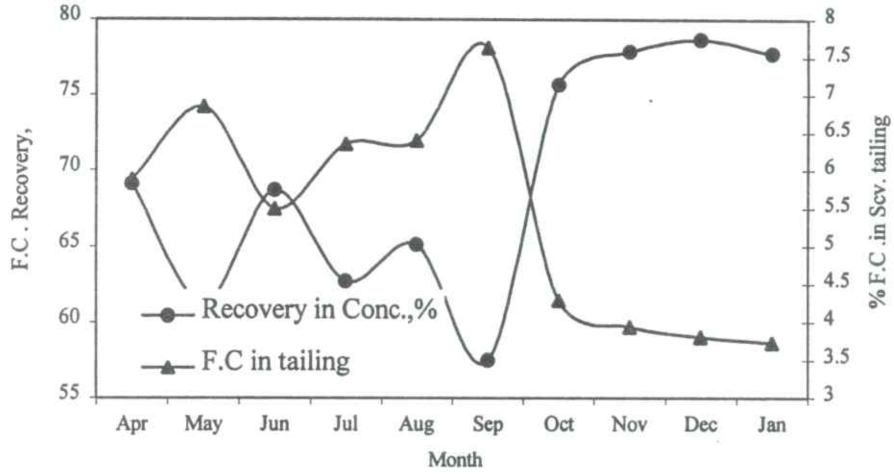

Fig.6a : Shivaganga graphite plant performance during 2002-2003

The data available with TAMIN on the timed samples collected from each of the 12 flotation cells (i.e., from each cell of the 6 twin cells) and the F.C content in their classified products of + 48 # (+ 310 micron) and - 48# [-310 micron] size fractions are given in **Figures.4a and 4b**. This data indicates that the last few cells contain significant amount of coarse material containing low F.C.

Circuit modifications incorporated

The rod mill product was adjusted to d_{80} 28 # [~ 530 micron] size and provisions were made to collect the rougher concentrate from all three twin cells instead of only two twin cells. Since the data collected by cell wise revealed that up to 6 cells the grade of graphite concentrate is more or less very close, hence the froth from all the three twin cells was collected as rougher concentrate. The 2nd battery of flotation cells was used as scavenger cell. One more twin cell is added to this bank of scavenger cells to ensure a longer residence time during an additional sample collection. The twin cell was available as spare hence used as an extension of scavenger cell for attaining longer residence time in the scavenger circuit. Provisions were made to grind the scavenger concentrate in twin ball mills after desliming in three hydro cyclone units. Adequate care was taken to ensure effective grinding since the scavenger concentrate contains lot of locked graphite particles.

The modified circuit configuration is shown in **Figure.5** and the samples were collected from the same 30 locations on three different days during the 1st shift (general shift). The F.C. content in all the samples collected from the 30 sampling locations were analysed and the results are given in **Figure.5**. The plant performance based on monthly average of grade and recovery after introducing the modifications is given in **Figure.6** to enable the comparison of the plant performance prior to the introduction of modification.

Results & Discussion

The P.G test results, which are generally carried out with meticulous care, indicated that the F.C. content has never exceeded

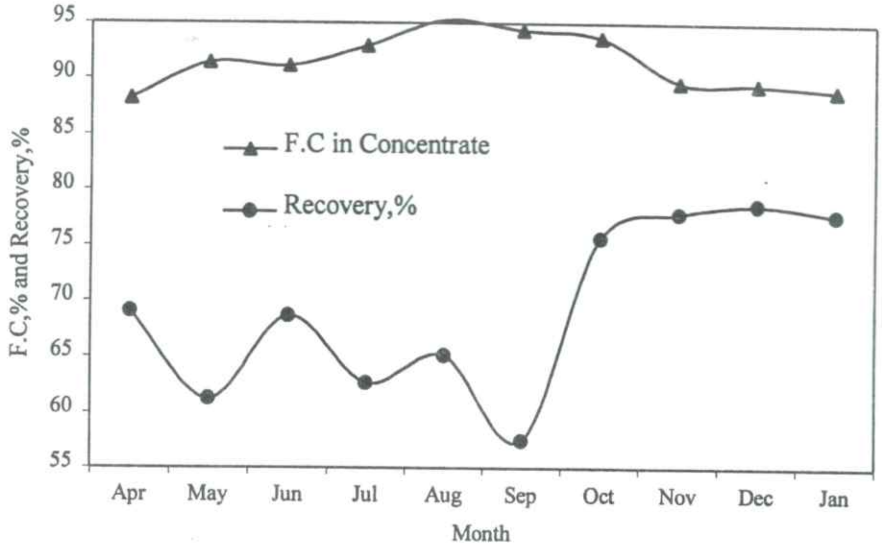

Fig.6b: Shivaganga graphite plant performance during 2002-2003

92.5% and the recoveries have also never gone beyond 76% as indicated by TAMIN when the plant was operated either as per the Flow sheet of **Figure.1** or with minor modifications, which is otherwise expected to produce 96% F.C. at 92% recovery. From the mineralogical data and from the data reported by various agencies who have audited the plant, it was very clear that the gangue is in association with the graphite grains leading to low grade of F.C. content in the products, if the rod mill grind size is not properly maintained. It is essential, therefore, to ensure the d_{80} size of the rougher flotation feed is below 28 # [< 530 μm] to achieve the 96% F.C. grade concentrate. This, however, is dictated by the liberation size of the graphite grains. The other plausible reason for the poor performance of the plant circuit **[Figure.1]** is the inadequate residence time provided for flotation. Since the column bubble generator also needs water to generate bubbles, there is additional input of water to the circuit besides the wash water from all the four columns. All these factors might have led to dilute the flotation feed thereby reducing the residence time, which is essential to achieve higher recovery. When the feed to cells or even to column is too dilute, the fine gangue minerals are difficult to be depressed and such fine particles will have the tendency to go along with the concentrate as carryover material especially if adequate care is not given to provide the uniform wash water spray over the column froth. Another perceptible disadvantage is the absence of data regarding the bubble size and the gas hold up in the column as there is no provision to measure them in the circuit.

The size and F.C. analyses of the rod mil feed and product indicate **[Tables 1& 2]** that nearly 40 to 50% of the carbon values are present in the –600 micron fraction of the feed. It is also apparent that the crusher output is not uniform and some times the rod mill feed contains significant coarse material. From the rod mill discharge size and F.C. analyses it is very clear that the gangue is predominant in the –75 micron fraction, which is likely to be carried over to the rougher concentrate during the rougher flotation. The laboratory flotation data on three rod mill discharge samples indicated **[Table.3]** that the gangue reports into the rougher float and the gangue is predominant in the fines of below 75 micron size. It is difficult to suppress such fine gangue in the column flotation unit, which is being operated at very low solids concentration without any control on the gas hold-up and bubble size. Based on the data of carbon content in both the fractions +310 μm and -310 μm size of the flotation concentrate collected from each cell **[Figure.4]**, it is considered prudent to collect maximum possible concentrate from the three twin cells as rougher concentrate and subject it to adequate scrubbing action in the ball mill so that some amount of flaky variety of concentrate at 96% F.C. can be obtained provided the rod mill grind size is finer than 530 micron size.

From the **Figures 4 a & 4 b** it can be seen that the products from the last five cells of the scavenger battery, contained low carbon values indicating the presence of significant gangue minerals in locked form. It is seen that the weight proportion of the + 310 μm and – 310 μm fractions are more or less the same and uniform and the F.C. content in the + 310 um fraction of the last 5 cells is relatively low. This necessitated an effective grinding system of the scavenger concentrate before it is subjected to flotation. Laboratory flotation studies carried out on two scavenger tailings samples of the plant containing 5.64% F.C. and 6.91% F.C revealed **[Table.5]** the possibility of further recovery of graphite but the grade is often less than 38% F.C.. Unless this product is effectively ground in ball mill, to ensure full liberation of the locked graphite grains, it is not possible to enrich the carbon to 96% F.C.. Therefore two ball mills were provided preceded by three hydro cyclone to effectively deslime the water in the modified circuit Flow sheet in **Figure.5** to facilitate the needed fine grinding with steel balls before it is subjected to flotation. It is seen from **Figure.3** that the ball mill is provided to grind the 6800 column concentrate. It is likely most of the locked scavenger concentrate grains report back to 6800 column tailings and recirculate into rougher floatation feed. Therefore the recovery is bound to be low. The F.C. content of the final tailings obtained from the laboratory flotation data on plant scavenger tailings revealed that it is possible to obtain < 2.5% F.C. bearing material as the eventual plant tailings. This confirms that by providing additional residence time of slurry during scavenger flotation, the overall recovery can be augmented significantly.

When efforts were made to get 96% F.C. in the product as per Flow sheet in **Figure .5**, it is ensured that all the wash water sprays are properly distributing the water as gentle sprays to cause the needed cleaning action to suppress the misplaced fine gangue in the rising concentrate It is for this reason three columns were operated in series to ensure the desired rejection of fine gangue i.e., to prevent the entrapment of fine gangue thus enabling production of high grade graphite concentrate.

