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PRESIDENT'S COLUMN

Greetings of the Season.

At the outset, on behalf of SGAT, I extend my best wishes to all the members a colourful, cheerful, active and prosperous New Year 2014. We are now at 34^{th} year of our existence as members of SGAT and we are all aware of the fact that SGAT is progressing well with the supports of all its patrons and well wishers. We are happy to note that SGAT has acclaimed a national level identity and various fora have expressed their desires to open centres of SGAT at various important zones of the country. This is indeed an achievement resulted due to inspiring efforts contributed by few dedicated members.

SGAT was instituted in 1980 with the main objective of promoting mineral development in a scientific and sustainable manner and in view of this, SGAT organized various Seminars/Symposia on different important issues pertaining to mineral development. SGAT also has the credit of publishing the first book on "Geology & Mineral Resources of Odisha" – a widely referred book by the mineral industries and other professionals. SGAT has also at the behest of the Govt. of Odisha has prepared "Blue Print on Mineral Development in Orissa during the decennium, 1997 – 2007" and "Vision Document for Mineral Development 2020 for Orissa". The efforts of the authors for the volumes are highly appreciated.

SGAT, with its own resources and contributions made by different well wishers could construct its own building with the provision of a conference hall, museum, library and council hall with all modern facilities.

However, these achievements have become history and now it is the time to maintain this tradition and facilities where the unselfish efforts and contributions of each member are solicited.

Let us pledge in this New Year to render all possible supports to bring more laurels to the fame and glory of SGAT, so that, we can contribute a lot to assist in obtaining positive growth in mineral development which would wipe out the negative image of mineral industries as a whole.

Please remember Mineral Development is vital for Nation Building and SGAT is for Mineral Development.

Your timely suggestions are welcome.

Dr. S.K. Sarangi
(President & Editor, SGAT)

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INNOVATIONS FOR SUSTAINABLE DEVELOPMENT OF MINERAL INDUSTRIES

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ABSTRACT

Sustainable development ensures conservation of ecology and environment including those of natural resources like minerals, water, and energy with simultaneous efficient economy for equitable social progress so that future generations do not face any disadvantages. Innovative but holistic approaches are necessary encompassing social, economic, and policy measures. We focus sustainable development of mineral industries focusing on statistical and computer based technologies. As is well-known Statistics is most effective technology of 21st Century and hence should be applied for currently low profiled mineral industry facing depletion of high-grade ores. Intensive exploration, optimal processes of mining, beneficiation and marketing using latest statistical technologies of optimization, risk minimization and sustainable growth is needed.

Marketable minerals occur at crustal shallow depths in rocks and ores which are heterogeneous solids comprising several ($C > 3$) distinct homogeneous minerals and usually contain pore spaces. Statistically homogeneous samples can be obtained using the concept of representative elementary volume (REV). Unfortunately, measurements on REV samples, lead to fractional constituents (c; $0 < c < 1$) for each distinct mineral and sum of all these fractions become 1.0. The main drawbacks of such data are: pdf of mineral fractions are Binomial for major (> 10%) and minor (1- 10%) constituents which reduces to Poisson if the constituent is very small (trace amounts, <1%); pdfs are not Gaussian so statistical technology can be applied, and since data is not Fullrank, C, but (C-1); so, unique inverse does not exist and gives spurious negative correlations among these constituents to confound inferences. Using measure theory, a $\log(c/(1-c))$ pre-transform of these fractional constituents eliminates all above drawbacks and makes the transformed random variables independent, so that univariate/multivariate/time-series methods are applicable(Sahu,2003,2005).

We list a few innovative applications and examples where these statistical technologies are in use:

EXPLORATION: (i) location of positive anomalies for further intensive studies; (ii) location of negative anomalies for acting as sinks of toxic elements/materials;(iii) identifying pathfinder elements/minerals using Factor Analysis and Canonical Correlation Analysis;(iv) feasibility of mining and of bidding new areas.; MINING: (i) Optimal mining (open pit vs. underground); Underground is preferred for ecology preservation;(ii) 3D optimal mine plans using lowest minable assay and computation of risk factor;(iii)mine extensions in vertical/horizontal directions to be used when necessary; BENEFICIATION:(i)Lowest mineable assay and beneficiation system needed, (ii)locating high-grade ores for conservation and later blending of low-grade ores,(iii)waste management policies/decision; and MARKETING:(i)optimal classification ore grades,(ii)optimal marketing strategy,(iii)blending of low-grade ores in situ and lying in dumps.

