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PRESIDENT'S COLUMN

Mineral resources, yardstick for measurement of nation's economic prowess normally occupy the forest covered areas. Exploitation of these resources normally degrade the forest land but with the development of scientific management of the mining operation, emphasis has been given to minimize de-forestation. Because of environmental awareness, conservation of forest has been prioritized, and thus restricted the exploration and exploitation of these non-renewable resources. While the development of mineral resources has become vital for the attainment of country's economic growth a scientific and judicious management of forest conservation should be attempted.

It is high time for Government to re-examine the Forest Conservation Act in order to have effective control on degradation of forest. It is also to be decided whether the mineral sector should grow to meet the growing domestic demand arising from population growth as well as increasing standard of living. This would also require additional mineral productions and extensive explorations to establish resources for future. Mineral resources and environment both are essential for future generation. Hence, judicious decision is imperative to have the balanced growth by development of mineral sector and simultaneous enforcement of forest conservation.

Analysis would reveal the real reasons of deforestation and tree felling which has to be taken care. On the other hand, Government have limited resources for effective administration and also funds for afforestation of degraded forests covering continuing deforestation. If scope is given, the organized mineral sector can be of substantial help in improving degraded forests. Government machinery for enforcement of Mining and Forest Acts have to jointly work to achieve desired results for the benefit of the country.

At the same time, in order to counter false and the adverse publicity, the mineral sector has to be eco-friendly and maintain adequate records to establish beyond doubt, their contribution towards forest, people and the nation.

Above views expressed by our Society in various seminars, workshops and forums for last few years is now being accepted by Government and public. It deserves wider review for early enforcement, which should continue to be our effort.

Dr. R. C. Mohanty
(President, SGAT)

**LEAD AND SULPHUR ISOTOPE STUDY OF THE SARGIPALLI LEAD DEPOSIT,
SUNDERGARH DISTRICT, ORISSA: INDICATORS OF SYNGENETIC PROCESS OF
ORE FORMATION IN A SEDIMENTARY BASIN**

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ABSTRACT

In the Sargipalli lead deposit; the sulphur isotope analyses of galena samples from the Sargipalli lead deposit shows a range of $\delta^{34}\text{S}$ values from -4.4 to $+5.3$ ‰ indicative of derivation of sulphur by sulphate reduction process within a limited reservoir in a sedimentary domain, with no mantle signature. The compositional character of the deposit (Pb/Zn ratio in the ore) is quite unusual when compared with that of many known sulphide deposits of the world. Lead and sulphur isotope studies reveal extreme uniformity of Pb isotope composition suggesting isotopically homogeneous, enriched felsic upper crustal source. The petrographic and chemical studies of ore and the host rocks indicate a metamorphosed synsedimentary exhalative origin of the lead deposit of Sargipalli in which the ore bearing fluid was thought to be discharged from the hydrothermal vents, and interacted with sea water towards the precipitation of ore conformably with the pelitic components suggesting the syngenetic process of ore formation.

Key words: Palaeoproterozoic, Lead deposit, Sargipalli, Lead and sulphur Isotope.

INTRODUCTION

The building up of supercontinents (e.g. Pangea) had three major first order consequences (a) a shrunken land area and increased ocean – floor surface ; (b) high heat flow through thickened continental “heat lens” and (c) decrease in number and length of midoceanic ridges. The first would lead to marine regression with coeval biotic crises. The second would cause increased partial melting of continental lithosphere which, in its turn would produce anorogenic granites with related Sn – W – base metal deposits and also spew out plateau basalt with high volcanic ash into the atmosphere. The third was responsible for lowering mean oceanic temperature ; low CO₂ release and

strong ocean current ; these aided by high volcanic ash in the atmosphere ushered in the Ice house climate. Similarly, rifting and dispersal of continents brought forth three major order phenomena which, in their turn, were harbingers of marine transgression, green house climate and ocean anoxic events, with expanded O₂ – minimum zones in the ocean – features that would offer favourable habitats / situations for a variety of mineral deposits. Barly and Groves (1992) recognized that cyclicity in the timing of specific classes of metal deposits coincides with episodes of supercontinental break up and assembly; metallisation related to anorogenic magmatism (sandstone – hosted Cu and Pb) are most abundant during onset of fragmentation while periods of

subduction and super continental accretion are prolific in porphyry – Cu, and volcanic – hosted massive Cu – Zn – Pb sulphides (VHMS).

The Proterozoic giant lead – zinc deposits in Africa, N America and Australia (<1.8 Ga) were all formed after a major global surge of anorogenic felsic magmatism that spewed Pb- rich volcanics over Proterozoic cratons. Erosion and transfer of bulk lead to rift basins where large deposits formed are testified by Sm/ Nd age data that distinguish the mantle separation age of the volcanics from that of the metasedimentary immediate source rock for the lead ores (Sawkins 1989). Here the causal connection between processes of crustal evolution and ore body generation is firmly established.

When the ranges of metal composition of volcanic – hosted massive sulphide deposits are compared with the mineralogy and petrochemistry of their coeval magmatic systems, both systems indicate progressive enrichment in LIL elements – the ores in Pb and Ba the rocks in K – implying a fundamental similarity of the two evolutionary trends of rocks and ores in time and space.

Phanerozoic basins preserve records of global sedimentary cycles of long and short orders with periodicities of ≈ 32 Ma and 250 Ma respectively, related to cyclic changes of ocean spreading rates (Force, 1984; Fischer and Arthur, 1977; Fischer, 1986). Matching these cycles with synchronized and same periodicities, there occur regression – transgression, biotic boom – crisis, icehouse – green house and ocean – anoxia cycles all of which seem interrelated in a complex manner to deep tectonic process and changing heat budget from the interior. The role of oxygen in determining mineralisation styles in the Phanerozoic has been

documented. It has been shown that a temporal correlation of volcanogenic massive sulphide, ophiolitic ores and sediment – hosted gold ores with ocean anoxic events exists when O₂-minimum zones were most extensive as the result of restricted ocean bottom circulations (imposed by high ocean – ridge volume and consequent sea level rise). In contrast, clastic-hosted Pb – Zn – Ag deposits formed during the intervening periods of low – ridge volume, attendant fall in sea level and well oxygenated bottom circulation.

The sulphide deposit of Sargipalli, in the Proterozoic fold belt of Gangpur, is dominated by lead. The deposit, located in a narrow arcuate zone with WNW-ESE trend, at Sargipalli occurs in the upper part of the metasedimentary sequence of the Gangpur Group. The stratabound ore body is hosted by garnet biotite schist, which has undergone deformation and amphibolite-facies of metamorphism. The ore zone is confined to a particular stratigraphic unit conformable to the stratigraphic marker horizons and litho-contacts. Field evidences suggests that the ore deposit was developed by syngenetic process in which the accumulation of sulphide grains was primarily controlled by stratigraphy.

GEOLOGICAL SETTING

The rocks of Gangpur basin spread over 3000 sq.km. area in the Northern Part of Sundargarh District, Orissa (Plate – I). These Proterozoic rocks consist of mostly the metasediments, and basic and granitic intrusives with in the Gangpur Group in the Eastern Indian Shield (Plate – II). The lead deposit of Sargipalli occurs in the South-Western peripheral part of the Gangpur basin around lokdega and Bharatpur villages (Plate – III). The dominant lithounits are represented by mica schist (with varying proportion of staurolite, locally developed

garnet, biotite, muscovite, sericite, chlorite, and quartz), dolomitic marble and mica schist. The mica schist is stratigraphically bounded by the underlying arenaceous bands and succeeding carbonate – rich litho-units. The schistose rock is the metamorphosed product of the pelitic and semi-pelitic rocks; ranging in composition from quartz wacke to quartzose clay and aluminium rich clay shales to feldspathic clay. Presence of cherty laminations, actinolite (with epidote and chlorite) and albitic plagioclase in quartzite and quartz schist indicate the derivation of these rocks from grey wacke that had a significant component of volcanic rock fragments. Exposures of buff to greyish coloured banded dolomitic rock and calc-silicate skarn are exposed discontinuously at several places mainly on the foot wall side of the mica schist. Exposures of amphibolite are very restricted in occurrence and found with in the mica schist and dolomite, limited to a thickness of about 50 Cm. The granitic rocks range in composition between alkali feldspar granite and syenogranite as per IUGS classification. Endoskarn has been developed at the contact of dolomite and granitoid rocks. The sedimentation in Gangpur Group took place between 1700 Ma and 2000 Ma (Sarkar, 1980) and the age of granitoid intrusion is about 850 Ma (Sarkar, 1972, 1983).

The area around Sargipalli is an integral part of Gangpur Supra-structures, which has undergone several generations of superposed folding. In the Sargipalli area the earlier generation of fold is a highly compressed E-W trending fold (Plate – III) with an overall plunge to the east. As a result of this intense deformation, movement of materials along the limbs of the fold took place in response to the mechanism of flowage and flexure – slip and also by shearing at the waning stage of fold movement when the rock units move to a semi-brittle state. At the time of

movement of E-W folds; “S” and “Z” type of folds originated on the limbs of the folded structure. Galena mineralisation is confined to the southern limb of this “S” type of the fold; the hinge portion of which is located to the north-east of Bharatpur (Ghosh et al, 2003) (Plate – III). The axial planes of small – scale fold and a fine crenulation cleavage show strong parallelism in attitude on the limbs of the above – mentioned “S” – type of folds. These small scale folds form rolls on the limbs of the major east – west fold. These show a generalised similarity with the E-W folds, but their exact relationship can not be deciphered due to superimposition of another generation of fold. Sarkar et al (1969) suggested that the time of deformations corresponds to either 893-993 Ma (determined on whole rock biotite – phyllite) or 866 – 912 Ma (determined on muscovite of muscovite schist).

The rocks of the area are metamorphosed and the metamorphism ranges from greenschist facies to amphibolite facies. The mica schist of the ore zone (characterised by the abundance of spessartine – rich almandine and the presence of occasional kyanite and sillimanite, absence of primary chlorite and staurolite) and dolomite, north of the ore zone (abundance of diopside in the skarns) show amphibolite – facies of metamorphism. Presence of both kyanite and sillimanite in the mica schist under the same P-T regime would indicate that the maximum temperature and pressure conditions of metamorphism attained in the area are between 500⁰ to 600⁰ C and 5 – 6 Kb, respectively.

CHARACTER OF THE LEAD DEPOSIT

The lead mineralisation in the Sargipalli area is primarily restricted to the argillaceous metasediments of Gangpur Group, represented by garnetiferous mica schist.

The distribution of this lithological unit is in conformity with the trend of shearing involved. Lithologically, the zone of mineralisation is also confined to the north by dolomitic rock and to the south by northern portion of mica schist indicating its stratabound character (Plate – IV). The ore lenses are conformable with the host schist. The mineralisation is mainly banded, with an alternate disposition of sulphide and silicate layers, even in micro-scales reflecting a stratiform nature. Locally, however, ore veins occur discordant to the schistosity, filling fractures of host rocks. Minor disseminations of sulphides are present in the vicinity of the ore lenses in mica schist as well as in the adjacent dolomite and calc – silicate skarn. Stratabound and stratified sulphides showing evidences of soft sediment deformation (primary sedimentary contortion of the ore and host rock layers) appear to reflect the primary, sedimentary and diagenetic process. Superimposed on these are the structures and textures mainly due to recrystallisation and annealing in response to subsequent metamorphism. Plastic deformation of galena and chalcopyrite are evidenced by fracture filling of these minerals inside silicates. Mechanical deformation feature in coarse galena grains is identified by serrated boundaries and bent cleavages, which possibly developed under low temperature (below 200^o C) and pressure conditions (Mc Clay, 1980). The effects of metamorphism are clearly recognized in the Sargipalli basemetal sulphides. Recrystallisation and annealing are shown by the polygonal fabric and triple point junctions of galena, sphalerite and chalcopyrite.

There is also no visible wallrock alteration in the host rock, which is indicative of the epigenetic mineralisation, where ore fluid reacts with the host rock. The granitoid rock of the area as a source of mineralisation can

be outright rejected because of its intrusive nature, much younger in age (~850 Ma) in comparison to the host rock (~1700 Ma) and the contained ore (range between 1682 Ma and 1695 Ma). The skarn rocks, which are formed by metasomatic alteration of dolomite at the contact of granitoid, are barren of any mineralisation. The characteristic feature of the sediment-hosted deposit is the presence of anomalous, apparently syngenetic metal values in the footwall sediments. Manganese appears first, followed by zinc \pm lead, iron and exhalative chert higher up in the footwall sequence. The footwall sediment of Sargipalli is enriched in lead at deeper mine level (120 mRL). The sulphide rich footwall is characterized by pyrrhotite-rich bands and laminations, similar to the sediment hosted sulphide deposit of Sullivan, Canada. Locally bedded chert and tourmalinite of exhalative origin are closely associated with the ore zone. The vertical distribution of copper in the sediment hosted deposits contrasts with that in the volcanic hosted ore bodies. Copper is not restricted to the stratigraphic footwall as in the case of the volcanic hosted deposits. Relatively, late copper enrichment is observed in many exhalative deposits. In Sargipalli, hanging wall rocks are rich in chalcopyrite.

The mineralisation in the Sargipalli Lead deposit is multimetal in nature with primary galena in association with chalcopyrite, sphalerite, pyrite and pyrrhotite. The ore reserve in the deposit is of the order of 2.06 Million Tonnes, having an average grade of 6.73% Pb, 0.33% Cu and about 50 ppm of Ag. The Zn content in the ore is insignificant (the average grade being 0.4%) and is below the recovery limit. Hence, the Sargipalli deposit is dominated by lead with subordinate amount of copper, zinc and silver.

LEAD AND SULPHUR ISOTOPE STUDY

Pb isotope analysis was carried out by Geospec consultants limited, Alberta Canada under contract from the Geological Survey of Canada. (Table-1) (S.L.Nos 1-4 previously reported by Ghosh et al, 1999) and (Sl. Nos 5-11 reported by Vishwakarma and .Ulabhaje , 1991). The Pb isotope analysis were performed on a VGMM 30 Mass Spectrometer and corrected for fractionation using correction factors derived from repeated measurements of the NBS SRM 981 and SRM 982 common Pb standards. The approximate analytical uncertainties for the analyses are 0.058, 0.060 and 0.062 percent for the $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ ratios respectively.

The Sulphur isotope studies of the two Galena samples (Table 2. S.L.No's 1 &2) were done in the petrology, petrochemistry and ore dressing wing , airborne mineral surveys and exploration wing of Geological survey of India, Bangalore. The samples are seen consisting predominantly of medium

to relatively coarse Galena with very minor chalcopyrite as well as pyrrhotite. Sphalerite is occasionally seen as very tiny inclusions within chalcopyrite. Prismatic grains of ilmenite are also not uncommon. The mineral separation technique was decided accordingly and Galena was separated for SO_2 extraction by bringing to required grain size. Initial dry as well as wet sieving, heavy media separation and magnetic separation utilising isodynamic separator; extraction and purification of the gas was carried out on the samples utilising the Sulphide line and later admitted to the mass spectrometer for isotopic analysis. The S isotopic analysis was carried out with the nuclide 6-60 RMS mass spectrometer .