The data obtained on two different days as per the Flow sheet in **Figure 5** revealed the possibility of obtaining a concentrate containing 96% F.C. at 72 & 82% recovery respectively. Thus, these results confirmed the possibility of obtaining 96% grade concentrate at above 80% recovery by incorporating the minor circuit modifications for the reasons stated above. The result obtained with extension of flotation time by integrating additional twin cell in the scavenger circuit indicated that a product containing 92% F.C. with 92% recovery can be obtained. This further substantiated that by providing additional residence time followed by effective grinding of the resulting scavenger concentrate, it is possible to achieve additional recovery while obtaining product with 96% F.C.. However, the monthly average grade remained at only 93.5% F.C. at 76% recovery as reported by TAMIN which is nowhere near the desired results, nevertheless the results are far superior to all the previous results obtained up to August 2002 as can be seen from the **Figure.2.** The plant data obtained for the last three months [**Figure.6**] as per the modified circuit revealed the consistency in the plant performance at around 78% recovery although the grade of the concentrate was around 90% F.C. Since the market demand of the plant during these three months was for the graphite concentrate containing around 90% F.C. grade, the circuit was allowed to operate to ensure high recovery while sacrificing the grade. The needed circuit modifications incorporated, without any additional investment, has yielded an improved recovery of around 10-12% at 96% F.C.. Minor modifications are essential to be incorporated in the flow sheet with additional investment to achieve consistency for obtaining 96% F.C with around 90% recovery The needed modifications in the circuit to achieve higher recovery consistently were suggested and are under active consideration of TAMIN.

CONCLUSIONS

It is possible to obtain graphite concentrate containing 96% F.C. at around 80% recovery by introducing minor modifications in the current plant circuit.

The critical factors required to augment the grade to 96% F.C. at around 80% recovery of graphite concentrate with out any additional investment are:

1. To ensure uniform feed to rod mill without the presence of significant coarse material and also the rod mill discharge to be below 500 micron size
2. The rougher concentrate needs to be collected from all the three twin cells followed by effective desliming and scrubbing in ball mill using cylindrical pebbles before feeding to the 1.0 M dia column. The column wash water spray need to be uniform and other column parameters need special attention
3. The scavenger concentrate contains locked graphite therefore needs to be effectively ground to ensure the liberation of locked graphite grains by desliming followed by grinding with steel balls to less than 250 micron size before it is fed to 1.2 M dia and the two 0.6 M dia columns in series.
4. The residence time in the scavenger cell is not adequate and requires couple of more twin cells to ensure the scavenger tailing assay to be below 2.5% F.C. which eventually dictates the overall loss in carbon recovery.

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REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEMS FOR ROCK-FRIENDLY MINING

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ABSTRACT

Huge quantity of mineral deposits lying below the crust is not explored. Remote sensing and Geographic Information System methods is one are nowadays used to delineate those deposits. This paper discusses the use of such methods for mining projects.

INTRODUCTION

As many of the potential minerals deposits are getting exhausted, the mining industry looks for new ore bodies by employing unconventional techniques. Further, mining companies are becoming more sensitive to environmental issues and are looking for new tools that can monitor and reduce the damaging effects due to mining operations.

Remote sensing is the science of acquiring, processing, and interpreting images and related data, acquired from aircraft and satellites that record the interaction between matter and electromagnetic energy (Sabins, 1971). It has been proven to be very useful in the investigation of abandoned mine sites and other sources of environmental pollution where heavy metals and lethal acids have adversely impacted the environment. Remote sensing images are used for mineral exploration in two ways: (1) map different structures especially the fractures that localize ore deposits; (2) recognize altered rocks by their spectral signatures. The use of Geographic Information Systems, (GIS) as a powerful tool to analyze and display data, is gathering momentum in the mining industry.

GEOLOGICAL MAPPING

The exploration geologist mainly linking geological data, seeks for useful geological structure in an area. All geological data, in order to be fruitful and productive, should be interpreted considering their geographic locality. Geographic Information System, providing presentation facilities and simultaneous data interpretation, enables the exploration geologist to prepare mineral potential maps with various data more quickly and precisely, which is very difficult to be carried out with traditional methods.

As a type of field information, satellite-based remote sensing information is the result of all the objects on the surface interacting with electromagnetic wave. Thus, all the objects on the surface are information carriers in which geological anomalies are involved. This results in a weak presentation of geological anomalies in some of the satellite images. This kind of weak information is just the target that we usually operate on by image processing.

Satellite remote sensing has provided us an effective method for geological mapping and mineral surveying. Geological structures and lithological and efficient characters, mineralization and alteration as well as bio-geochemical anomalies are the three types of information features that have normally considered in the procedure of minerogenetic prognosis using remotely sensed data. Through lithological interpretation and structural analysis, geologist can get some supplementary information for mineral exploration from satellite images. On geological studies using remote sensing technique, researchers have recognized various kinds of liner and circular phenomenon existed in the satellite images. Illustration in Fig-1 shows satellite image of highly deformed amphibolites schists in a gneissic terrain. This caused an extensive study on the relationship about minerogenetic geological background and the statistical information of liner-circular structures, and results in people's high attention to the ore-controlling function of these structures. It is of coarse difficult to achieve alternation and bio-geochemical anomalies from satellite-based images.

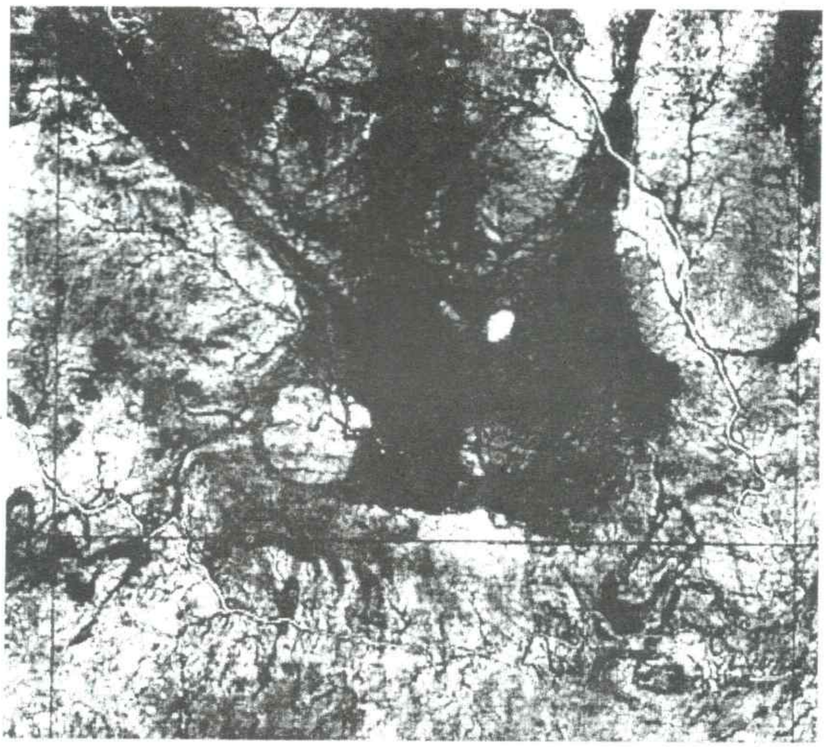

Fig: 1 Image shows highly deformed amphibolite schists in gneissic terrain.

REMOTE SENSING TECHNOLOGY

Interpretation of remote sensing images can be improved by linking analysis with a geographic information systems (GIS) database. Often only simple image analysis procedures are needed to extract information when combined with other spatial data. As mines location database is normally available, this information would allow overlaying the site locations over the image to detect evidence for correct identification of mine locations, apparent size and extent of tailings and disturbance due to mine process, evidence for erosion etc. Digital elevation maps (DEM) can be readily combined with image data sets to assess topographic patterns and how this affects potential losses or other problems with mine sites. Fig 2 shows natural colour ASTER image of the coal mining areas in the German State of North Rhine Westphalia.

UNDERGROUND MINING

Application of GIS in underground mining concentrates in four technical areas: land ownership and mineral claims, exploration management, production, and mine safety. The benefits of consolidating and archiving claim data and the ability to georeference property maps defined in local coordinates into state coordinate system is of paramount importance to a land and exploration manager. In the production area, GIS facilitates the optimal siting and querying of service installations relative to production centers to meet the production parameters. In mine safety, the siting of refuge chambers relative to production centers is optimized and areas of potential safety concern are identified utilizing GIS's proximity analysis. The same applies to finding the shortest route to emergency exits and preparation of maps to facilitate the prompt evacuation of mine personnel.

Land Ownership and Mineral Claims land managers can benefit from GIS's capabilities in tracking land leases, acquisitions and mine expansions. The table of attributes has fields for claim number and description, owner's name, category (patented, unpatented), royalty interest, survey control (name, coordinates, elevation, description of the monument), county zoning boundaries, township, range, and section boundaries, and corners, etc.