I. INTRODUCTION:

Large-scale industrialization and urbanization with greater consumption of mineral and energy resources since the Industrial Revolution have greatly depleted high grade resources available at shallow depths of crust. Therefore, more intensive search for these finite resources is necessary at greater depths and for lower grades besides optimal mining, processing and marketing in order to maintain sustainable development of economy, society and to have higher national growth. Mineral resources include high-grade marketable ores and/or associated low-grade ores which require blending and/or beneficiation to market the products at profit.

Rocks and ores comprise multi-element/multi-mineral materials containing more than three constituents (C>3) some of which need separation and/or beneficiation to remove non-marketable gangue minerals and waste materials. We are interested in Static characterization (invariant in time) of the heterogeneous solids (rocks/ores) which can be achieved through sampling if adequate material (> REV) sample from the rock/ore, where REV means the minimum volume/weight that is a represents elementary volume. Thus, integration of any random variable (fractional constituent, c with $0<c<1$) over the REV provides stable and unbiased statistics representing the characteristics of an equivalent statistically isotropic homogeneous sample. The probability density functions (pdfs) corresponding to the random fractional constituents (s.a., minerals, molecules, elements, or isotopes) of the rock/ore is having a Binomial distribution for major and minor constituents which reduces to a Poisson distribution for trace constituents. Realistic and accurate these pdfs are essential for optimal exploration, mining, mine planning, processing, blending, beneficiation and marketing of the concerned mineral resource. In contrast to rocks and ores, mineral geochemistry involves sampling of (homogeneous) minerals which would be much smaller in volume than REV for geochemical analysis and inference.

Major, minor or trace constituents of rocks and ores are Gaussianised using the log (c) pre-transformation since 1953 as advocated by L.H. Ahrens. However, this pre-transform is not always valid for different constituents and not necessarily independent for these constituents, hence a slight modification introducing multiplicative random errors and independence of transformed random constituents would be useful (see, Sahu, 1982,1995).

From statistical viewpoint, the main problems of geochemical analysis and inference of such data (without pre-transformation) are : (a) constituents are usually weight, volume, area, or length fractions but not Numbers as needed in statistics and probability, (b)weight fractions are not necessarily equal to volume, area or length fractions (as given in Stereology textbooks) since rocks/ores contain Finite pore spaces, (c) statistics obtained in 3D space are not equal to corresponding statistics on are on length or number basis unless the Total Measure tends to be infinite (but sample size is Finite). Four additional and more complex problems include: (i) Constant Sum or Closure: This constraint on fractional constituents induce spurious negative correlations among the constituents within samples which confound statistical and geochemical inference, (ii) data matrix has a rank (C -1) and is not FULLRANK (C) to have unique inverse ,(iii) fractional constituents are not Independent as required for parameter estimation and hypotheses tests, (iv) fractional pdfs are Binomial/Poisson but NOT Gaussian. The advantages of Gaussian distribution are: (a) Linear sums remain linear(i.e. sums of Gaussian is again Gaussian). (b) cumulants of order two are finite and hence, useful for parameter estimation for mean and variance, and of all higher order cumulants are zeros, hence dropped, (c) parameter estimation, hypotheses tests, risk analyses are simple and straightforward.

II. MATHEMATICAL AND STATISTICAL THEORY:

Fractional constituents (c; $0<c<1$) belong to a C-dimensional positive real space and cannot be viewed geometrically if number of constituents, C, is greater than three which is most frequent in rocks and ores. Aitchison (1986) and his coworkers later on, have proposed that fractional constituents belong to a C-dimensional Simplex. They have used rather complex pre-transforms such as, log ratio (lr), centered log ratio (clr) and isometric log ratio (ilr) to Gaussianise the pdfs and for statistical analyses. However, Carranza (2011) has shown that these complex pre-transforms still DO NOT solve the rank problem (rank is C-1 instead of C , as required)and inherent spurious negative correlations among the constituents within any sample. This is due to the fact that fractional constituents (c, with $0 < c < 1$) belongs to interior points of the Simplex but NOT to apexes, hyper-edges, hyper-planes, and some sub-compositional hyper-planes of this C-dimensional Simplex (Sahu, 2013 in press).