Table 2 also includes a set of 4 analyses (S.L.No's 3-6, previously reported by Ghosh, Thorpe and Ghosh , 1999). The above $\delta^{34}\text{S}$ values are reported as per mil 0/oo variations relative to the canyon Diablo Troilite (CDT) standard, the analytical precision being ± 0.2 0/oo.

Table 1.
Lead Isotope Data for Sargipalli Galena

S.L.No.	Location	Occurrence	$^{206}\text{Pb}/^{204}\text{Pb}$	$^{207}\text{Pb}/^{204}\text{Pb}$	$^{208}\text{Pb}/^{204}\text{Pb}$	Model Age Ma
1	210 mRL Hanging Wall	Coarse anhedral galena	16.781	15.813	36.607	
2	210.00 mRL Footwall	Fine polygonal galena	16.807	15.816	36.629	1682 Ma to 1695 Ma

3	120.00 mRL Footwall	Coarse anhedral to polygonal galena in massive band	16.791	15.814	36.607	
4.	120.00 mRL Footwall	Fine polygonal galena in thin band	16.797	15.814	36.629	
5.	210.00 mRL	Minute Dissemination of Galena	16.797	15.816	36.616	
6.	187.00 mRL	Massive band of Galena	16.784	15.810	36.614	
7.	187.00 mRL	Vein Galena	16.787	15.812	36.597	
8.	187.00 mRL	Thin band of Galena	16.790	15.813	36.607	
9.	157.00 mRL	Galena Vein near Quartz porphyroblast	16.773	15.809	36.617	1665Ma
10.	120.00 mRL	Coarse Galena Crystal replacing Mica schists	16.787	15.813	36.594	
11.	120.00 mRL	Galena vein near Quartz porphyroblast	16.802	15.817	36.619	

Data after Ghosh , Thorpe & Ghosh (1999) and Vishwakarma & Ulabhaje (1991)

Table 2
SULPHUR ISOTOPE DATA FOR SARGIPALLI GALENA

S.L.No.	Sample No.	Location	Sulphide	$\delta^{34}\text{S} \text{‰} (* \text{CDT})$
1.	SGPL/ Mines/02	90.00 mRL Hanging Wall	Galena	-4.4
2.	SGPL/Mines/03	60.00 mRL FootWall	Galena	+5.3
3.	S/16	210.00 mR L Hanging Wall	Galena	+1.7
4.	S/47	210.00 mR L FootWall	Galena	+0.8
5.	S/63	120.00 mRL FootWall	Galena	-1.7
6.	S/62	120.00 mRL FootWall	Galena	-3.2

S.L.No's 3-6; Data after Ghosh, Thorpe & Ghosh (1999)

*CDT :- Canyon Diablo meteorite (Troilite)

ORE GENESIS

The Sulphur isotope analyses of two Galena samples from the Sargipalli deposit shows a range of $\delta^{34}\text{S}$ values from -4.4 to +5.3 ‰ (Table 2) respectively averaging +4.85 per mil. The above Positive $\delta^{34}\text{S}$ values distribution is not narrowly constrained but shows fairly a wide separation. The widely separated $\delta^{34}\text{S}$ values in the given range are in general characteristic of derivation of Sulphur due to sulphate reduction within a limited reservoir in a sedimentary domain and bears no mantle signature (Neilson, 1979). Earlier Ghosh, Thorpe & Ghosh (1999) reported $\delta^{34}\text{S}$ data from 4 samples which shows a narrow range between -3.2 to +1.7 (Table 2).

According to Sangster (1976), the average fractionation of difference in $\delta^{34}\text{S}$ values between sea water Sulphate and Sulphide ores hosted in a marine sedimentary rocks is 14 ‰ though some resources indicated that the Sulphur isotopic composition of sea water sulphate and its evolution through time is yet not fairly known; assuming that middle Proterozoic sea water sulphate had an average $\delta^{34}\text{S}$ of 18 ‰ (Claypool et al., 1980), the Sargipalli data (14.4 ‰, according to Vishwakarma, 1996) are consistent with a sedimentary (sea water sulphate) source. Although the present data are too meager to make any generalization, the $\delta^{34}\text{S}$ values give indication of isotopic variation from 120.00 mRL to 210.00 mRL in the Sargipalli mine (Table 2). Whether such a variation will support an overall enrichment of isotopic ratios towards higher stratigraphic horizons (i.e. from 120 mRL to 210 mRL) as voiced by Vishwakarma (1996) is indeed difficult to estimate. However the isotopic variation between the two levels of Sargipalli lead mines (viz.

between 120.00 mRL & 210.00 mRL with 120m and 30 m depths below the surface) shows a variation of $\delta^{34}\text{S}$ values from -1.7 to +0.8 in the Sargipalli lead mine which indicates that the amphibolite-facies of metamorphism has not homogenised the primary distribution of $\delta^{34}\text{S}$ values (Von Gehlen et al. 1983, Parr, 1992, Vishwakarma, 1996). The variation of $\delta^{34}\text{S}$ values might result from the reduction of sea water sulphate by inorganic processes or by bacterial action (Spry, 1987). The $\delta^{34}\text{S}$ data may reflect Sulphur source involving biogenic or organic Sulphide.

The lead isotope analyses of the first four samples (Table 1) show small lead isotopic differences (Table 1) which appears to be Real (Ghosh, Thorpe and Ghosh 1999) and the data are in good agreement with those reported earlier by Vishwakarma and Ulabhaje (1991). It is also evident that Galena from both the veins and thinly banded ores has remarkably similar lead isotopic composition. The Sargipalli lead deposit has extremely homogenous lead isotopic composition (Table 1) (Ghosh, Thorpe and Ghosh 1999). The above data and those published earlier by Vishwakarma and Ulabhaje (1991) are essentially the same. Such homogeneity in stratabound deposits have been considered to be due to the derivation of lead from an isotopically homogenous source and the general lack of disturbance of the compositions by subsequent metamorphism.

Based on their lead and Sulphur isotope values; which agrees well with the data presented in this paper, Rai et al (1988); Vishwakarma and Ulabhaje (1991) and Vishwakarma (1996) suggested a sedimentary exhalative (Sedex) origin for the Sargipalli lead deposit. The ore bearing fluid was discharged from hydrothermal

vents, and this fluid interacted with sea water towards the precipitation of ore conformably with the pelitic components. Sarkar (1974) further suggested that the ore material may be derived from adjacent terrestrial sources during the weathering cycle; but based on Pb and S isotope studies, Vishwakarma and Ulabhaje (1991) and Ghosh et.al.(1999) suggested Synsedimentary exhalative (SEDEX) genesis of the deposit in which single stage lead derived from isotopical homogenous, uranium enriched, felsic upper crustal source though Sulphur was derived from the reduction of contemporary sea water sulphate source. Like most Sedex deposits (Sangster,1990 Skauli et.al. 1992) the Sargipalli Sulphide deposit may be considered to have an upper crustal source whereby lead was derived from crustal rock from land and Sulphur was derived from sea water sulphate (sedimentary source for Sulphur). The metal rich hydrothermal fluid as envisaged, acquired reduced Sulphur in the basin and as a result Sulphide precipitated and deposited at suitable sites conformably with the sediments representing syn-sedimentary ore formation. This model seems to be in close agreement with the ideas expressed earlier by Rai et. al. (1988), Vishwakarma and Ulabhaje (1991) and Vishwakarma (1996).

SUMMARY & CONCLUSIONS

1. Geological features of the Sargipalli Lead deposit indicate that the sediment hosted lead dominant sulphide deposit of Sargipalli is both of stratabound and stratiform in nature. The ore lenses are parallel to the compositional layering of the associated metasedimentary rocks. The ore laminae alternate with the layers of the host schist. Textural studies did not give any evidence to suggest that the ore layers selectively

replaced the silicate layers anywhere. The silicate layering is primary, supported by the presence of rounded tourmaline grains. Frequent contortions of both the ore and the Silicate layers are strongly indicative of the effects of diagenesis and these above mentioned features indicate their exhalative origin.

2. The extremely homogenous Lead isotopic composition and high metal value of lead indicates its derivation from Uranium – enriched felsic upper crustal source. The Sulphur Isotope analysis of galena samples from the Sargipalli deposit shows a range of $\delta^{34}\text{S}$ values from -4.4 to +5.3 permil respectively averaging +4.85 per mill. The widely separated $\delta^{34}\text{S}$ values in the given range are in general characteristic of derivation of sulphur due to sulphate reduction within a limited reservoir in a sedimentary domain and bears no mantle signature (Neilson, 1979). According to Vishwakarma (1996), there may be the possibility of a Sulphur source mainly from the inorganic reduction of sea water sulphate at a temperature of $\sim 300^\circ\text{C}$. Presence of pyrrhotite – rich bands and laminations in the deeper mine levels also indicate the reducing environment of ore deposition. The absence of oxidised zones around the ore body supports this view.
3. Based on the facts it appears that the Lead dominant mineralisation at Sargipalli contain well homogenized lead, derived possibly from upper crustal felsic terrain below or adjacent to (?) the basin. Franklin et. al. (1981) and Franklin (1986) suggested that the metal content of the hydrothermal fluids as envisaged

here is established by the buffering capacity of the host rocks as well as possibly by the actual metal content of these rocks. During cooling, provided that the fluid is always reduced and the pH is acidic, copper then zinc will precipitate leaving the residual liquid relatively enriched in lead. The lead dominant sulphide mineralization at Sargipalli represents sedimentary exhalative (SEDEX) mode of origin, which later remobilised and reconcentrated due to high grade metamorphism, According to Vishwakarma and Ulabhaje (1991) and Vishwakarma (1996), Lead was derived from the upper continental crust, the source rock possibly being the 2.20 Ga – old Singbhum soda granite which was initially rich in U-Th-Pb.

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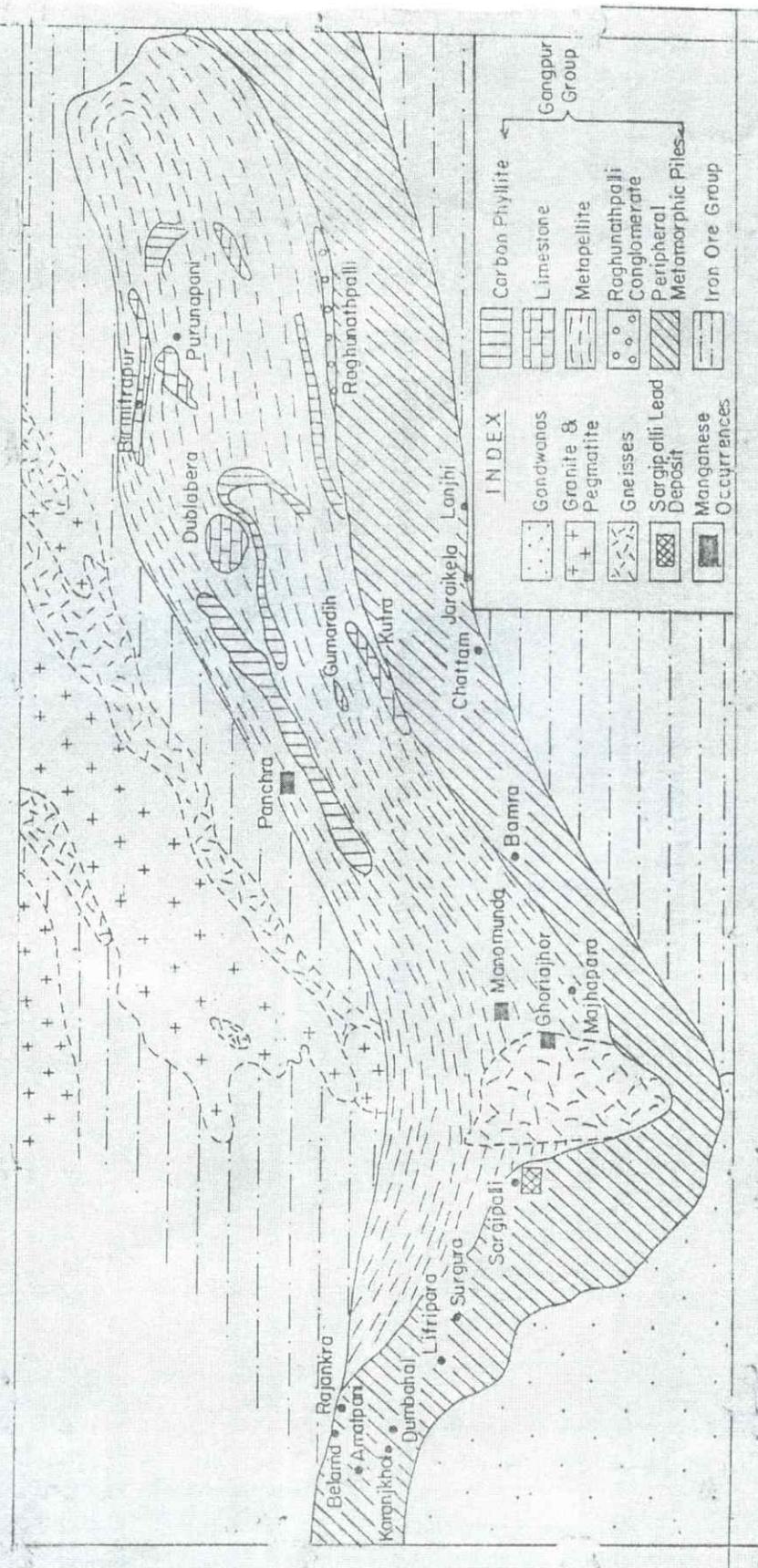
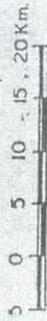
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GEOLOGICAL SURVEY OF INDIA

REGIONAL GEOLOGICAL MAP SHOWING METAMORPHIC PILES OF GANGPUR GROUP; NORTH ORISSA.