Exploration Management - For an exploration manager in the process of evaluating various mineral properties, GIS is a versatile tool for data consolidation, archiving, and quick access of information. In today's global economy, a mineral exploration organization typically controls various mineral properties in various stages of development and scattered around the globe. The implementation of GIS allows the exploration manager to georeference these properties and tap into a wealth of information made public in the Internet, in the form of DEM (digital elevation models), DRG (Digital Rater Graphics), DLG (Digital Line Graph), coverage's, orthoquads, etc. Typically, these mineral properties are defined in a local coordinate system; GIS enables the user to consolidate and georeference these properties into a world coordinate system.

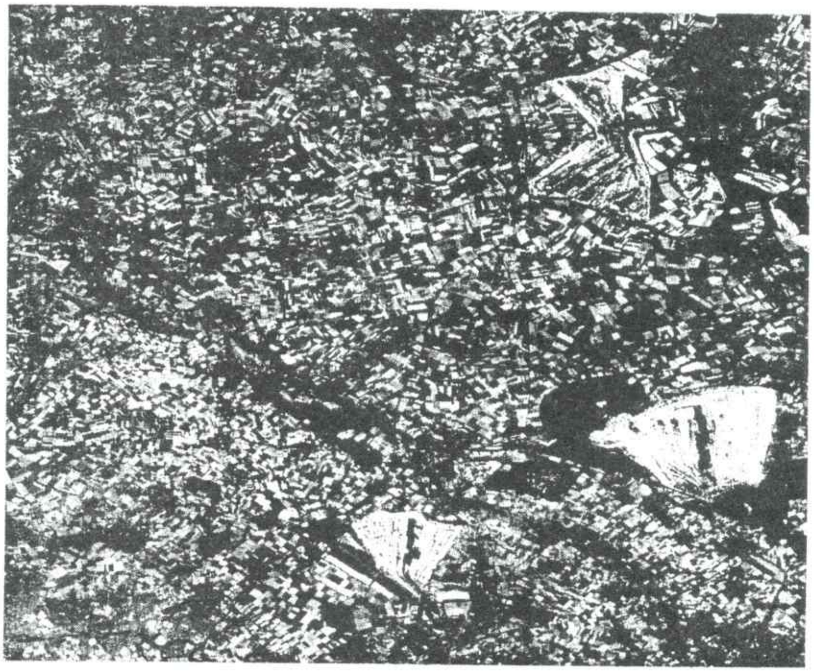

Fig: 2 Simulated natural color ASTER image in the German state of North Rhine Westphalia. It covers an area of 30 by 36 km, and was acquired on August 26, 2000. On the right side of the image are 3 enormous opencast coal mines

The exploration manager can take advantage of GIS's link between spatial and tabular data to access specific information such as assay, geotechnical, cadastral, metallurgical, environmental, and permitting data to prepare contour maps, derive surfaces, grade distribution, soil types, vegetation, cultural, wildlife, slope and aspect surfaces, neighborhood and zonal statistics, and other thematic layers of interest.

Production- In the area of production, GIS is ideally suited to assist the production and engineering planners in confronting the routine challenges of a mining operation. In particular, the siting and querying of service facilities relative to the main production centers is a strong feature of GIS.

Mine Safety - Mine safety is of paramount concern in the mining industry. In the effort to achieve the objective of safety and productivity, GIS can contribute in providing a safe working environment in underground mining by performing network analysis and determine the appropriate sites for refuge chambers and facilitate the prompt evacuation of mine personnel.

OTHER APPLICATIONS OF GIS IN MINING

Other uses of the growing GIS technology in the mining industry are summarized below:

- Transport routes: Mine planners utilize GIS in combination with remote sensing to plan the best alternative for transportation of goods and supplies to and from the nearest community to the mine site. Integrating thematic layers such as topography, land ownership, land-use, population, geotechnical, and climate can facilitate the objective selection of the economically and environmentally preferable alternative.

- Natural hazards: GIS and remote sensing assist the planners in identifying natural hazards such as potential landslides, floods, earthquakes, and volcanic eruptions prior to the construction of housing installations.
- Population distribution: Planners of a new mine may need information on population density, socio-economic distribution, labor resources, housing, and recreational infrastructure in the preparation of the environmental impact assessment.
- Selection of sites for housing and dumps: Use GIS capabilities for the selection of a housing site that meets safety, scenic, and recreational requirement within reasonable proximity to the mining operation. Topographic, vegetation, drainage, and soils coverage's together with concentration of toxic substances are incorporated in the analysis.

The image interpretation process with the support of a geological map permits the identification of the majority of the faults, verification of distribution pattern of certain lithological units and helps to select the possible target areas, favorable for mineralization. Spectral features evidenced by bands or changes in the shape of spectral curves, appear as a result of either electronic or vibrational process (Hunt and Salisbury 1971).

GPS IN MINING

GPS entered the Mining Industry as a fast and cost-effective instrument for survey. A shifting landscape is the very nature of mining operations; as shovels and dozers remove coal and ore, they reshape the mine's surface. Real-time GPS allows mining operations to keep on top of these constant changes and provide updated operating instructions to heavy equipment operators. In addition, GPS systems provide a fast and accurate solution for replacing and maintaining control points and calculating the volume of material moved.

Moving mining assets, including dozers, shovels, graders and draglines, are managed and guided using advanced GPS technology. Advanced GPS systems also track and monitor the status and location of dump trucks, providing reports to their heading and velocity as well as the size of the truck's load. Live GPS is used for monitoring and dispatching haul trucks or drills and for providing grade control on shovels. These data can also be tied to a GIS to monitor the location of all equipment, in real time.

ENVIRONMENTAL IMPACT

Many mines or contaminant are causes of pollutant migration. These small point-source locations may be within a larger geologic and ecological context. Often the goal is to identify these point sources due to their contrast with the surrounding vegetation and terrain.

Remote sensing by virtue of synoptic coverage at regular intervals, is quite useful in monitoring land disruption due to mining (Wier et al., 1973; Irons et al.; 1980; Parks et al.; 1987), detection of mine fires

(Richards, 1983), mining revegetation and the monitoring of reclaimed lands (Legg, 1986, 1994), water pollution assessment (Repic et al., 1991), monitoring (Lathrop and Lillesand, 1986; Lillesand et al., 1987), and detection of land subsidence (Mechaffie and Seargent, 1985; Volk et al., 1990). Besides, spaceborne spectral measurements also enable predicting the extent of forest cover due to mining (Murthy et al., 1997).

Remote sensing, a powerful technique in mineral prospecting, which can be adapted for environmental monitoring. Numerous factors create variability in satellite images that are imposed at multiple scales. Topographic patterns, illumination conditions, and atmospheric composition at the time of measurement are factors that vary at larger spatial scales and need to be accounted for in the analysis. Of the factors affecting local scale are evidence of disturbance, low or no vegetation cover, and changes in vegetation distribution. Environmental impact assessment is now an integral part of the mine planning. The lack of environmental management programme has laid to legacy of environmental impacts associated with the post-closure of the mines. These include water pollution, air (dust) pollution and general environmental degradation which limit the land use potential of the area. The large-scale spatial, high-resolution spectral remote sensing data, including aerial photographs and historical data provide a tool for environmental impact assessment and monitoring mining activity. Remote sensing data enables the identification, delineating and monitoring of pollution sources, distribution of affected areas including derelict land and surface land use.

LAND DEGRADATION

Mining industry is likely to degrade the land. It can not be completely eliminated but careful study can definitely minimize it. Where the vegetation cover is low, the signal received by satellite is dominated by the spectral properties of soils. Changes in these properties can be interpreted in forms of varying soil surface under land degradation process. Remote sensing techniques to characterize land degradation in mining areas based on two approaches: spectral mixture analysis and a set of indices describing the spectrum. It is also used for evaluating ecosystem vulnerability to land degradation, through combined analysis of spectrally derived land units and geomorphic units. Specific objectives consist of evaluating the potential of extending the indices describing the spectrum shape to the short-wave infrared region, and of identifying landscape units according to their sensitivity to land degradation.

SUBSIDENCE

Airborne remote sensing offers the potential to monitor to ground above the abandoned mine workings and identify potential subsidence hazards. Subsidence may have a direct topographic expression due to underground collapse and an indirect spectral expression, due to the affect of the subsidence on surface hydrology and indirect affect on vegetation. Techniques from photogrammetry and hyper spectral image processing can be utilized to process airborne image for an area of active subsidence in the mining areas.

The application of remote sensing for mapping surface spectral properties is well established. Thermal imagery can be employed to investigate soil moisture anomalies and the application of hyper spectral imagery in vegetation studies is a proven tool, although with limited application to subsidence studies.

Surface expression of subsidence

Depressions form on the ground surface as a direct consequence of subsidence. Surface depressions or troughs can occur due to pillar crushing or failure, the dimension of which depend on a variety of factors including the depth of workings and the overlying geology. Fig: 3 show the mechanism of subsidence.

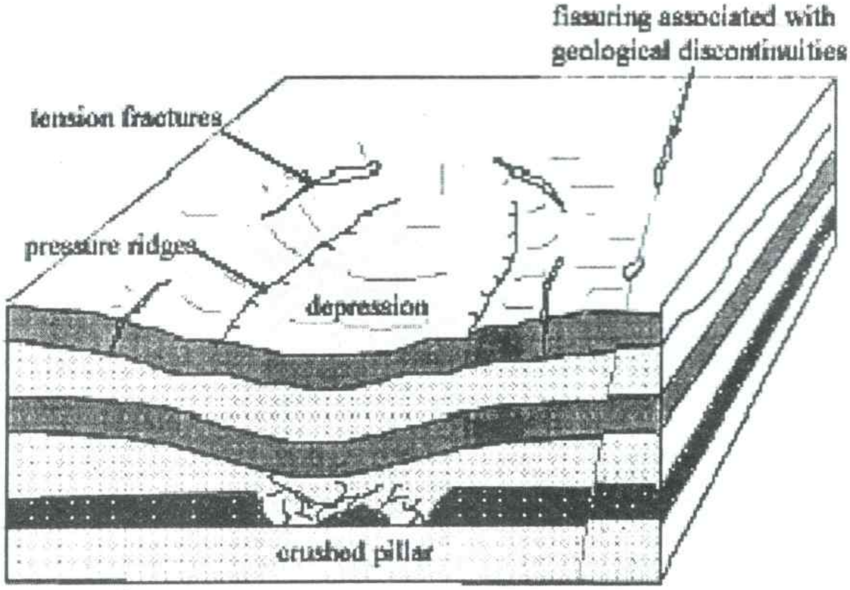

Fig: 3 Surface expression of subsidence due to collapse of support pillar in underground coal workings (after Bell and de Bruyn, 1999)

COAL FIRES

The majority of coal mine-related fires are started by spontaneous combustion, surface fires, and mine-related activities. Spontaneous combustion may be induced by coal fines, oil-soaked rags, hay, manure, and lumber in culm banks (Jones and Scott, 1939; Anthony et al., 1977, U.S. Department of Energy, 1993) or by exothermic oxidation reactions catalyzed by oxygen and moisture circulating through coal seam joints. One such reaction is (Limacher, 1963):

$$\mathbf{FeS_2\ (7/2)\ O_2 + H_2O \longrightarrow FeSO_4 + H_2\ SO_4}$$

Remote sensing technology has made it possible to detect coal fires and study their effects. Thermal and optical images along with field-based measurements can be used to determine the location, size, depth, propagation direction, burning intensity, temperature, and coal consumption of a fire (Zhang et al., 2002, in review; Vekerdy et al., 1999; Prakash and Gupta, 1999). This information can be useful for fighting fires in coal mine areas. Figure 4 shows a processed remote sensing image (Landsat Thematic Mapper (TM) image) of the Ningxia coal mining area in northwestern China (Prakash et al, 2001). The gray background image is a higher resolution optical image acquired in the near infrared region of the electromagnetic spectrum. This image has been fused to show the exact locations of the coal fires.

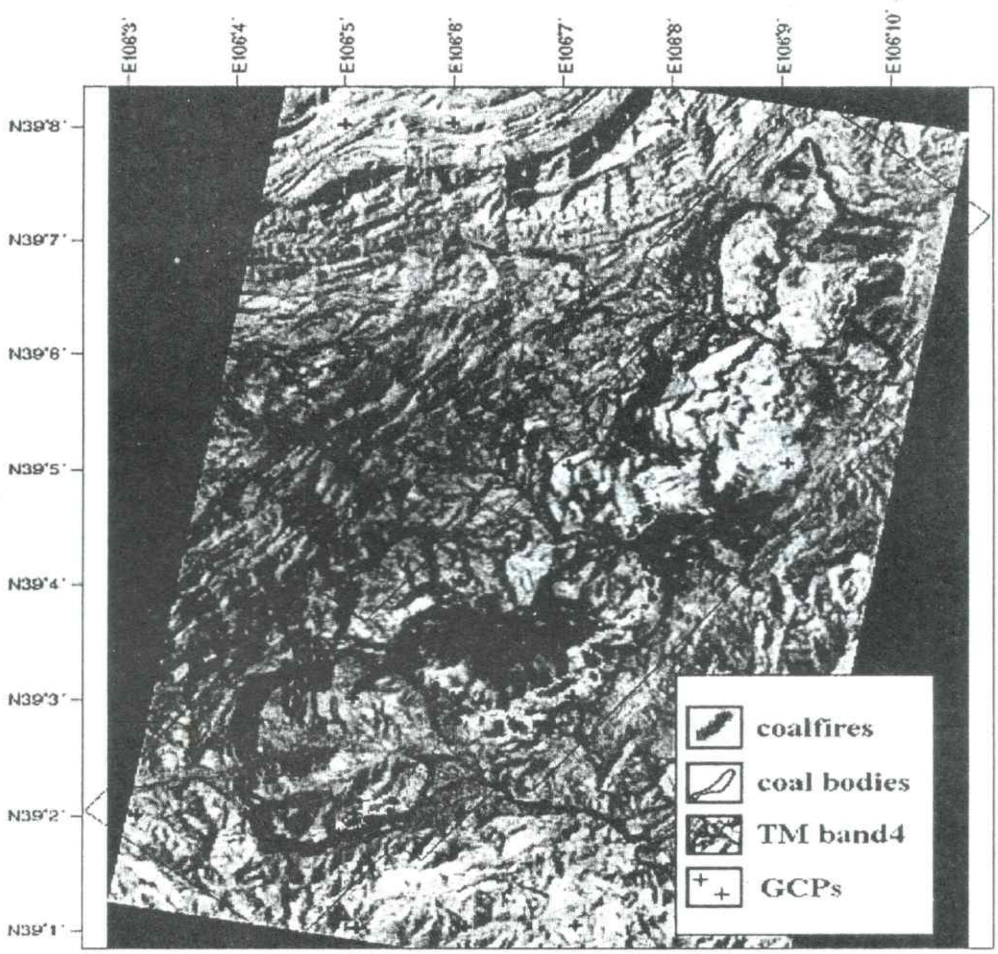

Fig: 4. Processed Landsat TM image of the Ningxia coal mining area in northwestern China. See text for description. (From Prakash et al., 2001).

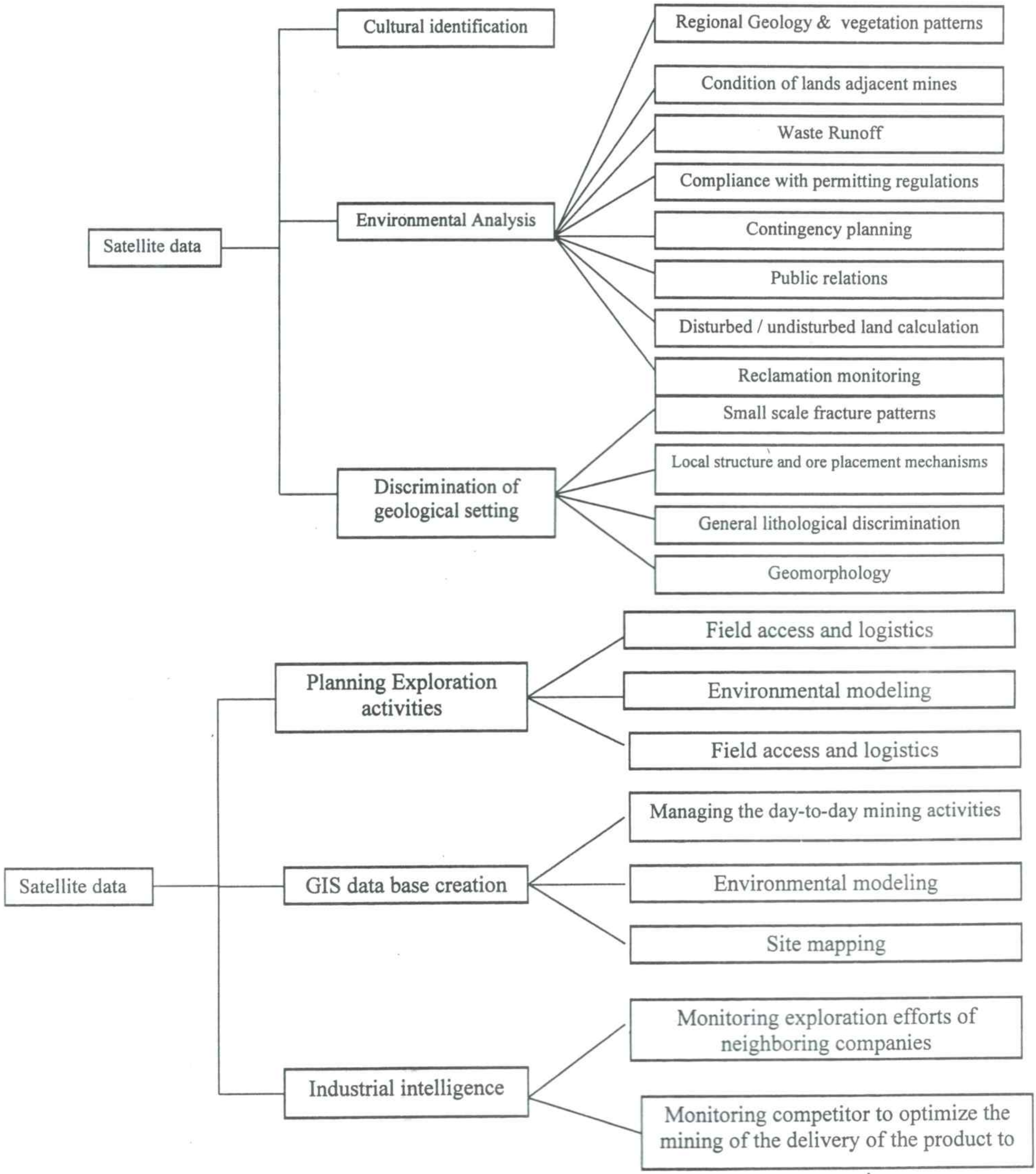

Fig: 5 Applications of Satellite data for various themes for rock-friendly mining

CONCLUSIONS

Remote sensing techniques coupled with a GIS could potentially provide a synoptic view of all landscape elements, low-cost coverage and use of spectral information for surface feature identification which will be very useful in the investigation of abandoned mine sites, coal fires and other sources of environmental pollution. GIS offers multiple applications in the mining industry with tools together, compile, process, display, analyze, and archive extensive volumes of data. It is also helpful to reconstruct the old landscape after the mining work is completed. Fig 5 shows the application of satellite.