PLATE - II



INDEX	
	Gondwanas
	Granite & Pegmatite
	Gneisses
	Sargipalli Lead Deposit
	Manganese Occurrences
	Carbon Phyllite
	Limestone
	Metapelite
	Raghunathpalli Conglomerate
	Peripheral Metamorphic Piles
	Iron Ore Group
Gangpur Group	

GEOLOGICAL SURVEY OF INDIA
**SIMPLIFIED GEOLOGICAL MAP OF PART OF EASTERN INDIANSHIELD SHOWING
 THE LOCATION OF SARGIPALLI BASEMETAL DEPOSIT, SUNDARGARH DISTT., ORISSA**
 SCALE

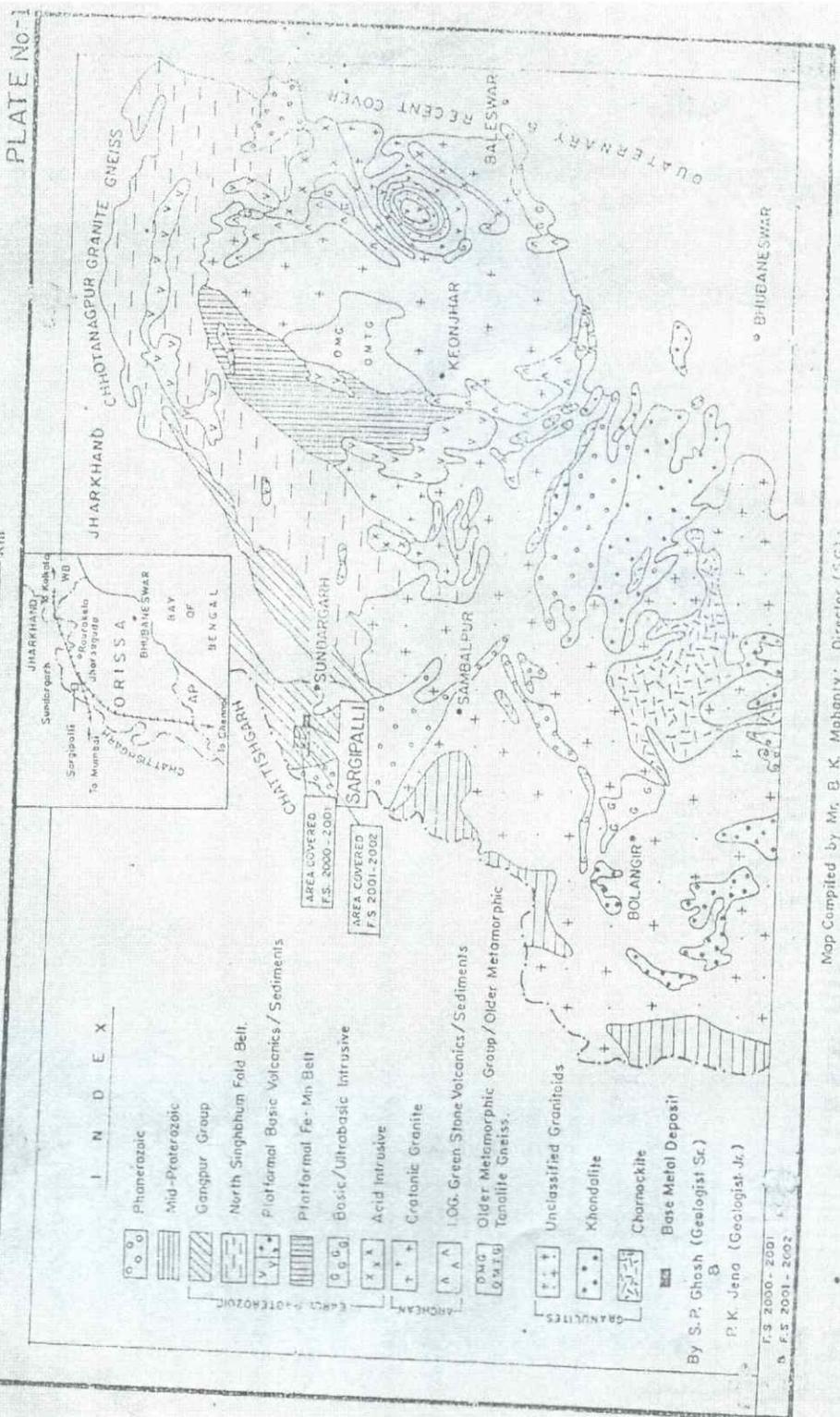
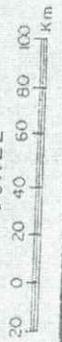


PLATE No-1

I N D E X

- Phanerazic
 - Mio-Proterozoic
 - Gangpur Group
 - North Singhbhum Fold Belt.
 - Platform Basic Volcanics/ Sediments
 - Platform Fe-Mn Belt
 - Basic/Ultrabasic Intrusive
 - Acid Intrusive
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 - Older Metamorphic Group/ Older, Metamorphic Tonallite Gneiss.
 - Unclassified Granitoids
 - Khondalite
 - Charnokite
 - Base Metal Deposit
- By S. P. Ghosh (Geologist Sr.)
 P. K. Jena (Geologist Jr.)

Map Compiled by Mr. B. K. Mohanty; Director (SG);
 Map & Cartography Division; Operations - Orissa; GSI, Bhubaneswar.

F.S. 2000-2001
 S. F.S. 2001-2002

CHEMICO-MINERALOGICAL CHARACTERISATICS OF DUNITE FROM SALEM, TAMILNADU

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ABSTRACT

The steel plants use mixture of dolomite/limestone and quartz/silica sand as the flux material. But now a days dunites are preferred as fluxing agents in iron and steel plants in place of dolomite as it has higher magnesia and silica and low alkalis.

Decade back dunite (an ultramafic igneous rock, very high in magnesium up to 54% and low in silica (<40% SiO₂) had almost zero utility value or were used as road metals. But recently it has attended the attention of economic geologists, metallurgists and environmentalists of the world over for variable economic significance. The dunites are found in abundance in Salem area of Tamilnadu either as dunite / ultrabasic complexes or in association with the magnesite mineral as host rock. In view of its economic significance, the dunites were collected from an active quarry of Salem and were investigated for its chemico-mineralogical characteristics.

Key words: *Dunite, Salem, Olivine, EPMA*

INTRODUCTION

Dunite, an ultrabasic rock which has been normally used as road metals is recently considered as industrial mineral because of their chemical composition. Since the last decade, dunites are considered as fluxing agents, substituting dolomite, for iron and steel industries because of their specific composition. Fluxes in a steel plant are important raw material required for removal of undesirable impurities in iron making stage. During iron making stage, major flux used is dolomite. When added through sinter, it reduces the thermal load of blast furnaces. (Lonial, 1996). The use of dolomite as a flux in sinter plant has been an age-old practice till recent past and these dolomites contain around 20% of MgO and

high alkali. But now-a-days high magnesian igneous rocks are preferred in sinter plant for better productivity because they contain high amounts of magnesium and silica, very low alkali and alumina, which make them suitable for use as a basic flux. High magnesium rocks are dunite, peridotite and pyroxenite in descending order of magnesium oxide content. Under Indian conditions, it is desirable to have a flux through which SiO₂ can be introduced in a pre-assimilated form. Dunite is the best substitute for the combined dolomite and quartzite as it gets easily assimilated into the melt and there is reduction in heat requirement in sinter making.

Another interesting example of utilisation of dunite is in environmental geochemical

engineering that is the process of neutralization of harmful industrial waste acids by the mineral olivine (otherwise called as olivine process) or high amounts of olivine bearing rocks. Forsterite olivine (Mg_2SiO_4) is a promising mineral as it constitutes both a neutralising agent and as an absorbent with affinity for copper (Kleiv and Thornhill, 2004). Olivine is a cheap magnesium nesosilicate and is build up of isolated negatively charged SiO_4^{4-} tetrahedra held together by octahedrally coordinated Si-O-Si bonds between the isolated SiO_4 tetrahedra which makes olivine the fastest weathering silicate mineral. The reaction mechanism is as follows:



During dissolution in acid the Mg^{2+} ions are separated by hydrogen ions, yielding $Si(OH)_4$ monomers and Mg^{2+} ions in solution, thus the reaction results in large reduction of acidity (Kleiv and Thornhill, 2002). Contrary to the neutralization with carbonate, neutralization with olivine does not produce undesirable carbon dioxide gas and contaminated gypsum. Additionally, it yields commercially interesting products, such

- as silica
- iron oxidized and precipitated as magnetite or hematite and
- magnesium sulfate

Olivines capacity to neutralise sulphuric acid is described by several investigators (Schuiling, 1986, Jonckbloedt, 1998; Kleiv et al., 2001; Morales and Herbert, 2001; Kleiv and Thornhill, 2002). Due to the high solubility of magnesium sulphate, the use of olivine as a neutralising agent will not result in

voluminous sulphate precipitates. This however, can be a problem when using calcite, for neutralising acids, as the calcium ions leached from the mineral combine with sulphate ions to form gypsum. The olivine process may, therefore, also be considered as an interesting alternative for current production process of precipitated silica. However, it is highly essential to know the exact mineralogical composition of these dunites, for utilisation either in iron making point of view or environmental/acid neutralisation point of view.

GEOLOGY AND MODE OF OCCURRENCE OF DUNITE

This ultramafic complex is composed of dunite, pridotite, pyroxenite, gabbro and their metamorphic products (Prasannakumar et al., 2002). These ultramafic rocks are considered to be the source of magnesium required for the formation of magnesite deposits of Salem.

Dunite sample was collected from an active quarry from Salem, Tamilnadu and examined under optical and electron probe microanalyser to decipher the mineralogy as well as mineralogical end member composition of olivines.

CHARACTERISATION

Microscopic studies: The dunite is green in colour, granular, composed of coarse grains of olivine and is densely packed, typically with allotriomorphic-granular (gabbroic) texture. Rarely these dunites contain very trace quantities of pyrite.

Mineral chemistry: The mineral chemistry was carried out by Electron Probe Microanalyser (EPMA), using a

JEOL, EPMA Super Probe, JXA-8600 Model with a current setting of 2×10^{-8} mA. Mineral standards were used with Standard Programme International (SPI) following ZAF correction procedures. Different grains of olivine were selected for the analyses from the sample and results are reported in Table 1. SiO₂ content ranges from 42.903 to 43.388%. FeO content in the range of 7.628 to 8.159% while MgO content ranges from 48.288 to 49.420%. Minor amounts of MnO (0.125 to 0.139%) were detected in all the grains while Al₂O₃, CaO, Na₂O, TiO₂ and Cr₂O₃ were detected in trace quantities in some while absent in

others. However, significant amounts of NiO were detected in all the seven grains analysed. End member compositions was calculated and derived from the formula on the basis of 4(O) following Deer et al., (1992). End member composition indicates 91.29 to 91.75 Mol.% forsterite and 8.21 to 8.66 Mol.% fayalite.

Bulk composition: The chemical specifications of major oxides (in wt.%) for suitability of the high magnesian rocks to be used as flux/sinter mix material in iron and steel industry is presented in Table 1. This Dunite is notably poor in alumina, soda, and lime.

Table 1: EPMA analyses (in wt.%) of different grains of olivine from Salem dunite along with their end member compositions

Elements		1	2	3	4	5	6	7
SiO ₂		43.061	43.258	43.030	42.903	43.016	43.388	43.015
Al ₂ O ₃		-----	0.060	-----	-----	0.026	-----	-----
FeO		8.116	8.035	7.628	8.159	8.002	8.023	7.927
MgO		48.512	49.039	48.818	48.288	48.448	48.677	49.420
MnO		0.139	0.147	0.137	0.132	0.127	0.133	0.125
CaO		-----	-----	0.001	0.001	0.001	-----	0.004
Na ₂ O		-----	-----	0.013	-----	0.053	-----	-----
TiO ₂		-----	-----	0.003	-----	-----	-----	-----
Cr ₂ O ₃		0.017	0.030	-----	0.020	0.003	0.055	0.020
NiO		0.389	0.386	0.358	0.415	0.403	0.393	0.362
Total		100.234	100.955	99.989	99.919	100.078	100.670	100.872
Formula on the basis of 4(O)								
Si		1.0396	1.0366	1.0391	1.0395	1.0398	1.0421	1.0318
Al		-----	0.0017	-----	-----	0.0007	-----	-----
Fe		0.1639	0.1610	0.1541	0.1653	0.1618	0.1612	0.1590
Mg		1.7460	1.7518	1.7574	1.7442	1.7458	1.7428	1.7672
Mn		0.0028	0.0030	0.0028	0.0027	0.0026	0.0027	0.0025
Ca		-----	-----	0.0000	0.0000	0.0000	-----	0.0001
Na		-----	-----	0.0006	-----	0.0025	-----	-----
Ti		-----	-----	0.0001	-----	-----	-----	-----
Cr		0.0003	0.0006	-----	0.0004	0.0001	0.0011	0.0004
Ni		0.0076	0.0074	0.0070	0.0081	0.0078	0.0076	0.0070
Total		2.9602	2.9622	2.9611	2.9603	2.9610	2.9574	2.9680
End member composition	Fo	91.42	91.58	91.29	91.34	91.52	91.53	91.75.
	Fa	8.58	8.42	8.21	8.66	8.48	8.47	8.25

“-----” Indicates not detected; Fo - Forsterite; Fa - Fayalite.

DISCUSSION

Bulk chemical composition of the Salem dunite shows the presence of all the chemical constituents within the specifications. These dunites come under the suitable category of the Ghosh et al., (1998;) classification of high magnesium

bearing rocks (Table 3). The deleterious constituents like Al_2O_3 and Cr_2O_3 are present within the permissible limits. These dunites also contain low LOI as compared to the conventional carbonate flux with LOI varying from 40-45%.

Table 2: Bulk chemical composition of Salem dunites (in wt.%) along with the Specification of dunite for use as flux in iron and steel making

Constituents	Specifications	Composition of Salem dunite
MgO	> 35	45.09
SiO ₂	< 48	41.05
Fe ₂ O ₃	8 to 12	5.430
Al ₂ O ₃	< 2	1.570
CaO	< 2	1.470
Na ₂ O	Combinedly	0.047
K ₂ O	< 0.02	0.029
TiO ₂	Not reported	0.018
P ₂ O ₅	Not reported	0.022
MnO	Not reported	0.057
LOI	< 14	4.380
MgO/SiO ₂	Not reported	1.098

Another important factor of chemical bias ought to be considered during flux selection is fouling index (Rf) which could be determined by the following equation.

$$Rf = (\text{Base}/\text{Acid}) \times Na_2O = 0.057$$

$$\text{Base} = Fe_2O_3 + CaO + MgO + Na_2O + K_2O$$

$$\text{Acid} = SiO_2 + Al_2O_3 + TiO_2$$

Rf values of the Salem dunites are found to be low (0.057) and are well comparable to those of the high magnesian rocks of Boula-Nausahi Igneous complex (Mohanty et al., 2001) while the same for limestone and dolomite are 0.75 and 1.09 respectively.

Table 3: Classification of ultramafic rocks for suitability for iron and steel making

Constituents	A	B	C	D
SiO ₂	< 40	< 45	> 45	> 50
MgO	> 35	> 30	< 30	< 25
Al ₂ O ₃	< 3	< 3	< 3	< 3
Total alkalies	< 0.2	< 0.2	< 0.2	< 0.2
Cr ₂ O ₃	0.6	0.6	0.6	0.6
CaO	2 to 3	2 to 3	2 to 3	2 to 3
LOI	< 14	< 14	< 14	< 14

A= Suitable; B=marginally unsuitable but if blended with high grade rocks may be feasible;

C= Unsuitable, can be judiciously used if blended; D= unsuitable

CONCLUSIONS

Salem dunite mostly contains fresh olivine having 91 Molar % of fosterite and 9 of Mol. % fayalite. Utilizing this as a flux dunite in iron making will also be cost effective and it can substitute the conventional flux. This, Salem dunites have a great promise both as a source to of substitute flux as well as for use in the neutralization of waste acids.