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PROBABILITY OF EARTHQUAKE AND TSUNAMI IN ORISSA

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ABSTRACT

The possibility of a damaging earthquake in Orissa in general and Cuttack-Bhubaneswar twin cities in particular is discussed. The presence of numerous fault zones and delimitation of a seismic zone III area in Orissa are responsible for the apprehension of a damaging earthquake in Orissa. There need to be more realistic delineation of areas under seismic zone III based on proper evaluation of the past earthquakes (e.g. their magnitudes, epicentre, focus, felt area, damage record of buildings and isoseists etc.) and crustal changes along and across many fault zones. In order to establish seismotectonic activity of numerous fault zones rigorous research efforts are warranted based on modern methods of evaluation such as geodetic, global positioning system, geomorphic and leveling techniques etc. Considering present observations, a damaging earthquake in Orissa and more specially in Bhubaneswar and Cuttack is less likely. On the other hand tsunami hazard is more probable because of its geographic position with respect to Andaman – Sumatra subducting plate boundary on the eastern shores of Indian Ocean.

Key Words : Earthquake, Tsunami, Fault Zones, Seismic Zone III, Orissa

INTRODUCTION

There is a lot of discussion these days on possibility of damaging earthquakes in Orissa and more especially in the twin cities of Cuttack and Bhubaneswar. The Government is also preparing to handle any such event. However, such a damaging earthquake in Orissa is never discussed on a scientific basis. The Latur earthquake of 1993 (Gupta,1994) and the Bhuj earthquake of 2001 (Ravishanker and Pande, 2001) are the background for anticipating a damaging earthquake in Orissa and possible devastation in seismic zone III areas of Orissa, in which the twin cities lie. For tsunami hazard in Orissa the Sumatra tsunami of Dec. 2004 had its background. Orissa has fortunately been saved from the tsunami danger.

The Latur earthquake occurred in a 'stable continental region' at a "never expected" place marked within seismic zone I. It killed 10,000 people. The severe devastation has been due to a shallow focused moderate earthquake of magnitude 5.5 to 6.4 occurring at 3.47 AM

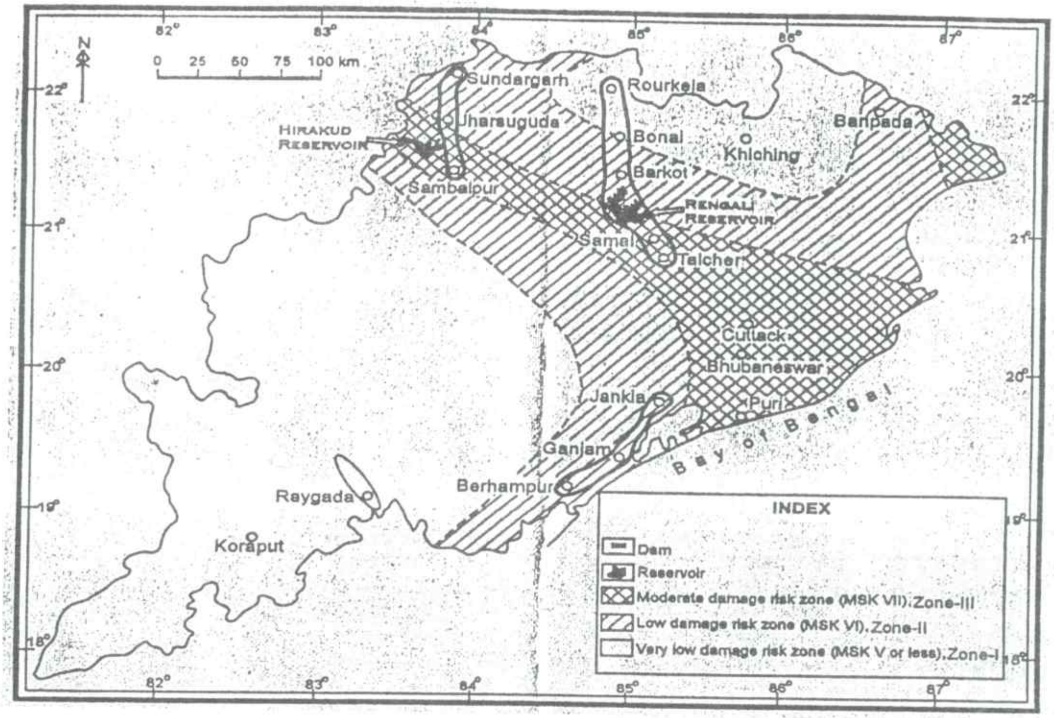

Fig.1 Earthquake zoning map of Orissa

(when people are most asleep indoors) which shattered the poorly built mud plastered bouldery houses. Most people in areas of intensity VII and VIII were completely buried beneath. However there are no fault zones in the area. The cause of the earthquake has not been properly explained (Gupta, 1994) though believed to be due to a hidden weak zone beneath the Deccan traps. This earthquake was very much an accidental event. One cannot think of its parallel in Orissa. There are hundred and one fault zones in Orissa and there could be accidental earthquakes any where in the state, not necessarily in Cuttack and Bhubaneswar.

The Bhuj Earthquake (2001) also occurred in the stable continental region setting. It is a known seismic prone area since long and major earthquakes have witnessed the area (Ravishanker & Pande 2001, Gupta & Gupta 2003). Gujrat has been mapped in seismic zones V, IV and III etc. stated that Ahmedabad suffered without any ambiguity. It may be stated that Ahmedabad suffered devastation even though lying in zone III (Moderate damage zone). It is about 300 km away from the epicentral area with intensity of earthquake X. Only 3.8% of total death has been reported from zone III lying between isoseismal VII and VIII. Many buildings in Ahmedabad collapsed because of poor design of tall buildings in alluvial foundation. One cannot compare situation of Ahmedabad city lying in zone III with in Orissa, more specially in Cuttack and Bhubaneswar. Orissa never lies close to any large magnitude earthquake of 7 to 8 or above. Any past earthquake in Orissa does not have a record of intensity VII and hence no area of the state could be mapped in seismic zone III.

SEISMIC ZONE III STATUS IN ORISSA: BMTPC - 1997

A part of Orissa running west to east and lying along "Mahanadi Rift" or "Gondawana Graben" has been mapped as Seismic Zone – III (Fig. 1) by Govt. of India agency, BMTPC (1997). It includes Hirakud reservoir, Sambalpur, Jharsuguda, Rengali reservoir, Talcher coal mining area, Dhenkanal, Cuttack, Bhubaneswar, Puri and Konark etc. Usually, the principle in preparing seismic zones is based on seismotectonics i.e., the history of past earthquakes, and presence of tectonically active fault zones. Regarding seismic history there is a few and incomplete record of earthquakes. The maximum earthquake magnitude has been reported as 5.3 around Barkot-Bonai terrain in the Brahmani Valley above the Rengali reservoir. This area is shown in Zone – II (Fig. 1) by BMTPC (1997). There have been earthquakes of magnitudes less than 5 in many parts of Orissa (Sambalpur, Talcher, Bonai, Rourkela, Sundargarh, Keonjhar etc). Very small magnitude earthquakes have been felt in Cuttack and Bhubaneswar or in Puri and Konark. Over the centuries there has not been a single report of death or major damage to any construction.

that some areas like Barkot - Rourkela, Jharsuguda - Sundergarh and Berhampur - Jankia, which lie outside zone-III of BMTPC-1997 are seismically more active.