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FLY ASH MANAGEMENT IN INDIA – A REVIEW

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ABSTRACT

Indian energy scene is dominated by coal in view of insignificant reserves of other types of fossil fuels such as oil and natural gas. The annual growth in demand for coal is increasing @2.71% in India and currently over 340mt of coal is being produced. About 70% of the coal produced are used in power generation. The Indian thermal grade coal being high in ash (+35%), its burning in boilers generates fly ash which is a very fine powder and can remain air borne to pollute air, water and land, because its constituents include heavy toxic metals like Cu, Ni, Co, V etc. The current generation of fly ash in India is about 118mt/ year. The disposal of flyash has become a major problem requiring large tracts of land for dumping and thus reducing the availability of agricultural land besides contaminating underground water resources with traces of toxic material. The pozzolanic character of fly ash has made it amenable to be used in production of blended cement. Standard quality fly ash can be used as a blending material in cement manufacture to the extent of 35% for improvement in quality, cost reduction and conservation of resources. The other area of flyash utilization include land filling, mine filling, construction of roads and embankment, manufacturing of bricks, agriculture etc. At present in India about 50mt of ash is being used annually in these areas. R & D efforts should be made to enhance its use.

Key words – Toxic, Leachet, Pozzolanitic, Radon, Ash pond

INTRODUCTION

The Indian economy while steadily climbing its growth path, an excellent GDP growth of 6-8% has been achieved since 1994. In the year 2006-07 the GDP has grown in excess of 8%. To sustain this growth, our energy requirement is increasing at an annual rate of 6-7%. The Indian energy scene is dominated by coal and would continue to do so for many decades in view of large reserves of coals in India in comparison to oil and natural gas reserves. Over the past twenty years India's dependence on imported crude oil has increased from 30% to 70%. To meet

the energy shortages, an integrated energy policy gives thrust on such renewable energy sources such as wind, bio-mass and the sun. India is also integrating its foreign, defence and nuclear policies to country's energy security by import of fuel grade uranium to enhance generation of electricity from nuclear power plants. In view of near self sufficiency in thorium, technology development to process indigenously available thorium to nuclear fuel grade material has assumed priority. **Fig.1** shows the present share of different fuels and energy sources in generation of electricity in India.

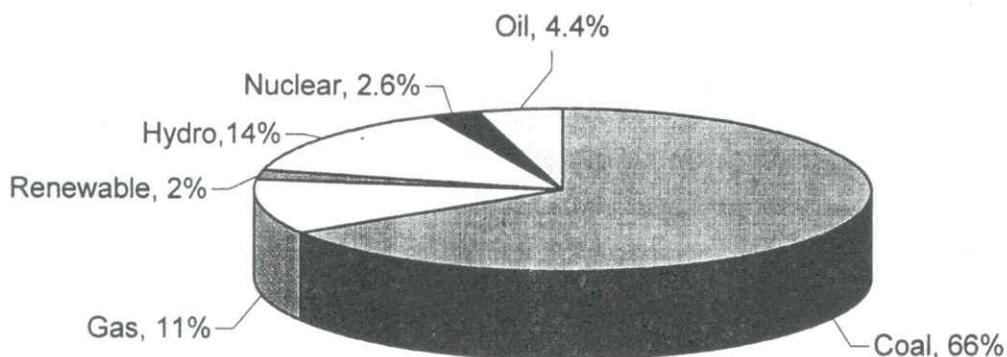


Fig. 1 : Fuel and energy share in production of electricity in India

The growth of the coal mining industry was very slow till nationalization of sector in the early 70s. The growth of coal production in India in these years since nationalization has been impressive not only to meet the requirement of power sector, but also of manufacturing sectors like steel, fertilizers, cement and others. Currently India produces over 340 million tonnes of coal to meet the requirements of these sectors. As on 31st March 2005 the country has a total installed capacity of 118419MW for generating over 587 billion units of electricity. The thermal power plants account for installed capacity of over 62,000MW. In spite of increase in power generation the demand for electricity in the country has outstripped the supply and the shortages continue to restrict our GDP growth. The shortage of electricity in the country is shown in **Fig. 2**. Considering the resource base of coal in India the Govt. decided to add 16.5 Gigawatt of new coal fired generating capacity during the 10th plan period and plans to add more than 50 Gigawatts of

new coal fired capacity during the 11th plan. Every form of energy conversion such as burning coal for electricity generation has some environmental implications. The bulk of Indian coals belong to non-coking thermal grades containing high ash in excess of 35%. About 15 metric tonnes of coals are burnt daily for a 1 MW plant and on an average it generates 0.3 kg of coal ash per KWH of electricity generated (**Fig. 3**). The collection and disposal of ash cause serious problems, which in turn contribute to environmental pollution. Two categories of ash are normally generated in a coal based thermal power station.

- a) Bottom ash – Collected at bottom of boiler furnace as a result of burning activity.
- b) Dry fly ash – Collected from different rows of electro static precipitators in dry form.
- c) The above two types of ashes stored is termed as pond ash.

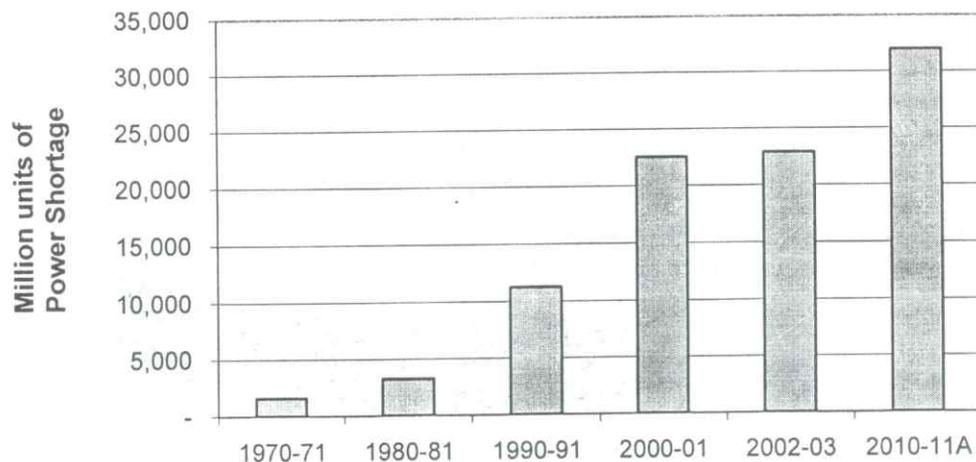


Fig. 2 : Power shortage in India

Currently over 118 million tonnes of ashes are produced all over India by thermal plants and generation would exceed 200mt by 2011-12 in case coal based thermal power generation is doubled.

The coal based thermal power generation units both in utility and private sectors in Orissa are given in Table No.1 and these plants have potential to generate 10mt of fly ash annually.

Table No. 1 Coal based Power Plants in Orissa

1.	Talcher STPS	3000 MW
2.	Talcher Thermal	460 MW
3.	Ib Thermal	420 MW
4.	NALCO CPP, Anugul	960 MW
5.	NALCO, Damanjodi	57 MW
6.	Rourkela Steel Plant	128 MW
7.	ICCL – Chowdwar	108 MW
8.	Hindal Hirakud	167.5 MW
9.	Nava Bharat Ferro Alloys, Anugul	30.0 MW
10.	OCFL, Paradeep	55 MW
11.	PPL, Paradeep	32 MW
TOTAL		5417.5 MW

ENVIRONMENTAL POLLUTION POTENTIAL

The 75% of the coal ash is in the form of “fly ash” which is a very fine powder.

Fly ash is generally grey in colour, abrasive, acidic and refractory in nature and possesses pozzolanic property. It has a fineness of 4000 to 8000 sq. cm. per gram. Its particles, ranging in size from as much as 120 to less than 5 microns in

equivalent diameter, are light and has the potential to get air borne and pollute the atmosphere. Prolonged inhalation of these particles causes fibrosis of lungs, bronchitis, pneumonites and other diseases. The chemical composition of

the fly ash generated in some coal based thermal power plants are given in Table No. 2

Table No. 2 Analysis of NTPC fly ash

Sl. No.	Constituents (%)	Fly Ash						
		Stn.A	Stn.B	Stn.C	Stn.D	Stn.E	Stn.F	Stn.G
1.	LOI	0.94	0.33	0.63	0.32	0.58	1.31	0.115
2.	SiO ₂	55.50	63.40	60.1	59.97	64.31	63.04	65.2
3.	Fe ₂ O ₃	4.40	4.52	5.80	5.75	4.45	5.12	7.73
4.	AL ₂ O ₃	36.40	29.70	26.50	27.9	25.6	28.40	23.45
5.	CaO	1.20	0.55	4.80	0.85	1.03	0.50	0.47
6.	MgO	0.50	0.50	1.20	1.00	0.97	0.46	0.46
7.	SO ₃	--	--	0.35	-	-	-	-
8.	Na ₂ O	0.30	0.38	0.22	0.15	0.60	0.23	-
9.	K ₂ O	0.80	0.85	0.75	0.70	1.02	1.13	-

Indian coals contain 16 to 18 trace elements like B, Ba, Co, Cu, Ga, Ge, La, Mn, Mo, Nb, Ni, Pb, Sn, V, Zr etc., which get concentrated in coal ash. The toxicity level of these trace elements varies- Copper is twice as toxic as the same weight of Zinc and Nickle is eight

time as toxic. The ash generated are stored in ash ponds and heavy metals present may contaminate the ground water through the process of leaching. The results of study of leachate characteristics of fly ash generated in some thermal power plants are given in Table No.3

Table No. 3 Leachate characteristics of fly ash

Sl. No.	Parameters Concentration in µg/L	Source		
		Korba	Talcher	Farakka
1.	Arsenic	1.2 – 6.2	0.6 to 2.5	4.0
2.	Barium	28 – 236	10 – 26	809
3.	Cadmium	<0.1 – 1.2	< 1 -3	< 1
4.	Chromium	<1 -7	5-10	91
5.	Copper	12 -112	114 – 280	4
6.	Lead	8 – 78	29 – 66	6
7.	Manganese	61 – 136	< 0.5	<0.5
8.	Mercury	< 0.5	< 0.5	< 0.5

9.	Nickel	20.63	8-24	<1
10.	Zinc	36 – 112	57 – 143	197
11.	Fluoride	-	1090 – 1260	900

Dumping of fly ash require large tracts of farm land and posses serious threats to all living beings and adversely affects vegetation. The excess burial of fly ash degrades the valuable agricultural land.

UTILISATION OF FLY ASH

The efforts made in the last decade to utilize the fly ash waste as a material for value addition have yield rich dividend. These have helped to increase the meagre utilisation of 3percent of generated 40mt. fly ash in 1994 to an impressive 50percent of 118mt generated in 2006. The major areas of utilization of fly ash include use in manufacture of cement & bricks, construction of roads, embankments and dykes, land fill and agriculture etc.

Currently in India fly ash based Portland Pozzolana Cement (PPC) constitutes about 60% of the total production of

165mt of cements of all types. In this type of blended cement maximum of 35% of flyash is being used. Blended cements are replacing OPC (Ordinary Portland Cement) because of major advantages such as lower heat of hydration, high resistance to alkali aggregate reactions, more durability, resistance to acid attack, sulphate resistance etc. Fly ash content in PPC can be increased if following actions are taken.

1. Using only dry fine fly ash from ESP/ bag filters.
2. Lowering carbon content of fly ash by proper buring of coal in boiler.
3. Using classified fly ash

Properties of flyash suitable for cement production as stipulated in IS 3812 -2003 are given in Table No. 4

Table No 4 : Properties of fly ash for use in cement/ concrete as per IS: 3812-2003

Characteristics		Grade - I	Grade - II
1	Fineness m ² /kg (min)	320.0	250.0
2	%age on 45 μ (max)	34.0	40.0
3	Strength activity index % (min)	80.0	80.0
4	Lime reactivity N/mm ² (min)	4.5	4.0
5	Loss on ignition % (max)	5.0	5.0
6	Reactive SiO ₂ % (min)	20.0	20.0

Manufacturing of building bricks using fly ash can reduce its accumulation. Since conventional bricks consume top soil suitable for agricultural use, there is

increasing pressure to ban the production of conventional bricks and switch over to fly ash bricks. Fly ash brick is identical to conventional fired brick in dimension and

physical characteristics but the technology of manufacture is an improvement over sand lime brick making. The product is made by mixing fly ash with water and lime (lime is not necessary if fly ash has high levels of lime), pressing and compacting the mixture in a mould or press and curing the brick in a steam autoclave. The technology developed by Central Fuel Research Institute (CFRI), National Council for Cement and Building Material Technology (NCB) and Central Building Research Institute (CBRI) etc. is being used in factories producing bricks which are used for wall construction in residential, commercial and industrial buildings. The process is based on the reaction of lime with silica of fly ash to form calcium silicate hydrate, which constitute the main binder in these products. The bulk density of the brick is 1.55 g/cc, cold crushing strength 100-150 kg/cm², water absorption capacity 20% and brick is not affected by salt and air. The brick does not loose strength unduly. The expansion due to moisture is +0.06%. The manufacturing process eliminate burning of coal used in clay bricks and helps to conserve resources and reduce emission of CO₂ gases.

Fly ash is endowed with immense soil amendment characteristics, for it changes the soil texture for the better, improves water holding capacity, optimizes pH value, reduces crust formation, improves soil aeration, enriches micronutrients such as Fe, Cu, Zn, Mo, B etc. and macronutrients like K, P, Ca etc. Fly ash can be used to increase plant productivity, but before adopting mass scale application to increase agricultural production it is

necessary that agriculture, food and genetic experts thoroughly examine the resultant farm produce from fly-ash applied lands and certify it as a safe product for consumption considering toxicity, nutritional values and radioactivity. Some of the trace elements have the tendency to concentrate in varying amounts in different parts of the plant. For example Ni is often more concentrated in the seeds than in leaves and stems.

Another area for fly ash utilization is its use as a land filling material and as a replacement of sand stowing in underground coal mines. Sand stowing in mines is an important conservation method. Mine filling with fly ash eliminates excavation and transportation of scarce river sand and substantial reduction in water requirement for the process. This also helps in increasing coal output as facilitate mining of coal stuck up in pillars. The sand resources of the rivers in and around the coal field have considerably depleted and sand transportation, distances are progressively increasing adding to its haulage cost and also coal cost.

Another area for fly ash consumption on mass scale is in construction of roads and embankment replacing soil utilization. The quality of construction is better due to good compaction, high internal angle of friction, high range of OMC etc., Road construction become easy and faster and conservation of soil helps to increase agricultural produce, The total utilization pattern of 48 million tonnes of fly-ash in India during 2005-2006 is depicted in in **Fig. 4** and the year-wise ash utilization at STPS is depicted in **Fig. 5**

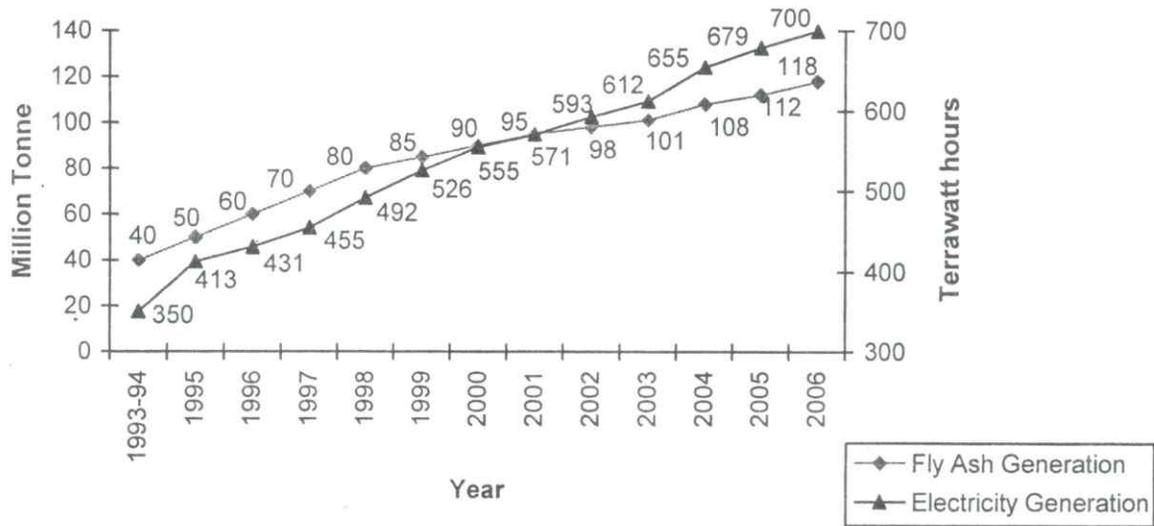


Fig. 3 : Ash & Electricity Generation in India

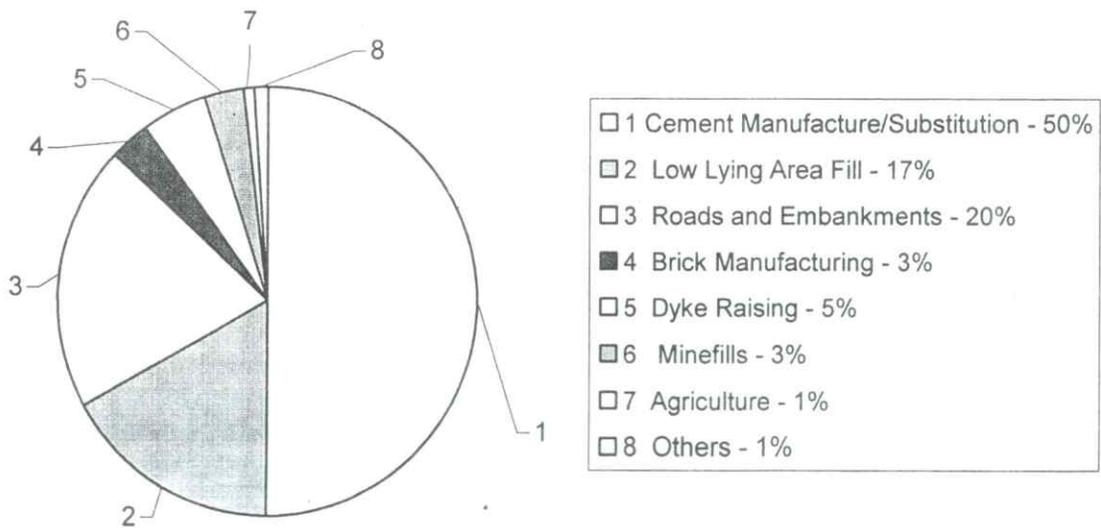


Fig.4 : Total Utilisation Pattern of Fly Ash

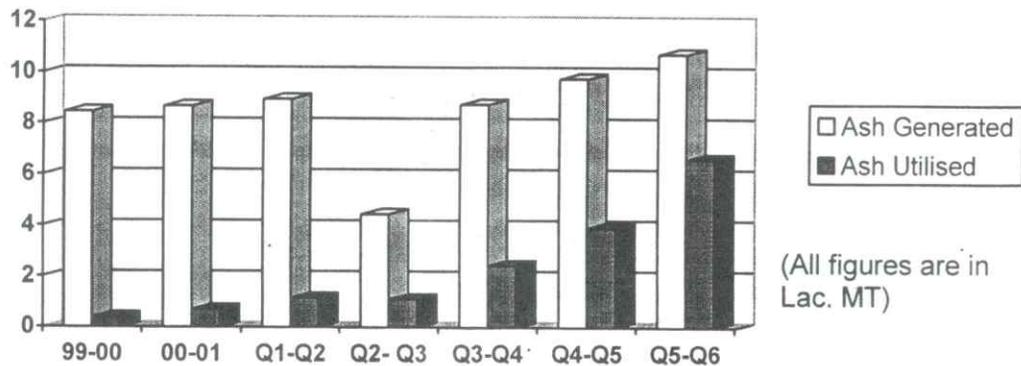


Fig. 5 : Yearwise Ash Utilisation at STPS

RESEARCH & DEVELOPMENT

Identification and development of promising and potential technologies on utilization of fly ash assumes importance to achieve the goal for 100% utilization. R & D infrastructure must be developed. R & D output must be demonstrated by setting up demonstration-cum-confidence building pilot plants.

Prof. Michael A. Powell, University of Western Ontario experimented on the use of fly ash along with urban sludge for

forestry to check on the aspect of radiation. The test results of his experiments on emanation of Radon from Indian bricks made using fly ash are given in Table No.4 a, b & c. His opinion is that these bricks may not be allowed for construction in North America as the radiation level is high. In India, where there is much more exchange of air inside a building with the outside air the diluted concentration is considered safe. It would depend on the type of building and ventilation.

Table No. 4 –a Emanation Data

BRICK 1

Brick Origin : Sample of fly ash bricks made by C.B.R.I. from Ash collected from Fly Ash Ponds of T.T.P.S., Talcher.

Description : Almost Square, Grey Brick, 5 cm X 5 cm X 5.2 cm

Surface Area : 152 cm²

Measured Radon Concentration (pCi/L)	Total Radon in Apparatus (pCi)	Emanation (pCi m ⁻²)	Emanation (KBq m ⁻²)
1.95	8.87	584	21.6
1.98	9.00	593	21.9

Table No. 4-b Emanation Data

BRICK 2
 Brick Origin : Sample of fly ash bricks made by C.B.R.I. from Ash collected from fly Ash Ponds of T.T.P.S., Talcher.

Description: Cuboid, Grey Brick, 10.4cm x 5.3cm x 3.02cm

Surface Area: 204.65 cm²

Measured Radon Concentration (pCi/L)	Total Radon in Apparatus (pCi)	Emanation (pCi m ⁻²)	Emanation (KBq m ⁻²)
2.52	11.47	560	20.7
2.04	9.28	454	16.8
2.01	9.15	447	16.5
2.52	11.47	560	20.7

Table No. 4-c Emanation Data

BRICK 3
 Brick Origin : Sample of fly ash bricks made by C.B.R.I. from Ash collected from fly Ash Ponds of T.T. P.S., Talcher.

Description : Cuboid, Grey Brick, 10.4cm x 5.3cm x 3.02cm

Surface Area : 204.65 cm²

Measured Radon Concentration (pCi/L)	Total Radon in Apparatus (pCi)	Emanation (pCi m ⁻²)	Emanation (KBq m ⁻²)
2.40	11.47	560	20.7
1.67	9.28	454	16.8
1.40	9.28	311	11.5

Another area for fly ash consumption on mass scale, that could be considered, is to mix fly-ash with polymers and produce value added products. But this would require R & D work. If such an application becomes feasible, the problem of fly ash disposal will be solved. The potential areas include manufacture of alum, alumina, paints, synthetic wood, cenospheres etc.

Cement sector is the largest consumer of flyash. Its use to the tune of 16mt during 2004-05 led to the cost saving of about

Rs.3200/- crore for saving in energy cost (replacement of clinker which is energy intensive, approximately 4GJ of energy per tonne of cement), reducing input cost of raw material and transportation cost. There are international standards which permit even upto 55% addition of fly ash in blended cement. More benefits would accrue if in India, through R & D work, the utilization level can be enhanced from 35% level in cement manufacture.

ENVIRONMENTAL & CONSERVATION ISSUES

Human activity, particularly the beginning of the Industrial Revolution is increasing the level of Green House gases in the atmosphere and small changes are causing dramatic effect in global climate and environment. CO₂ has been identified as the most prominent source of green house gas effect. Each year over 25 billion tonnes of CO₂ are put into the atmosphere by human activities. Only about 3% of the emission is engaged in the natural flux between the atmosphere and oceans or land. The balance is critical, for CO₂ is responsible for over 60% of human induced global warming. All countries of the world are required to reduce CO₂ emission and as per Kyoto declaration in 1997, the developed countries would reduce this emission by 5% (about 600 million tones) by 2010 and developing countries like India would contribute by adopting cleaner technologies involving less use of fossil fuels like coal.

In Indian context, annual replacement of about 50 million of cement grade clinker by fly ash would mean avoiding burning of about 30 million tonnes of coal and reducing annually about 30 million tonnes of CO₂ being released in addition to reduction of other pollutants like SO₂, NO_x, etc. Saving in coal consumption in cement manufacture alone would give an additional lease of life to India's proved reserve of 102 billion tonnes of coal inventories. Fly ash helping in manufacture of cement, production of mortar and concrete would also help in conserving limestone in the country for 1600kg limestone is consumed in producing a tonne of clinker. As per the estimates, India has lime stone reserves, which are expected not to last for more than 50 years.

CONCLUSIONS

With the increasing application of fly ash in manufacture of blended cement, concrete products, in manufacture of bricks that replaces bricks made of top soil, fly ash can no longer be considered as a waste material. But fly ash based products have to compete with products made by conventional methods and to ensure their edge in the competition fly ash not only be supplied to user industries free of cost but also the cost of transportation need to be subsidized by generating power plants, for otherwise the generating units are required to meet the cost of disposal. Ministry of Environment & Forest (MOF) has prescribed time limit for the user agencies to gradually switch over from the conventional products to flyash based products within a radius of 100km of a thermal power plant. Ban on use of top soil in manufacture of bricks can not be enforced without ensuring availability of flyash based bricks and therefore public awareness is very important as such products are greener and need to be given preference. Further, such products should be kept away from Govt. taxes of any kind for some time. The co-operation between R&D organization, Power Plants, user Industries and Government is essential for achieving total utilisation of fly ash generated. Public awareness must be enhanced for preferential use of fly ash based products.

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NEED OF GEOTECHNICAL INVESTIGATION

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ABSTRACT

Slope stability is an important factor in the design and operation of open cast mining, quarrying and civil engineering excavation projects. In open cast mining, the design of stable slopes will have significant impact on the economics on the entire project. Long term monitoring of slope stability is essential to ensure that the risk to personnel, equipment, buildings and other infrastructure located nearby can be properly managed. Geo-technical Investigations forms an integral role in the opencast and underground mining operations, design of tailings dam facilities, stability analysis of waste dumps, management and design of other related civil engineering projects.

The basic data for undertaking stability analyses comes from the slope geometry, results of test-pitting or drilling, in-situ testing, laboratory testing and, in the case of rock slopes, joint mapping. Depending on the size and location of the slope, surface water and ground water hydrology will also play an important role. From the results of the site investigation, the predominant failure mechanisms and failure geometry can be defined. For existing failures, back analyses would be undertaken based on failure mechanism and slip surface geometry inferred from the site investigation. Where sufficient rock mass strength data has been collected, probabilistic methods can be used for the analyses of slope stability.

INTRODUCTION

In the early days, mine designs are solely based on historical experience with necessary design modifications to suit some of the known ground conditions, based on field experience and sound engineering judgment. Now a days, due to weak strata conditions followed by high extraction methods, a variety of design and operational problems need to be addressed. The main objective in utilizing these techniques is to

ensure that designs are based on sound engineering principles to suit the best advantages. The main function of mine design or mine planning in the broadest sense is to financially evaluate and optimize the mining project or operation.

The three main stages of characterizing the mine design process comprise of the following components shown in Table -1.

Table-1: Generalised Components of Mine Design Process

Conceptual Modeling	Phasing Base	Detailed Designs
<ul style="list-style-type: none"> Minerals and Rock mass data input 	<ul style="list-style-type: none"> Grade constraints 	<ul style="list-style-type: none"> General mine layout
<ul style="list-style-type: none"> Geological, geotechnical interpretation 	<ul style="list-style-type: none"> Geological reserves 	<ul style="list-style-type: none"> Mine-extraction sequence
<ul style="list-style-type: none"> Geological and geotechnical volume models 	<ul style="list-style-type: none"> Mining constraints 	<ul style="list-style-type: none"> Slope/Bench design or stope design layout
	<ul style="list-style-type: none"> Mining Reserves 	<ul style="list-style-type: none"> Schedules and evaluation
	<ul style="list-style-type: none"> Selection of Mining Methods 	
	<ul style="list-style-type: none"> Production reserves 	

GEO-TECHNICAL ASSESSMENT

The assessment of mine planning from geotechnical view-point usually requires

three major sets of data which is shown in Table-2.

Table -2. Sets of data acquisition for Geotechnical assessment

Mining Environment	Rock mass Characterization	In-situ Stress analysis	Mining Method/ Designs	Monitoring Programme
Geological setting	Intact rock mass strength properties	Numerical Methods	Selection of proper mining method Open Cast Underground Opencast / Underground	Geo-technical instrumentation for monitoring pit slopes or underground structures
Hydrology	Discontinuity data	Structural tests for stability	Ore extraction sequencing	Pit slope monitoring Ground monitoring during stoping operations
Mining history	Rock mass quality	Empirical techniques	Blasting and rock Breaking, Primary development, mine drainage	Monitoring Ground vibrations

Thus, description of the mine environment is essentially the foundation upon which an assessment is built and should include geological, hydrological and historical data on failures, if available. Pertinent details of the regional and mine geology are required to cover the general characteristics of the

rock types, structures, mineralization and geological history. It is also important to record details of ground water, surface water and precipitation given the effect of water on strength of intact rock and geological discontinuities and thus overall stability of rock masses.

REVIEW OF EXISTING CLASSIFICATION SYSTEMS

Rock mass classification is a means of evaluating the quality and expected behaviour of rock masses based on the most important parameters that influence the rock mass quality. Many researchers have developed rock mass classification systems and each may be more appropriate than others to use in different circumstances. One of the first such systems to be developed is the Rock Quality Designation (RQD) system. This system only accounts for the frequency of jointing within a rock mass as a measure of its quality. Later systems which have been developed such as the RMR and NGI Rock Tunneling Quality Index use the RQD as one of their measurable parameters, but also include factors such as intact rock strength, joint spacing, joint condition, field stress, and groundwater effects.

The other classification systems include Mining Rock Mechanics Rating (MRMR), Rock Mechanics Index (RMI), Basic Geological Index (BGI) and Slope Mass

Rating (SMR). Extensive published literature on application of these classification systems is available in several websites/ journals. Some classifications are used for opencast mines and some are used for underground mines.

Rock mass classification systems are important because they provide a consistent means of describing quantitatively the rock mass quality. This in turn has led to the development of many empirical design systems involving rock masses. Most of the Rock Mass Classification systems were evolved for hard rock mines, and unfortunately there are few classification systems available for soft rock masses. The evolution of basic rock mass rating system and adjustments were summarized in Table No.3. Before applying any classification systems for rock mass characterization, the advantages and limitations of these classification systems and its utility in open cast and underground mining applications need to be judged based on site- conditions.