FAULT ZONES IN ORISSA

Faults have been loosely associated with earthquakes; this is partly true. Seismotectonic activity of fault zones is important for associating them with earthquake hazard. The Himalayan fault zones are tectonically active; hence there is chance of earthquakes in Himalays. The Son-Narmada Rift is active;

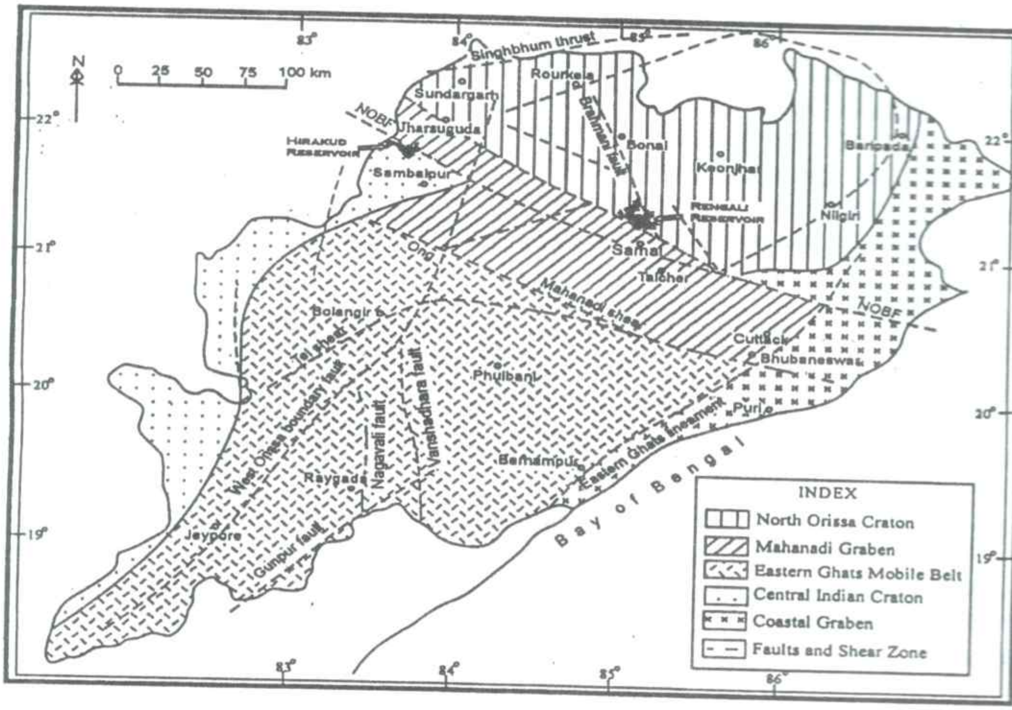

Fig.2 Fault and fracture zones in Orissa

As per the definition of Zone-III, presented in the Manual of Building Material & Technology Promotion Council of Govt. of India (BMPTC, 1997), the associated seismic intensity is VII. Since seismic intensity VII has not been reported any where in Orissa there can not be a Zone III area. Thus all areas in Orissa should lie in seismic Zone II. It may be mentioned here

hence there is chance of earthquakes. In Orissa there are numerous fault zones (Fig. 2 and Mahalik, 2001b) cris–crossing the state. For example, the North Orissa Boundary Fault runs for hundreds of kilometers from Chhatishgarh through Hirakud reservoir, Rengali reservoir, Kamakhyanagar, Dubri industrial complex into the Bay of Bengal at Dhamra. All these faults were formed millions of years back and are now mostly dead. If they are active, there would be crustal movements and seismicity. However, very few evidence of crustal changes have been recorded along any of the fault zones. Of late, seismicity has been recorded around Sambalpur and Bonai areas. These appear to be related to the two major reservoirs in the area, e.g. Hirakud and Rengali.

STATUS OF CUTTACK AND BHUBANESWAR

These twin cities have large population and their seismic vulnerability is being discussed under Urban Earthquake Vulnerability Reduction Programme of the Govt. of India. These twin cities have never witnessed any notable past earthquakes, nor have seismically active weak zones. They do not deserve to be included in Zone III of the seismic zoning map of Orissa as given by BMPTC (1997). Some geoscientists discuss about faults lying beneath Bhubaneswar and Cuttack to cause an earthquake, making the twin cities earthquake vulnerable. Some speak of a fault lying beneath Bhubaneswar airport, which would cause an earthquake. This appears unreasonable and needs scientific support. However, for any 'accidental' damaging earthquake such preparations in urban conglomerations is welcome.

PROBABILITY OF EARTHQUAKE IN ORISSA

The numerous fault zones in Orissa are not tectonically active. They are not associated with notable crustal changes. Even though there is record of several past earthquakes, none has been found to be damaging to buildings. These could be at best classed as 'frightening' type under MSK Intensity Scale-VI (BMTPC, 1997, P 21).

Latur earthquake, which occurred in seismic Zone I, even without any known fault zones, has been considered as an "accidental" event. Based on this an "accidental" damaging earthquake may occur anywhere in Orissa and not necessarily in Bhubaneswar or Cuttack. It could affect Hirakud dam, Rengali dam, Talcher mining area, Rourkela industrial belt, Dubri industrial area etc. Hence, there should be general preparedness throughout Orissa to meet a future earthquake; especially all buildings, ordinary or complex, need to have an aseismic design. Rigorous research is needed to collect details of past earthquakes e.g., their magnitude, depth of focus, epicenter, felt area, damage history etc which will help in understanding their association with fault zones and even with the major reservoirs of the state. Study on neotectonic activity in Orissa is not yet taken up. There should be research on crustal movements along fault zones by employing modern methods such as geodetic, global positioning system, geomorphologic etc. Orissa has now an upgraded seismic observation centre at Bhubaneswar with Broad Band Seismograph and plans to have another two at Jharsuguda and Rayagada. These facilities will be useful in understanding the seismic status of Orissa.

TSUNAMI HAZARD IN ORISSA

Nobody earlier thought of tsunami disaster in India. It has been a real threat now. The Sumatra tsunami of December26, 2004 has shown it. Three lakh people died in Indian Ocean peripheral countries from Indonesia to Somalia. Orissa has been saved. Tsunamigenic earthquake (Sumatra, 2004) and volcanism (Krakatoa, 1883) were events, which were responsible for global disaster. These are the result of convergent plate tectonics, where the Indian plate subducts beneath the Burma plate to give rise to major earthquakes and volcanism beneath Indian Ocean bed and creates tsunami waves of most devastating nature. This is bound to come in future as the process of plate tectonics continues in Andaman- Sumatra belt. Any major tsunami event would affect Orissa coast. Thus tsunami is a real danger to Orissa coast than earthquakes. There must be a comprehensive coastal zone management plan in Orissa to save the coast from twin dangers of tsunami and cyclone.

CONCLUSIONS

A few conclusions can be presented :

1. Based on the existing knowledge of past earthquakes and activity along numerous fault zones possibility of a damaging earthquake in Orissa is remote.

2. An "accidental earthquake" of the Latur type may however take place in any part of Orissa and one should be prepared for it.
3. Seismic Zone III area as suggested by BMTPC for Orissa needs a redefinition.

4. Neotectonic studies along major fault zones should be undertaken employing modern methods.

5. Largely populated urban centers like Cuttack and Bhubaneswar needs special preparation to overcome any seismic disaster.

6. Tsunami hazard in Orissa is more real because of its geographical situation with respect to the Andaman – Sumatra subducting plate boundary in the eastern shore of Indian Ocean.

A comprehensive coastal zone management plan is needed to save the coast from the twin hazards of tsunami waves and storm surge of recurring cyclones.

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SGAT News

- **Dr. Amit Chatterjee,** an eminent metallurgist of our country and currently Adviser to the MD, Tata Steel delivered a talk on **Iron and Steel Industry in India and rest of the world** on 7 April 2005 at Bhubaneswar. The event was largely attended.

- In the context of signing of as many as 35 MOUs for setting up iron and steel making facilities in Orissa, Shri B.K. Mohanty, Advisor made a presentation on 17th May 2005 to the Principal Secretary, Steel and Mines Department, Govt. of Orissa about the reserve and availability of Iron ore for the existing and upcoming iron and steel plants.

- Shri Supriya Brahma, Assistant Hydrologist Central Ground Water Board, Ministry of Water Resources (Govt. of India) was awarded Ph.D degree in 2005 from Utkal University (U.U.) under supervision of Dr. (Mrs.) Madhumita Das, Professor in Geology (U.U) and Dr. J.K. Mohanty, Scientist-E2, Regional Research Laboratory, Bhubaneswar.. The topic of his Ph.D. Thesis is Pollution of Ground Water by industrial effluent in parts of Balasore and Mayurbhanj district Orissa (India).

- Shri P.S.R. Reddy, presently working as head mineral processing and energy Technology Dept. Regional Research Laboratory (CSIR), Bhubaneswar has been promoted to scientist "G" (Director Grade Scientist) with effect from September 2003

- Dr. B.M Faruque, Member of SGAT and Director, Marine Wing, Geological Survey of India and Convenor of IGCP India was nominated as chairman of the Session on 1st June 2005 of the IGIP 464 Final meeting.

- Dr. V.N. Misra has got his superannuation as Director Regional Research Laboratory, Bhubaneswar on 30th June 2005. Dr. R.P. Das, has taken over the charge as Director.

Obituary

SGAT mourn the sad demise of Shri M.R. Das, Mine Owner, Shri S.K. Misra, Formerly G.M. of OMC and Shri S.N. Tripathy, formerly in Directorate of Mines and Geology, Govt. of Orissa and esteemed members of the Society. SGAT pray before the almighty to restore their souls in peace.