Table No.3. Basic Rock Mass Rating System and Adjustments

Method	RMR ₇₆	RMR ₈₉	MRM	RMS	SMR	CSMR	M-MR	SRMR	GSI
Intact strength	0-15	0-15	0-20	5-20	0-15	0-15	0-15	0-30	0-15
Block size	8-50	8-40	0-40	8-30	8-40	8-40	0-40	8-40	8-50
- Spacing	*	*	*	*	*	*	*	*	*
- RQD	*	*	*	*	*	*	*	*	*
Defect condition	0-25	0-30	0-40	3-14	0-30	0-30	0-30	0-30	0-25
- Persistence							*		
- Aperture	*	*	*	*	*	*	*	*	*
- Roughness	*	*	*	*	*	*	*	*	*
- Infilling	*	*	*	*	*	*	*	*	*
- Weathering	*	*	*	*	*	*	*	*	*
Ground water	0-10	0-15	*	1-6	0-15	0-15	0-15	-	10
Defect orientation	(60)-0	(60)-0	63-	5-20	(60)-0	(60)-0	(12)-(5)		
- Strike	*	*	*	*	*	*			
- Dip	*	*	*	*	*	*			
- Slope dip -					*	*			
Excavation	-	-	80-	-	(8)-15	(8)-15	80-100%	-	-
Weathering	-	-	30-	3-10	-	-	60-115%	-	-
Induced stresses	-	-	60-	-	-	-	-	-	-

Major plane of weakness	-	-	-	-	-	-	70-100%	-	-
Total Range	52-100	52-100	0-120	25-100	60-115	63-141	7-105	8-100	18-100

PRACTICAL SLOPE DESIGN

The design of rock slopes in open cast mines involves first gaining an understanding of the pit slope geo-technical parameters. During the feasibility stage, this information will be gathered through a geo-technical data collection program that includes mapping of outcrops, diamond drilling, and laboratory testing. The orientation and frequency of geologic structure is the most important control on slope stability. Practical slope design address the following aspects:

- Assessment of the stability of slopes under specified conditions
- Evaluation of the possibilities of the failure of slopes.
- Determination of the influence of proposed changes on a slope.
- Comparisons of the effectiveness of alternative remedial or preventive measures .
- Sensitivity analyses for evaluating the influence of variations in critical parameters such as geometry, material properties and groundwater conditions on the stability of slopes
- Analysis of failures that have already occurred. This helps to understand failure mechanisms and obtain in-situ material properties.
- Design of remedial or preventive measures for slopes, and
- Assessment of the effects of exceptional loadings such as earthquakes.

The most important use of slope stability analysis is in the optimization pit slopes and the effect of on this on stripping ratio. Slope design must encompass many other factors such as access roads, drainage and reclamation and revegetation, keeping in view of progressive and final mine closure plan.

Various reviews of slope design methodologies has revealed that strength of the rock mass determination is difficult. For rock masses in a particular region, back analysis of previous failure proves to be the only practical approach for obtaining relevant strength parameters. However, interpretation and translation of such data from one geological environment to another is linked with problems. Design method for rock slopes can be divided into mainly four categories, namely :

1. Limit equilibrium methods
2. Numerical modeling
3. Empirical methods
4. Probabilistic methods

CASE STUDIES

The problem of pit slope stability is a matter of concern when the mines operations go deeper followed by weak strata conditions as being experienced in Goan iron ore mines and in Sukinda valley chromite mines. A review of cases available on the subject demonstrates that the displacement, stress distribution, ground water, strength and stability of rock formations. are significantly influenced by properties and distribution of strata. Similarly pit slope monitoring studies

carried out indicated that the mechanism of slope failures can be complex and dependent on failure pathways, where certain units fail first and it is followed by subsequent failures due to redistribution of stresses from the proceeding zone. The results of many laboratory studies and monitoring of the slopes have lead to an awareness of various mechanisms of failure and the conditions under which they occur. On a laboratory or



Fig. 1
Gross instability of benches

It is necessary in any slope stability program to understand the failure mechanisms and the possible conditions under which they may occur. However, our ability to assess different failure types or its combination or dynamic process is limited with the present methodologies adopted. The problem for designers of slope is how to cope up with complexity and variability. The process of design must consider observations on rock behavior and fracture mechanics, monitoring of rock movements and stresses together with an assessment of the simplified mechanisms of failure to obtain an understanding of ground behavior. Computer methods can assess the interaction of ground interacting rock failure mechanisms in complex geological conditions.

In most instances the shape of the distribution function for input parameters is

bench scale, the structurally controlled failure mechanisms such as planar, shear, wedge are well understood whereas in real world situations, the failure mechanisms are much more complex involving a many other variables due to complexity in behaviour of geological materials. The progressive bench slope failure mechanism are shown in the photographs (**Fig. 1 & Fig. 2**).

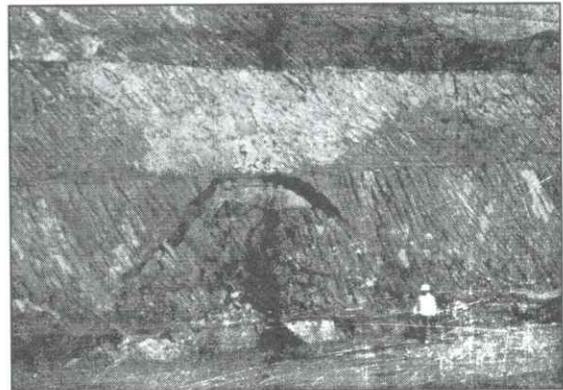


Fig. 2
Local bench Failures

unknown and even so with probability analysis, engineering judgment is often used to assume the shape of the distribution function. Probability analysis are useful way of analyzing slope stability problems providing assumptions on which they are fully recognized. Other debating issue in geotechnical literature is, which slope stability method is correct include the following questions such as:

- Does it cover force equilibrium
- Does it consider moment equilibrium
- Does it have local or global factor of safety
- Does it consider inter-slice shear strength
- Does it allow non-vertical slices
- Does it allow progressive failure
- Is it Kinematically admissible

Different values of Factor of Safety are often compared by quoting factor of safety values. Finite Element Analysis using most modeling techniques do not necessarily produce the “right” answer. And for slope stability analysis in complex geology, could in fact produce misleading results. Secondly, factor of safety values should not be quoted to high level of accuracy since the input parameters will rarely be known with sufficient accuracy to warrant this level of definition for the factor of safety. In summary, the stability of any slope is dependent of the method of analysis. Some methods of slope stability analysis are better suited to some problems than others. And in this respect, the geotechnical engineer should choose the method of analysis carefully. No one method is ideally suited to all problems and users should be aware of the advantages and limitations of different methods.

Slope stability problems:

There are two scales of slope stability problems;

- Gross stability
- Local stability

Gross stability refers to large volumes of material, and gross instability involves, in case of deeply weathered rocks and soil, large “rotational –type failure.

Local stability refers to much smaller volumes the corresponding failure that can affect one or two benches at a time are due to:

- Shear planes, jointing
- Slope erosion due to surface drainage
- “Piping” caused by ground water flow emerging at the ground surface.

Problems of local instability can be serious and can lead to gross instability if not attended to: for example the effect

of surface erosion in open pit slopes is particularly strong and damaging.

FAILURE MECHANISMS

Circular Failure

When the material of hill slope is very weak such as soil, heavily jointed or broken rock mass, the failure is defined by a single discontinuity surface but will tend to follow a circular failure path. The conditions under which a circular failure will occur arise when the individual particles comprising the slope are very small as compared to the slope and when these particles are not locked as a result of their shape and tend to behave as a ‘soil’.

Circular Failure Charts

This type of failure is similar to the famous slip circle failure of earth and rock fill dams for which analysis is well known. However, a series of charts are available to carry out the rapid check on the factor of safety of soil or waste rock mass whose properties do not vary much.

Toppling failure

This type of failure generally occur when the hill slopes are very steep and comprise highly jointed rocks in vertical layers or columns. Such failures are common. This type of failure involves rotation of columns or blocks of rock about some fixed base seen in mountain regions in the form of accumulated scree at the base of steep slopes. These screes are generally small pieces of rock which get detached from the rock mass and fall individually into the accumulated pile. This toppling failures are of three types viz flexural toppling, block toppling and block-flexural toppling depending on the nature of discontinuities or the jointing pattern.

GEO-TECHNICAL INSTRUMENTATION AND MONITORING

Geo-technical instrumentation is one of the on-line activities in opencast or underground mining to study the rock mass response during the excavation sequence. It plays a vital role in deriving meaningful information on rock mass behaviour and for installation of support during progress of mine development.

Now a days, several types of monitoring instruments are being manufactured in our country, which is relatively inexpensive as compared to imported ones. Several types of instruments have a specific purpose of monitoring. These include measurement of in-situ stress, change in stress, strain, load, deformation, closure measurements and displacement etc. The instrumentation goals should be well defined before taking up choice and type of instrumentation and its costs. The following considerations need to be made prior to Instrumentation planning:

1. To provide accurate, timely data on rock mass and its behaviour of on-site correlations with periodic events and observations
2. To establish data base of events in chronological order, that would be useful in establishing the predicted and observed conditions
3. To maintain valid data acquisition system with specification followed by Installation Plan
4. To monitor the strata conditions in order to develop proper and timely support measures to maintain the safety of excavations.

Table. 4. provides a summary of geo-technical instrumentation suitable for slope stability investigations.

Table. 4. Summary of instruments suitable for slope stability during excavation:

Measurement	Suitable Monitoring Instruments
Surface deformation	Surveying methods, Crack gages, Tiltmeters, Multi-point liquid level gages
Sub surface deformation	Inclinometers, Fixed borehole extensometers, slope extensometers, shear plane indicators, multiple deflectometers, in-place inclinometers, combined inclinometer-piezometer system, Acoustic emission monitoring
Ground water pressure	Single or multi-point piezometers, combined piezometer and inclinometer systems

In order to gain an understanding of the long-term stability of slopes, it is necessary to have a good slope monitoring programme to provide a forewarning of instability so that remedial measure can be implemented

before critical situation arise and stabilizing the slope by monitoring program to verify whether the desired safety has been achieved.

PROBABILISTIC ANALYSIS

Probabilistic analysis is receiving increasing acceptance in several areas of geo-technical engineering. In slope stability analysis it has been recognized that the factor of safety is not necessarily a good indicator of the probability that a slope would fail. A slope can have a factor of safety higher than that of another but still have higher threat of failure. This is due to the fact that factor of safety analysis utilizes average values of parameters and thus can mask the wider variation (uncertainty) in the values of the different parameters affecting stability. With probabilistic analysis engineers will be able to assess the risks of failure associated with different slope conditions.

SLOPE DESIGN CURVES

Slope performance curves provide a valuable tool in the design process where rock mass failure plays a strong control in the stability of slopes. The curves are derived from the performance of stable and unstable slopes plotted on a slope angle versus slope height. The curves are often site specific and take into account the impact of existing failures, the remaining time frame for mining and the acceptable risks to the mining operation.

Extending slope design curves from being a site specific tool to a general tool must be treated with caution. Early attempts at doing this include **Lane (1961)** and **Fleming et al (1970)** for slopes in shale, **Coates et al (1963)** for "incompetent rock" slopes, **Shuk (1965)** for natural slopes, **Lutton (1970)** and **Hoek (1970)** for general rock excavations.

Slope design curves have been developed based on a number of stable and unstable open pit mine slopes. Shear strength estimates for rock slopes that were proposed by **Bieniawski (1976)** are too high for

values of GSI below 40. The design curves using strength estimates proposed by **Robertson (1988)** predict steeper angles than the author's design curves. Most slopes will be structurally controlled and therefore a rock mass rating system will not be applicable for most slope design. Empirical slope design using rock mass rating systems should only be considered for slopes in rock masses with GSI values lower than about 45 and only after any potential structurally controlled failures have been investigated.

SLOPE STABILITY GUIDELINES: GENERAL CONSIDERATIONS

Considering the back analysis of slope failures the factors that influence the slope stability include:

1. Attitude of formations contacts, structural elements in relation to attitude of slope
2. Nature of slope forming materials
3. Presence of major discontinuities like dykes, faults, sills, folds etc
4. Position of ground water table
5. Irregularities in pit design (abrupt changes)
6. Condition of benches

For a desired slope (Height and inclination), the relative influence of the above factors can become determinant "stability-wise". Based on the above guidelines, and field experience in Goan Iron Ore mines the failure diagnostic weightage has been evolved with the following parameters:

1. Change in slope angles: 40%
2. Laterite cover and structural conditions: 25%
3. Ground Water uplift pressure: 15%
4. Surface erosion: 10%
5. Irregular pit design: 5%
6. Unidentified reasons: 5%

REMEDIAL MEASURES

Based on the geo-technical investigations conducted the following measures need to be ensured for maintaining safe workings:

1. Monitoring with EDM to measure slope movement and to take timely action if the movement crosses critical limit.
2. To ensure meticulous execution of approved mine layout – aspects like slope angle, bench height, width and maintaining excavation limits
3. By constructing buttress walls by placing the waste material preferably laterite muck at the toe of the excavated clay benches to provide toe support of the benches and will minimize slope movement.
4. Dewatering the slope face by lowering the water table by pumping the water around the pit boundaries or drilling drain holes into the pit slope face.
5. Segmenting the overall slope faces with stepped out excavation.
6. Workings along strike direction to be restricted upto 100-150m.
7. To maintain a general pit slope angle of 25°-28 ° in clayey formations.

CONCLUSIONS

The slope instability problems at Goa and Sukinda can be attributed due to the influence of several factors such as local geo-technics, incompetent nature of the foot wall and hangwall rocks and hydro-geological problem arising due to raising of

water table during the monsoon, and impervious nature of the foot wall strata. Necessary protective measures are suggested to minimize the risk of strata movement using ground monitoring. Further numerical modeling and analysis is in progress to evaluate the relationship between slope height and slope angle with reference to Factor of Safety to develop slope design curves.

ACKNOWLEDGEMENTS

The authors wish to thank the Head of the Department, Department of Mining Engineering, VNIT, Nagpur, Dr. J.L. Jhetwa, Director (Retd), CMRI, for providing encouragement to publish the paper. The views expressed in the paper are the authors own and not necessarily to the Organisation they belong.

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Mineral Prospectivity of the SADC Region

This article is intended to summarise current understanding of the geological evolution and distribution of minerals in the Southern African region. More importantly, we hope to stimulate new thinking on the excellent prospectivity of the region so that new mineral resources may be unlocked as a driver of future economic development. The views expressed herein are those of the authors and not those of the SADC or EU authorities.