INTERNATIONAL SEMINAR

VISION MINERAL DEVELOPMENT 2020 (VMD 2020)

16-18 December 2005
Hotel Mayfare Lagoon
Bhubaneswar, Orissa, India.

Organised By

Society of Geoscientists and Allied Technologists (SGAT) India

In a view to mark its Silver Jubilee Year SGAT considered it appropriate to organize this Seminar VMD2020 to highlight recent development, innovations and state of the art in the concepts and techniques in all activities encompassing Mineral Development. The following is the list of session topics to give you an idea of the planned content.

Concept of Ore genesis
Mineral Exploratioon & Sampling Techniques
Assessment Reeserve & Grade
Ore Body Modeling
Mining Methods-Surface and underground
Mine Planning
Mineral beneficiation, conservation
Utilisation of Mine Waste
Extractive Matallurgy, Mineral Based Industries-Prospect & Problems
Role of Geology in Disaster Management
Designing Engineering Structures
Environmental Management Practice
Legislative Measures Global & India
International Trade
Infrastructural Development
Role of IT
Mining & Community Interface, Regional Development
Manpower Planning & HRD

EXHIBITION

A trade exhibition is planned to be held during seminar in the Exhibition Ground, Unit-III, Kharavelanagar, Bhubaneswar. Organisation are invited to display /advertisement their expertise, range of activities, products available for sale.

REGISTRATION

Member of SGAT - Rs.1200/-
Others - Rs.2500/-
Overseas delegates - Rs.100/- US $
Accompanying persons-Rs.600/ 50 US $
Sponsorship - Rs.50,000/US$ 2000.00 (Four delegates free)
Co-sponsorship - Rs.30,000/ US $ 1500.00 (Two delegates free)
Exhibition Space - 12' x 15' x 9' = Rs. 10,000.00 + Rs. 2000.00 towards Electricity Charges.

Enquiries

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AWARD - 2005

SGAT AWARD OF EXCELLENCE – 2005

Nominations are invited for SGAT Award of Excellence – 2005 in the Proforma enclosed. Persons awarded in the past should not be re-nominated. The proforma (7 sets) completed in all respects and duly signed by the proposer should reach the General Secretary, **Society of Geoscientists and Allied Technologists (SGAT)** at 267, Kharavela Nagar, Bhubaneswar – 751 001 on or before 30th September' 2005.

The Award will be in the form of a citation and a cash award.

Any person (member or non member) who has made outstanding contribution in the field of geosciences, mining, metallurgical and mineral process engineering, mineral beneficiation, environmental management in mines or whose work has helped in upgrading the quality of life in mining environment or whose work has led to significant development of mineral resources of a region, state or country shall be eligible for the award. Self nomination is possible.

1. Name of the persons proposed :
2. Date of birth :
3. Designation & address :
4. Educational qualifications :
5. Professional experience :
6. Membership of Professional bodies :
7. List of publications with names of journals :
   Vol. and Issues (if possible, send important reprints)
8. Details of outstanding work
   (Please attach a separate sheet)
9. Any other information

Signature

Place:

Date:

Full name and address of the
Member/Institution proposing

SITA RAM RUNGTA MEMORIAL AWARD - 2005

Nominations are invited for Sita Ram Rungta Memorial Award in the proforma given below. Any person (member or non-member) who would have made significant contribution in Mineral Exploration, Planning and/or Mineral Beneficiation involving utilisation of mine waste/sub-grade ores and minerals will be eligible for the Award. Persons awarded earlier should not be re-nominated. The Award will be in the form of a citation and cash. Self nomination is possible.

Proforma for Nomination

1. Name of the persons (in Block letter) proposed :
2. Date of birth :
3. Designation & address :
4. Educational qualification :
5. Professional experience :
6. Membership of Professional Bodies :
7. List of Publications with names of Journals (Issues/volumes) if Possible, send important reprints :
8. Details of outstanding work (Please attach a separate sheet) :
9. Any other information :

Signature

Place:

Date:

Full name and address of the Member/Institution proposing

Note:

The work should be original, innovative and of applied nature in the areas of Mineral Exploration, Planning and/or Mineral Beneficiation involving utilisation of mine waste/sub-grade ores and minerals leading to its productive adoption in the field level.

The nomination (in 7 sets) in the prescribed proforma should reach the General Secretary, **Society of Geoscientists and Allied Technologists (SGAT)** at 267, Kharavela Nagar, Bhubaneswar – 751 001 on or before 30th September 2005.

Prof. H.H. Read Memorial Gold Medal

The Society of Geoscientists and Allied Technologist, Bhubaneswar a non-profit making organization professional Society since 1980 will award every alternate year starting from this year a gold medal named after Prof. H.H. Read the famous Professor of Imperial College of London to a researcher who has done excellent work on Indian granites within the last two years. The fund has been created by one of his very old students from India who prefers anonymity.

The workers are requested to send their publications (3 copies each) from July 2003, onward till July 31 2005 to the Secretary, SGAT, 267, Kharavelanagar, Bhubabneswar by the end of August 2005.

A Board, based on the works will finalise the name of the candidate to be awarded the Gold medal in the Annual day meeting to be held on December 18 this year and the expected to come to receive it.

This may kindly be circulate in the department for information of the workers on granite who may prefer to send their publications (three copies each) to the Secretary before the date mentioned above for incorporate of their names in the list of candidates.

The decision of the Society is final and abiding.

► **Other News**

NATIONAL RIVER CONSERVATION PLAN

Rivers are a source of sustenance of our culture and civilization. However, increasing population associated with industrial and other developmental activities has resulted in degradation of rivers in India. Thus, once considered to be the lifeline of the nation, rivers are slowly becoming health hazards for the people. This has prompted the Central Govt. to lunch a river cleaning programme during 1985 with the initiation of Ganga Action Plan (GAP). Subsequently the GAP Phase – II was approved in 1993 for pollution abetment for river Yamuna and Gomati. Programme was further extended to other major rivers of the country in 1995 under the National River Conservation Plan (NRCP). Later in 1996 GAP Phase – II is merged to NRCP. The present approved cost of NRCP is Rs. 4688 Crores. The scheme presently covers 31 stretches of polluted rivers in 157 towns spread over in 18 states. The important works being taken upon under NRCP include:

- Interception and diversion works to capture the raw sewage flowing into the river through drain and their diversion for treatment.
- Provision of sewage treatment plant for treating the diverted sewage
- Provision of low cost sanitation works to prevent open defection on river bank.
- Provision of electric crematoria and improved wood crematoria to conserve the use of wood and help in reducing the water pollution and ensuring proper cremation of the bodies brought to the ghats.
- River front development works such as improvement of bathing ghats etc.
- Other minor miscellaneous works like plantation and public awareness etc.

GANGA ACTION PLAN PHASE-II

GAP Phase-I was the first attempt of the government to clean the river Ganga. The plan was formulated on the basis of a comprehensive survey of the Ganga basin carried out by CPCB in 1984. The survey indicated that out of total measurable point sources of pollution 75% was on account of municipal sewage from towns located along the banks of the river and 25% was on account of industrial effluents. Under this programme 259 schemes have been completed in 25 towns in Uttaranchal, U.P., Bihar and West Bengle at a cost of Rs. 452.00 crores. 33 sewage treatment plants having capacity of 865 million liters per day have been created. As a result the length of polluted rivers stretch has reduced from 740 Kms to 437 Kms (Kannuj to Varanasi)

Rivers Covered Under NRCP

Adyar	Chambal	Khan	Musi	Satluj	Tambrabaruni
Betwa	Damodar	Krishna	Narmada	Subornarekha	Vennar
Bhahmani	Ganga	Kshipara	Penniar	Tapti	Vagai
Cauvery	Godavari	Mahanadi	Pamba	Tunga	Wainaganga
Cooum	Gomti	Mandovi	Sabarmati	Tungabhadra	Yamuna

859 projects with a value of Rs 3253.92 crores have been sanctioned under NRCP. This is in addition to 261 projects sanctioned under GAP phase-I. The total expenditure incured till 31.06.2004 under NRCP is Rs. 1645.37 crores including the states share. A sewage treatment capacity of 1045 mld has been created under this plan.

Water Quality

The water quality monitoring of the Ganga river done at selected locations revealed that the river water quality has shown improvement over the pre GAP period water quality

Parameter	Pre GAP Phase(1986)	2003
BOD in mg/l	5.5-15.5	1.2 – 6.1
DO in mg/l	5.9 – 6.6	7.2 – 8.1

Progress during Tenth Five Year Plan (2002-2007)

An outlay of Rs. 1417.00 crores have been provided under NRCP. Out of which Rs. 816.55 crores are expected to be spent during the last financial year (2004-2005)

Name of the work	Approved Cost in Crores Rs.
1 Additional town in Goa (mandovi Action Plan)	11.09
1 Additional Town in Orissa	48.29
1 Additional Town in Karnatak	46.27
1 Additional Town in Kerala	18.44
1 Additional Town in Andhra Pradesh	344.04
Yamuna Action Plan phase-II	624.00
Gomatui Action Plan Phase – II	263.26

NRCP Programme in Orissa

Programme operation in four cities namely Cuttack in River Mahanadi and Talcher, Chanbali and Dharmsala in river Brahmani have been approved for Rs. 23.98 crores against which works amounting to Rs 6.84 crores have been sanctioned based on DPRs. An amount of Rs. 2.20 crores has been released to the implementing agency and an expenditure of Rs. 1.53 crores has been incurred.

In addition under the direction of supreme court, pollution abetment works at Puri have been taken up at an approved cost of Rs. 48.29 cores. Rs 3.00 crores has already been released to the implementing agency.

NATIONAL ELECTRICITY POLICY LAUNCHED

The National Electricity Policy, one of the key instruments for providing policy guidance to the Electricity Regulatory Commissions in discharging their functions and to the Central Electricity Authority for preparation of the National Electricity Plan has been launched today by the Union Power Minister, Shri P.M. Sayeed. The Policy aims at accelerated development of the power sector, providing supply of electricity to all areas and protecting interests of consumers and other stakeholders keeping in view availability of energy resources, technology available to exploit these resources, economics of generation using different resources, and energy security issues.

Objectives of the Policy

a) Access to Electricity – Available for all households in next five years.
b) Availability of Power – Demand to be fully met by 2012. Energy and peaking shortages to be overcome and spinning reserve to be available.
c) Supply of Reliable and Quality Power of specified standards in an efficient manner and at reasonable rates.
d) Per capita availability of electricity to be increased to over 1000 units by 2012.
e) Minimum lifeline consumption of 1 unit/household/day as a merit good by year 2012.
f) Financial Turnaround and Commercial Viability of Electricity Sector.
g) Protection of consumers' interests.

The National Electricity Policy lays down the approach for developing Rural Electrification distribution backbone and village electrification to achieve the target of completing household electrification in next five years as envisaged in the National Common Minimum Programme. The policy also envisages financial support in terms of capital subsidy to States for rural electrification and special preference to Dalit Bastis, Tribal Areas and other weaker sections for rural electrification.

It seeks full development of hydro potential. Choice of fuel for thermal generation is to be based on economics of generation and supply of electricity. Exploitation of non-conventional energy sources such as small hydro, solar, biomass and wind for additional power generation capacity is also envisaged. Development of National Grid is an important feature of the Policy.

The Policy recognizes the need for ensuring recovery of cost of service from consumers to make the power sector sustainable. The existing cross-subsidies for other categories of consumers need to be reduced progressively and gradually.

The policy recognizes that a minimum level of support is required to make the electricity affordable for consumers of very poor category. Consumers below poverty line who consume below a specified level, say 30 units per month may receive special support in terms of tariff which are cross-subsidized. Efforts would e made to ensure that the subsidies reach the targeted beneficiaries in the most transparent and efficient way.

The National Electricity Policy lays special emphasis on time bound reduction of transmission and distribution losses and advocates promotion of competition aimed at consumer benefits.

The policy estimates that to meet the objective of rapid economic growth and " power for all" including household electrification, an investment of the order of Rs. 9,00,000 crores would be required to finance generation, transmission, sub-transmission, distribution and rural electrification projects upto the year 2012. Public sector investments, both at the Central Government and State Governments, will have to be stepped up and a sizeable part of the investments will need to be brought in form the private sector. Public service obligations like increasing access to electricity to rural households and small marginal farmers have highest priority over public finances.

Private sector has various options for investments. To attract adequate private investments in power sector, return on investment will need to be provided at par with, if not preference to, investment opportunities in other sectors. Appropriate balance will be maintained between the interest of the consumers and the needs for investment.

Open access in transmission will promote competition and in turn lead to availability of cheaper power. The policy emphasizes that the Regulatory Commissions need to provide facilitative framework for non-discriminatory open access at the earliest including technological upgradation of the State Load Dispatch Centre by June 2006 to ensure data acquisition capability on a real time basis.

Open access to distribution networks, initially for bulk consumers, would increase the availability of cheaper and reliable power supply. State Regulatory Commissions have been mandated to notify regulations by June 2005 for laying down the road map for introducing open access in distribution. It has also been envisaged that the amount of cross-subsidy surcharge and additional surcharge to be levied from consumers who are permitted open access should not become so onerous that it eliminates competition.

The Policy stipulates that Regulatory Commissions should regulate utilities based on pre-determined indices on quality of power supply. Parameters should include frequency and duration of interruption, voltage parameters, harmonics, transformer failure rates, waiting time for restoration of supply, percentage defective meters and waiting list of new connections. The Commissions would specify expected standards of performance.

The policy emphasizes that the Central Government, State Governments and Electricity Regulatory Commissions will facilitate capacity building of consumer groups and their effective representation before the Regulatory Commissions. This will enhance the efficacy of regulatory process.

The policy also emphasizes on higher efficiency levels of generating plants through renovation and modernization, transmission capacity to have redundancy level and margins as per international standards, adequate transitional financial support for reforming power utilities, encouragement for private sector participation in distribution, putting in place independent third party meter testing arrangement, adoption of IT system for ensuring correct billing, speedy implementation of stringent measures against theft of electricity, emphasis on augmentation of R&D base, energy conservation measures, appropriate tariff structure for managing the peak load, development for training infrastructure in regulation, trading and power market, providing boost to renewable and non-conventional energy sources, and necessary regulations and early appointment of Ombudsman for redressal of consumers' grievances.

FACTS ABOUT THE OCEANS

The amount of water contained by the oceans is around 1.6 billion Cubic Km.
Biggest to smallest oceans are the Pacific, Atlantic, Indian, Southern (Antarctic) and the Arctic.
The Pacific Ocean covers an area more than 163 million Sq. Km.
About 54 seas are recognized.
The average salinity is 35 parts per thousand.
Temperature ranges from -2oC in the Arctic and Southern oceans to 36oC during summer in the Arabian Gulf.
Fastest Fish in the Sea is the Sail Fish (110 Kph)
Biggest Coral reef in the world is greater barrier reef of Australia.
Diatoms are a kind of plankton. The shells are used to make dynamite.
Killer whale is 7m long.
Penguins are good so dimmers and can stay under water for about 18 minutes.
Sperm whale can reech 3000m. depth.
Tallest seaweed, Giant Kalp nearly 60m tall.
Biggest Marine Animal, Blue Whale recorded length 31m. weight 193tons.
Highest Recorded Ware. The greatest wave evor recorded was created by a massive land slide in an inlet in Alaska (July 9,1958). The falling rock caused a wave to surge up the opposite side of the bay which reached a height of 530m.
Deepest part of the Ocean: The challenger deep in the Mariana Trench, between Japan and Papua New Guinea has a maximum recorded depth of 11033 m.
Biggest Tide: The difference in height between high and low water in the Bay of Fundy, in Canada is 16m.
Highest Submarine Mountain: The top of Mount Kee in the Pacific Ocean is 10203m. above the seafloor. It is significantly higher than Mount Everest, the tallest mountain on land (8850m).
Source: Story of the Oceans, Geological Society of India and Department of Ocean Development.

LARGEST GAS FINDS IN RECENT TIMES

Sakhalin 1 & 11 in Russia: 20 trillion cubic feet, Janz in N.W. Australia 20 trillion cubic feet, Reliance/Niko in Krishna-Godavari basin: 14 trillion cubic feet, GSPC consortium in Krishna-Godavari basin:20 trillion cubic feet & Cairn Energy in Barmer 1 billion barrels per annum.

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Full Name :

Designation :

Mailing Address :

Date of Birth :

Academic Qualification :

Professional Qualification :

Signature of Applicant :

Date of Application :

Name & Signature of two Life Members recommending the candidate :

1. 2.

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Decision of the Council : Candidate is selected as Life Member/Institutional Member/
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Member intimated on his election and copy of the rules sent to him on—

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Institutional Member : Rs. 20,000/-

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(Guidelines to Prospective Authors)

Research papers, review articles, short communications, announcements and letters to editors are invited on topics related to geosciences, viz, mineral exploration, mineral characterization and beneficiation, mining, materials science, metallurgy, mineral industry and trade, mineral economics, environment, education, research and development, legislation and infrastructure related to mining, mineral policy and mineral development planning.

Submission of manuscript implies that it is original, unpublished and is not being considered for publication elsewhere. Two copies, complete in all respects (with copies of figures and tables), are required to be submitted. Originals tracings of figures and tables should be enclosed separately. Each manuscript must be accompanied by a computer diskette (floppy) containing the electronic version of the text. Electronic files of figures, if available, should be submitted in a separate diskette. In each case, the details of software and type of equipment used should be clearly indicated.

Journal Format: **A-4 size**
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(a) Title: Centrally aligned, bold, capital
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Tables: Each table must be provided with a brief caption and must be numbered in order in which they appear in the text. Table should be organised within A-4 size and should be neatly typeset for direct reproduction. Tables will not be typeset by the printer, so their clarity and appearance in print should be taken into account while the author(s) prepare(s) them. Use of 10 points Time New Roman/Arial Font for table is recommended.

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