Geological Evolution of the SADC Region

The surface of Southern Africa, at an average elevation of 1000m, has come about over the last hundred million years as the land gradually rose 1,500m above sea level. Erosion continuously took place, with at least an average 500m thickness of rock being preferentially removed to sculpt the present topography. In so doing, the Karoo flood basalts (300-150Ma), initiated during the rifting and break-up of the supercontinent of Gondwana, were eroded away, but leaving remnants such as the Drakensberg basalts (205 to 142Ma) in Lesotho. The uplift also caused tensional, gravitational strains in the great mass of the continent giving rise to the present day rift valleys and the development of the great stratovolcano, Kilimanjaro. This rifting will eventuate in a large portion of eastern Africa separating over a few million years and moving east as part of the Somali tectonic plate (Maps 1 and 2).

While erosion has undoubtedly destroyed many mineral deposits, it has also penetrated down into the earth to

the oldest rocks. This process has revealed, through generations of prospecting combined with mining, and to civilisations' benefit, a wide range of valuable mineral commodities from gold and platinum in the Archean (3600 to 2500Ma) to coal within parts of the Karoo sedimentary sequence (290 to 242Ma). In order to better understand how mineral deposits came into being and the timing and emplacement in geological environments where new deposits may be discovered, a brief review of Southern Africa's long geological history is presented.

Archean Craton Development

The earth is about 4700 to 4500 million years old and by 3900Ma it had cooled sufficiently for a worldwide ocean to form, perhaps to an average depth of four kilometres. The molten rock beneath the earth's thin crust segregated into a lighter, upper granitic layer and progressively heavier material with depth. By 3800Ma linear volcanic belts had developed in many regions, along the margins of the granitic segregations which had begun to gather together as proto-continentals. By 3600Ma these proto-continentals has grown to the extent that they formed by accretion large, deep rooted granitic areas with overlying volcanic rocks.

These are the cratons which are the defining characteristic of the Archean (Map 3). The early Archean eon may be said to extend from 4500Ma, at the time of the moon formation impact, to the Paleoproterozoic at 3600Ma, prior to the development of continents. The Hadean followed by the shorter Isuan, European

stages, overlaps with the South African, Swazian stage from 4000 to 3000Ma. This article is primarily concerned with the Paleoproterozoic onwards. (Figure 1) The specific gravity of the continental crust is less than that of the basaltic ductile rock underlying the ocean floor; thus the continents adjust their height above the ocean floor in much the same manner as an iceberg has about ten percent of its mass above water. This is known as isostatic adjustment. However, there must be other factors at work in the case of the continents. As mentioned above, Southern Africa has risen 1.5km in the last 100 million years for no obvious reason. There are clearly other forces at work. Perhaps the position of the continent relative to underlying mantle convection cells exerts an influence. In any event, it is evident that some of the vital chapters in earth's history have yet to be read while others appear to be seen as if 'through a glass, darkly'. The proto-continents were separated by thin, crustal, basalt-covered oceanic floors comprising about 75% of the planet's surface area. Continental crust is generally thought to be about 40km thick, increasing to about 95km beneath mountain chains such as the Andes. In today's SADC region, the continental roots extend as much as 150 to 250km deep, compared to about 5 to 10km thickness of the oceanic crust.

During the early Archean, in areas where the volcanic accumulations rose above the ocean surface, they were eroded and produced flanking greywacke sedimentary rocks. These volcanic belts attained great cumulative thicknesses, not necessarily at the same location. For example, the Barberton greenstone belt in South Africa and Swaziland, may have represented a total accumulation of

15km. Later intrusion of the volcanic areas by granitic domes resulted in the volcanic belts having steep dips around the flanks of the domes. Subsequent erosion of the flatter-lying volcanic rocks above the domes produced the reticular pattern of the steeply dipping volcanic rocks around the domes we see today. For the most part, the volcanic rocks are well preserved and only weakly metamorphosed, except where they have been subjected to intense folding, as in the case of the Limpopo mobile belt. The Archean volcanic rocks, primarily basaltic, were partially differentiated, during their formation, to produce a ten to fifteen percent felsic or rhyolitic component favourable for the deposition of base metal massive sulphide (VMS) deposits. Similarly, gabbroic and ultramafic components are favourable for the occurrence of nickel mineralisation. Venting of high temperature fluids saturated with sulphur and dissolved minerals, mixing with cool, saline waters at the ocean floor, may have produced the world's first sulphide deposits. It is possible that life began at these deep submarine volcanic vents, where sulphur feeding microbes developed at about 3500Ma. During crustal evolution, heat, augmented by radioactive decay, was trapped within the earth. The continued functioning of large convection cells in the earth's mantle caused linear breaks in the weaker oceanic crust and the continental masses moved apart at the rate of several centimetres a year. Under these conditions, an advancing continent would override the ocean floor and its overlying sedimentary accumulations derived from the land, and reincorporate them within its mass. This recycling process has enabled the earth's land area to remain relatively constant over time,

even if its geographic distribution has been very variable. As time went on, the moving protocontinents collided to form continents, which, after further collisions, formed supercontinents before eventually breaking up. The early history of the continents is not well known, but by the later Paleoproterozoic, at the time of the Zimbabwe orogen at 3300Ma (Figure 1), a substantial 'African' continent had formed. In all, there may have been four cratonic areas in southern Africa, a very large one in the west, the Kasai craton, and three in the east, aligned from north to south, the Tanzanian, Zimbabwe and the Kaapvaal cratons respectively. Additionally, the island of Madagascar is underlain by cratonic material dating from the African detachment event of 200Ma. After the Zimbabwe orogen, continental type sedimentation took place in part of southern Africa some 300 million or more years earlier than elsewhere (3074-2714). The deposition of the Mesoproterozoic Witwatersrand fluvial, quartz conglomerates took place within this long time period. Recent work gives a date of 3030Ma for rounded pyrite and uraninite in the Witwatersrand, indicating a similar age for rounded gold granules, suggesting that the gold is older than the enclosing sediments. The large quantities of gold in the Witwatersrand appear far too great to have been derived from greenstone belts and appear to have been deposited as placers. However, determining the nature of the gold's source will be critical in guiding exploration for similar deposits in Africa and elsewhere. Collision between the Kaapvaal and Zimbabwe cratons gave rise to the Limpopo mobile belt in the Neoproterozoic. The emplacement of the Great Dyke complex took place towards the end of

the Limpopo orogeny and the emplacement of the Bushveld Complex at the early onset of the Ubendian orogeny at 2050Ma. It is noteworthy that both the Limpopo and Ubendian orogenies, separated by 350 million years in time, appear to correlate with worldwide orogenies. It is difficult to understand such apparent all encompassing orogenies in the context of normal plate tectonics, where plates have active margins associated with collisions and passive margins which are not disturbed. By the later Archean the evolution of life had gradually reached a stage where some organisms had mastered the complex process of photosynthesis and thus continued to progressively oxygenate the atmosphere. One effect of this was that uranium minerals became soluble in oxygenated water and consequently were no longer developed as placer deposits. More significantly, banded iron formation (BIF) began to be deposited, through biogenic/chemical processes with increasing frequency. In the Archean the rate of BIF deposition was slow, perhaps because photosynthesis with oxygen as a waste product was to some degree toxic to blue green algae which needed time to evolve greater tolerance. Anaerobic micro-organisms were unable to survive in oxygenated environments.

Proterozoic

The Archean, including the early Hadean and Eoarchean stages, since the formation of the earliest earth rocks, lasted for more than two billion years (4550-2500Ma). The ensuing Proterozoic lasted almost two billion years (2500-545Ma) and is predominantly represented by terrestrial and marine sedimentary rocks with a subordinate volcanic component.

Huge quantities of BIF were laid down within shallow marine sedimentary basins during the Paleoproterozoic (2500-1600 Ma). Thereafter, iron which previously had been accumulating in the oceans in ionic form since the early days of the earth, became depleted and the rate of iron deposition fell off.

The Proterozoic sedimentary rocks represent erosional products of the Archean granitic and sedimentary terrane which have been preserved for an extraordinarily long 2.5 billion years of the earth's history. Additionally, except where the Proterozoic sedimentary succession has not been affected by mobile belt, or mountain building episodes, it remains little disturbed by geological events over vast time periods. This stability is, in turn, a function of the long durability of the upper mantle beneath the cratons. However, tectonic events resulting in mountain building in the mobile belts enveloping the cratons occurred during the Ubendian (2000-1800Ma) and the Irumide (1350-1100Ma) orogenies (Map 3).

The formation of the Great Dyke of Zimbabwe (2575Ma) and the Bushveld Complex (2050Ma) took place at the end of the Neoarchean and the Paleoproterozoic respectively. It is noteworthy that the Great Dyke was emplaced shortly after the Limpopo orogeny (2900-2600Ma) and the Bushveld Complex at the end of the Ubendian orogeny. Both these orogenies appear to have been pan-global (Figure 1).

There are several theories for the formation of the Bushveld Complex, including a meteorite impact causing a mantle hot spot plume to break through

to surface. Alternatively, there may have been, as favoured here, a large scale surface collapse corresponding to possible detachment between the upper mantle and the crustal rocks. The enormous collapse crater infilled with mafic magma which began to cool and differentiate into a layered complex.

Some further underlying collapse may have caused the centre of the complex to sag, resulting in a depressed surface, which was not filled up by further magma incursion as the magma in the feeder fracture zones surrounding the depression may have solidified.

At the end of the Irumide orogeny (1350-1100Ma) during the Mesoproterozoic, rifting from the proto-Atlantic coast, opened the Damaran sea as far northwest as the present day Zambian Copperbelt and caused oceanic floor to develop within the rift.

Parts of Africa which had become detached during the Mesoproterozoic rejoined during the Pan African event (650-500Ma) as the Gondwana supercontinent was re-established.

Rotational movement in the cratons caused further shearing within the mobile belts. With the infilling of the Damaran rift and tectonic movement (550Ma), extensive low angle thrust sheets developed in the northwest end of the rift as part of the Lufilian Arc. Additional thrust sheets may have developed from the axis of the rift.

Post-Proterozoic

With the passing of the Proterozoic, the Palaeozoic (500Ma) commenced in the waning stages of the Pan African

orogen. Whereas the Archean and its predecessors lasted about two billion years and the succeeding Proterozoic a similar time span, the post-Proterozoic, by comparison, has endured a mere half billion years. For most of the world's land mass, the Palaeozoic onwards was much more geologically active as a consequence of plate tectonic movement and the development of great mountain chains. Yet, in much of Africa, sedimentation and denudation continued as before, indicating the continent continues to occupy a quiet position between mantle convection cells. However, diverging convection cells did result in the break-up of the Gondwana supercontinent, commencing about 200 million years ago; a process that appears to have reactivated in East Africa over the last few million years.

Southern Africa is remarkable in having very little post-Proterozoic deformation, except for the Cape Fold Belt at its southern extremity. The long lasting stability present at the core of the Gondwana supercontinent throughout the past continues today.

Mineralisation: Timing and Controls Archean Greenstone-Hosted Gold

Shear and vein hosted gold was deposited in the greenstone belts during the Archean and into the early Proterozoic, principally at the times of granite emplacement. From time to time these epigenetic systems were reactivated along major structures and later gold bearing shear zones penetrated up into the overlying Proterozoic.

The greenstone belts were largely of basaltic composition but, like the gold

mineralization were derived from poorly evolved upper mantle material from which heavy metals had not, as yet, settled out. A feature of these types of volcanic terranes worldwide is the presence of massive copper-zinc sulphide deposits (VMS). However, massive sulphide deposits are comparatively rare in Africa, perhaps because of the deep erosional level of many of the cratons. Where gabbroic intrusions are present, nickel deposits developed most commonly by the gravitational accumulation of the nickel sulphide, pentlandite, at the base of the intrusion.

It would seem that as the cratons grew, areas of the upper mantle cooled to a degree where it ceased to differentiate, and thus retained in the lower cratonic regions zones of high metal content. Parts of the lower crust where this metal rich material remains may be tapped periodically by tectonic and mineralisation processes.

Trans SADC Lineament

It is apparent from the geology, and gravity/magnetic interpretation of SADC (Map 2) that there is a major, extremely long-lasting lineament or geosuture extending NNE from the south coast of Africa to eastern Zambia, the 'Trans SADC Lineament'. From the eastern edge of the Karoo basalts to the south of Lesotho it passes east of the Witwatersrand and very close to the Premier kimberlite (1180Ma), then through the Bushveld. The lineament appears to be cut off by the Limpopo Mobile Belt (2900-2600Ma), suggesting that the lineament predates the Limpopo orogeny. It then continues along the line of the Great Dyke and again appears to

fade out across the Zambesi belt (1350-1100Ma). Further north, near the boundary between Mozambique and Zambia, there are two post-Proterozoic areas that may mark the northerly trace of the lineament, which northwards appears to merge with the southern margin of the Damaran rift. The Trans SADC Lineament may have provided fluid pathways for mantle mineralisation events to move towards the surface.

Witwatersrand Gold (3030Ma)

Mineral fields such as the Witwatersrand, underlain by the Dominion lavas, may have eventuated from the reworking of early epigenetic gold deposits, to be distributed in narrow beds of clast supported quartz pebble conglomerate. Exploration for new gold deposits need not be restricted to rocks of the Witwatersrand type, but may consider exploring for the gold source rocks following a different model, other than of gold derivation from eroded greenstone belts, such as the Barberton. A speculative alternative exploration model would be to consider strong uplift on a regional scale, due to delamination movements between the lower crust and the mantle, followed by large ring structure collapse. High level intrusion of gold-enriched material in the depression, might have subsequently provided a source for the Witwatersrand gold. However, primary gold may yet exist in wallrock of the regional subsidence zone.

Similar Proterozoic conglomerates elsewhere in the SADC region may host uranium rather than gold, as at Elliott Lake in Canada.

Manganese (2600 to 2100Ma)

The overriding of the Kaapvaal craton by the Zimbabwe craton caused basin development in the Kaapvaal leading to the deposition great thicknesses of carbonate rocks. Proposed models for manganese deposition cover a range of processes, from large-scale epigenetic replacement of BIF, to submarine volcanogenic -exhalative activity, to chemical sedimentation.

The Great Dyke (2575Ma)

The Great Dyke appears to have intruded along a considerable length of the Trans SADC Lineament. Differentiation of the mafic intrusion resulted in zones of chromite and platinum group metals (PGM), making up a considerable proportion of global PGM resources. Potential exists for structures similar to the Trans SADC Lineament elsewhere. Such structures may occur in the very large post-Karoo depositional areas. Refined techniques, such as regional airborne gravity surveys may be warranted to detect these structures. Such surveys may need to be undertaken collaboratively by international agencies and national Geological Surveys.

Bushveld Complex (2050Ma)

Whether or not the Bushveld Complex resulted from a catastrophic astroboule impact, its evolutionary history continued for several millions of years. It would also appear that granitic rocks similar to the upper phase of the Complex are known as far away as 200km in Botswana. These areas and others may be prospective for great resources of platinum, chrome and vanadium similar to the Bushveld

Complex itself. The occurrence of a 100km diameter outcrop pattern of Lower Proterozoic rocks showing through the Post-Karoo deposits, some 200km southwest of the Bushveld Complex, suggests the possible presence of a similar hidden structure. Looking further afield, the extensive presence of Proterozoic ultramafic rocks north of Zimbabwe into northwestern Mozambique may warrant further investigation for Bushveld analogues.

Lead-Zinc (1600-1000Ma)

The *Pering* and *Gamsberg* shale hosted zinc deposits occur in Mesoproterozoic sedimentary basins in South Africa. Similar deposits may occur in southwest Namibia and in similar settings elsewhere. The Zambian *Kabwe* limestone/shale hosted zinc deposit type warrants exploration in equivalent geological environments.

The Damaran Rift (640-450Ma)

The development of the Damaran Rift and subsequent Pan African orogeny is tied in with a variety of deposit types within a wide geographic range. As oceanic crust developed in the widening rift, seafloor-type sulphide deposits developed, an example being the *Matchless* base metal orebody.

At its northeastern end the Damaran Rift terminates abruptly against the thrust sheets of the Lufilian Arc and the Bangweulu block. There may be a sheared, structural connection from the Copperbelt through the Zambesi belt to the Trans SADC Lineament. Again an epigenetic model is suggested, with the source of the metals being from the upper mantle to the lower crust via deep

seated vertical discontinuities. As the mineralisation was deposited in a sedimentary environment, it would be reasonable to expect related sedimentary features within the mine sequence. Mineralisation may also have taken place in the vicinity of the boundary faults along the north and south boundaries of the rift. The *Tsumeb* base metal deposit is a reminder that there may be deep seated northeasterly trending structures away from the rift margins. The key feature is whether these structures have access, either vertically or laterally, to an epigenetic source of mineralisation. Uranium mineralisation, in gneissic and granitic terrane, appears to be related to Damaran rifting as the *Rossing* mine occurs close to the failed arm of the rift along the Namibian coast. It should be noted that the boundary faults of the Damaran rift appear to pass by the Bangweulu block with the southern branch appearing to merge with the Trans SADC Lineament. These areas may provide fertile exploration opportunities.

Karoo (300-150Ma)

Following an ice age (180Ma), extensive cool climate coal deposits of great economic importance were formed. Uranium 'roll front' deposits of economic significance are found also in the Karoo. Intrusion of diatreme kimberlites reached a peak during this time (140-210Ma), with later placer deposits developing in the Cenozoic (25Ma-Present). About one percent of kimberlites worldwide contain diamonds in economic quantities. Kimberlite diamonds formed at a depth of 150 to 200km beneath cooler, deep cratonic crust.

Post Karoo (150Ma-Recent)

The chemical weathering of low grade deposits under wet, tropical conditions caused mineral enrichment as in the case of nickel laterite, and may break down clays to form bauxite. Similarly, the leaching of silica from low grade BIF, in some cases assisted by hydrothermal processes, resulted in residual iron enrichment.

Conclusions

Remote areas, and where there is strong tectonism as in the mobile belts, or where there is post-Karoo cover, have been under-explored and merit greater attention. With the development of improved exploration models and methodologies, previously well-explored areas may lead to mineral discovery equal to the best from the past.

❖ **Seminar Brochure**

Society of Geoscientists and Allied Technologists (SGAT)
jointly with
International History of Mining Congress, Australia
shall be organizing an
International Seminar on Mining History
during 13-16, December 2007 at Bhubaneswar.

THEME:

The proposed topics include:

A.	Mining Technology & Engineering History
	Geology & Mines Education Prospecting & Exploration
B.	Mining & Sustainable Development
	Mining & Mineral Processing Technologies
	Smelting & Refining
	Mine Safety & Health
	Environmental protection & reclamation
C.	Mineral Legislation
	National Mineral Policy
	State Mineral Policy
	Rehabilitation Policy
D.	Industrial & Business History
E.	Socio-cultural History
	Industrial Relation, Mining Communities, Migration
F.	Archiving the Mining History & Heritage

Call for Papers

- Submission of Abstract -15 June 2007.
- Acceptance of Abstract - 30 July 2007
- Submission of Full Paper - 30 October 2007

Registration

Registration Fees (per participant)	-	Before September 2007	After September 2007
For Indian Nationals	-	Rs. 3000/-	Rs. 3500.00
For SGAT Members	-	Rs. 2000/-	Rs. 2500.00
For Overseas Participants	-	\$100 US	\$120 US
For Accompanying person (Indian Delegates)	-	Rs. 2000/-	Rs. 2500/-
(Overseas Delegates)	-	\$50 US	\$60 US

Patrons	-	Rs. 2,00,000.00 / \$ 4500 US	Five delegates free of registration will be permitted
Indian Sponsors	-	Rs. 50,000.00	Three delegates free of registration will be permitted
Overseas Sponsors	-	\$2000 US	Three delegates free of registration will be permitted

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For further Details contact:-

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❖ SGAT News

SGAT had conducted the State Level EMAP on 9th & 10th February 2007 at Bhubaneswar. 10 numbers of schools had participated in the event. DAV Public School, Unit-VIII, Bhubaneswar was adjudged as the winner.

The members of the Executive Council of SGAT during its meeting held on 27.04.2007, are pleased to decide that the registration fee for the **International Seminar on Mining History** to be held on 13-16 December 2007 at Bhubaneswar shall be Rs. 2000/- for the members of SGAT if the registration fee is received before Sept'07. A fee of Rs. 2500/- shall be charged if the registration fee is received after Sept'07.

❖ News about members of SGAT

At a function organized by M/s Mahanadi Coalfields Ltd. at Burla on the occasion of Utkal Diwas on 01.04.07, Shri S.N. Padhi was felicitated for being the only person from Orissa to occupy the Chair of Director General of Mines Safety. Other dignitaries felicitated were Shri U.S. Mishra (only person from Orissa become Director, CBI), Padmashree Maguni Das (Gotipua Dance), Shri Tirkey (Hockey), Shri Shib Sunder Das (Cricket) and Shri Sudarsan Maharana (Sand Artist).

In the Golden Jubilee Seminar of Mining Engineers' Association of India held at Hyderabad from 6th to 8th April, 07, Shri S.N. Padhi, Member of Executive Council of SGAT and Director in the OMC Board, chaired the technical session on Opencast Mining. Due to the last hour absence of Dr. T. Subbarami

Reddy, Hon'ble Minister of Mines, Govt. of India and as requested by the organizers, he was the Chief Guest of the Golden Jubilee year function and distributed Golden Year Jubilee Awards to distinguished mining engineers and luminaries.

Shri B.K. Mohanty, Advisor, SGAT attended the Golden Jubilee celebration of MEAI held at Hyderabad during 6th to 9th April 2007.

Shri S.N. Padhi, DGMS and member, SGAT Executive Council was the Chief Speaker in the final day function of the Metalliferous Mines Safety Week of Bhubaneswar Region held at OSCOM mine of M/s Indian Rare Earths Ltd. on 26.2.07. On this occasion, he also released the Oriya version of the Metalliferous Mines Regulations, 1961.

Regional Research Laboratory (RRL, Bhubaneswar) has been renamed as Institute of Minerals and Materials Technology (IMMT).

Prof. B.K. Mishra, Director, IMMT received Mineral Beneficiation award from Indian Institute of Mineral engineers for the year 2006-07.

Dr. S.K. Sarangi, General Secretary, SGAT has attended the International Seminar on Mines 2006 held at Singapore during 24th to 30th March 2007.

Dr. S.K. Sarangi has received the **International Arch of Europe Award in Frankfurt, Germany** on behalf of his company "GEOMIN CONSULTANTS (P) LTD." for its commitment to quality, leadership and excellence.

Dr. S.K. Sarangi and Shri R.N. Mohapatra have also visited Kyrgyzstan during 15th to 23rd May 2007 to explore certain mineral prospects for development.

Press Meet

On 10.02.2007, SGAT has convened a press meet to apprise various important issues related to mineral development in the state including adoption of transparent **Mineral Policy and Rehabilitation, Resettlement and Reclamation of Policy** of the State Government. SGAT suggested various scientific solution to address the problems related to mineral development in the state. SGAT, a scientific non profit making body volunteered their services for facilitating the State Government to prepare the blue print for the development of mineral resources and also can assist in providing newer technologies for optimum utilization of non-replenishable mineral resources.

❖ Other News

New Members

1. **Mr. Mohammed Ilyas Ansari**
Ex. Head, Mineral Beneficiation
Division
IMMT, Bhubaneswar
N/4, 156, Nayapalli
IRC Village
Bhubaneswar – 751 015
Orissa
2. **Mr. Chinthapudi Eswaraiah**
Fellow Scientist
Institute of Minerals and Materials
Technology
Bhubaneswar
3. **Mr. Shreerup Goswami**
Lecturer
Department of Environment
F.M. University, Vyasa Vihar
Balasore – 756 019
4. **Mr. Rabi Narayan Mahapatra**
7, Vasundhara Complex
P.O:KIIT,Bhubaneswar – 751024
Orissa
Bhubaneswar

AWARD - 2007

SGAT AWARD OF EXCELLENCE - 2007

Nominations are invited for SGAT Award of Excellence – 2007 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' 2007.

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
8. Vol. and Issues (if possible, send important reprints):
9. Details of outstanding work :
(Please attach a separate sheet)
10. Any other information :

Signature

Place:

Date:

Full name and address of the
Member/Institution proposing

SITA RAM RUNGTA MEMORIAL AWARD - 2007

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 2007.

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 researchers are requested to send their publications (3 copies each) from July 2005, onward till July 31 2007 to the Secretary, SGAT, 267, Kharavela Nagar, Bhubaneswar by the end of September 2007.

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 23rd December 2007. The awardee shall be intimated in due time.

This may kindly be circulated 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.

AN APPEAL

We are pleased to inform you that SGAT has already got allotment of land measuring 90' x 45' in IRC Village, Nayapalli area of Bhubaneswar. SGAT has already taken the possession of the land on payment of land cost and after registration of the land.

SGAT desires now to construct its own Auditorium with other utilities components in the same plot. This is estimated that an amount of about Rs. 50.00 lakhs shall be required to complete the first phase of construction. In view of this it is proposed to meet these expenses through donations from members and various institutions. SGAT has already applied for obtaining income tax relaxation under Rule 80 – G which would be obtained shortly.

An appeal is, therefore, made for a generous contribution towards building fund of the Society. All payments can be sent either by Cheque/Demand Draft payable at Bhubaneswar in favour of “Society of Geoscientists & Allied Technologists” and may be sent to The General Secretary, Society of Geoscientists & Allied Technologists 267, Kharavela Nagar, Bhubaneswar – 751 001, Orissa.

Your generosity for this noble cause shall be highly remembered

Thanking you
Yours sincerely

Dr. S.K. Sarangi
(General Secretary)

NOTICE

Notice is hereby given for holding the 27th ANNUAL GENERAL MEETING on 23 December 2007 at 5.30pm in Hotel Swosti, Bhubaneswar. The following items will constitute the Agenda.

K.S. Mahapatra Memorial Lecture

Confirmation of proceedings of the 26th AGM held on 16 December 2006

Presentation of the Annual Report for 2006-2007 by the General Secretary

Presentation of audited Accounts for the year ended 31 March 2007 by the Treasurer

Resolution proposed by members, if any

Presentation of SGAT Award of Excellence - 2007 and Sitaram Rungta Memorial Award – 2007, H.H. Read Gold Medal Award 2007 and Best Paper Award 2007.

Address of the President.

Declaration of Election Results for the Council 2007-2009.

Vote of thanks

All members are requested to make it convenient to attend the A.G.M. Members are requested to submit proposals for any resolutions need to be approved and amended during this A.G.M. The resolutions shall be submitted to the General Secretary by 15th November 2007

(General Secretary)

OBITUARY
Bimal Prasad Patnaik
(28th July 1964 7th May 2007)



SGAT family deeply mourns the untimely sad demise of Bimal Prasad Patnaik, one of its esteemed member on 7th May 2007 at Kalinga Hospital, Bhubaneswar. He was a mine-owner and was engaged in the mining of unique Blue Granite of Bendalia area in Ganjam district.

As an active member of SGAT, B.P. Patnaik was contributing generously towards Environment Awareness Programme, organized by the Society at field level. The Society conveys its deepest condolence to the members of the bereaved family.

G.B. Mohapatra

Submission of Papers For SGAT Bulletin

(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

Language: English

Manuscripts

Manuscripts should be typed in double spacing with wide margins on one either by electronic typewriter or computer (size 12 point Times New Roman font). The title page should include the title of the paper, name(s) of author(s) and affiliation(s). The title should be as brief as possible. An informative abstract of not more than 500 words to be included in the beginning. Not more than 5 key words are to be listed at the end of the abstract. Text of research papers and review

articles should not exceed 4000 words. The short communication is for quick publication and should not exceed 1200 words.

Headings

Different headings should be in the following format.

- (a) Title: Centrally aligned, bold, capital
- (b) Author(s): Centrally aligned, short name, bold, first letter of all words capital followed by communication address (Not Bold)
- (c) Abstract: Left aligned, bold
- (d) Key words: Left aligned, bold
- (e) Primary heading: Left aligned, bold, capital
- (f) Secondary heading: Left aligned, first letter of each word capital
- (g) Tertiary heading: Left aligned, first letter of first word capital
- (h) Acknowledgements: Left aligned, bold, first letter capital
- (i) References: Left aligned, bold, first letter capital
- (j) Figure Caption: Left aligned, first letter of first word capital, below the figure
- (k) Table Caption: Left aligned, first letter of first word capital, at the top of the table

Illustrations

All illustrations should be numbered consecutively and referred to in the text. They should conform to A-4 size and carry short captions. Lettering inside figure should be large enough to accommodate upto 50% reduction. One set of hard copy of all figures (either tracing in ink or laser prints) should be provided in a separate envelope marked "Original Figures". Photographs should be of good quality with excellent contrast, printed on glossy paper. Colour photos are acceptable, provided the author(s) bear the cost of reproduction. Figure captions should be provided on separate sheet.

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.

References

- (a) References in the text should be with the name of the author(s) followed by the year of publication in parenthesis, i.e. Patnaik (1996); Patnaik & Mishra (2002); Nayak et al. (2001)
- (b) Reference list at the end of the manuscript should be in alphabetical order, in the following format: Sehgal, R.K. and Nanda, A.C.(2002) Paleoenvironment and paleoecology of the lower and middle Siwalik sub-groups of a part of North-western Himalayas. *Jr. Geol. Soc. Ind.*, vol. 59, pp. 517-529

(c) Articles from the books should follow the format given below: Windley, B.F. and Razakamanana, T. (1996) The Madagascar – India connection in a Gondwana framework. In: Santosh, M. and Yoshida, M. Eds.) *The Archaean and Proterozoic terrains of South India within East Gondwana.* *Gond. Res. Group Mem. No.3, Field Sci. Publ., OSAKA*, pp. 25-37

(d) Books should be referred to as: Sengupta, S.M. (1994) *Introduction to Sedimentology.* Oxford and IBH Publ. Co. Pvt. Ltd., New Delhi, 314 pp.

Submission of manuscript

Manuscripts strictly conforming to the above format should be mailed directly to Editor in his mailing address available in the bulletin. Manuscripts not conforming to the format of the journal will be returned.

All the manuscripts conforming to the standard format of the bulletin will be reviewed by specialist referees before publication.

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