From measure-theory, fractional constituents (c; $0<c<1$) belong to the open interval (0,1) and have a Binomial/Poisson (NOT GAUSSIAN) distribution excluding the non-admissible points 0 and 1 in this line. This is absolutely necessary; otherwise the rock/ore is NOT a C-dimensional Simplex. In such a system, additive probability measure is not applicable and a multiplicative probability model (Odds ratio) leading to a log-Gaussian or log-normal Model (as proposed by Ahrens in 1953) would be appropriate with some modification such that the log(odds ratios) of the constituents become independent and Gaussian (homogeneous variances).The simple modification for log(odds) as proposed in Sahu (1982,1983,1995) is the following: If c is lognormal , the its complement (1-c) is also a fractional constituent and hence would also be lognormal. Using theory of linear addition(subtraction) of Gaussian random variables to be Gaussian (that is sums of Gaussian pdfs are closed/ remain Gaussian); we obtain log(c/(1-c)) is Gaussian and this pre-transformation involves only one constituent (c), which makes log (c/(1-c)) transform to be independent of all other constituents in the rock/ore(see,sahu,1982,1983,1885). This log (c/(1-c)) pre-transform Gaussianises the pdfs of fractional concentrations while simultaneously eliminating the other four crucial drawbacks (I to iv) of Binomial/Poisson distributions as listed earlier. Mathematical proof based on measure-theoretic analysis is given by Le Cam (1986) and by Le Cam and Yang(1990). The author and his many students have used the log(c/(1-c)) pre-transform to Gaussianise fractional concentrations(c) in geochemistry and applied to exploration, estimation, modeling , hypotheses testing for several Indian ore deposits including those of gold, iron ores, lead-zinc, copper ,phosphate etc.

However, other log ratios such as lr, clr, ilr (proposed by Aitchison and coworkers) are not independent since the denominator constituent involves the numerator constituent and the rank of data matrix still remains C-1 (NOT fullrank, C, as is required) (see also, Carranza,2011).

III. APPLICATIONS:

Statistics in the technology of 21st century and along with current capability of computers, it will be essential, beneficial and most useful to mining and mineral processing industries. A log (c/(1-c)) pre-transform of fractional concentrations (c; $0 < c < 1$) yields the desired independence and Gaussian pdf of each constituent in the rock or ore. This is necessary for characterization/estimation of parameters of each pdf, and for hypotheses tests and inference. Univariate and multivariate statistical models are used for single and multiple pre-transformed random variables, respectively. These models are useful for geochemical exploration, mining, mine planning, mineral processing and beneficiation and for marketing such that maximal profits with minimum environmental damage can be achieved to obtain sustainable economic and societal growth. Some applications of statistical (Gaussian) technology to mineral industry are listed below (not exhaustive) for getting the feel of different scenarios involved:

EXPLORATION:

a. Detection of positive anomalies for further intensive search
b. Detection of negative anomalies for use as sinks for toxic materials/elements
c. Decision on Pathfinders using Factor model for single-element and Canonical Correlation for multiple-elemental ores
d. Decision on feasibility of mining using open pit or underground mining method
e. Decision to choose New Areas for ore exploration which are to bid when necessary

MINING:

a. Development of optimal mine plans using concentration contours and risk analysis
b. Decision on lateral and vertical extensions to present mine plans

BENEFICIATION:

a. Decision on lower limit of assay for grinding
b. Decision on optimal beneficiation process and system to be installed
c. Locating high grade ore zones for conservation and for later blending and marketing
d. Waste management decisions and related operation planning

MARKETING:

a. optimal classification ore grades by separation and/or beneficiation/blending
b. future marketing of non-marketable ores in situ or in dumps by blending and/or beneficiation.

EXAMPLE 1: Estimation of ore reserves and average assays:

In the past spatial distributions of assays and their pdfs were not accounted for and simple calculations yielded these quantities based on geometry of ore-body and arithmetic averaging of assays within mineable ores. Geology of syngenetic deposits produces uni- or multi-metal Binomial/Poisson distribution having homogeneous variances, whereas epigenetic deposits are likely to possess bimodal (low-assays in hostrock and higher assays in ore zones) distributions that need separate treatments. A log (c/(1-c)) pre-transform of fractional assays achieves linearity, Gaussianity and homoscdesticity of variance with elimination of spurious negative correlations among the constituents (Sahu,2003,2005).

A. Syngenetic deposits:

The lower limit of assay value for mineable ore is given by lower 95% confidence limit of mean which should be marketable as well. Multimetal ores are converted to single metal ore through addition of equivalent prices of these metals or by using a principal component of the mineable/marketable elements. The associated risk factor should be evaluated for use of lower 95% confidence limit.

B. Epigenetic deposits:

Bimodal Gaussian pdfs can result as the mean in hostrocks may be much less than in ore body. Univariate/multivariate discriminant function (LDF) easily separates these two modes for separate calculation of reserves and average assays.

Since mineable ore zones may lie within ore body, or partly in ore body and hostrock, the geometry of mineable ore zone can be complicated. A 3D mine model is necessary to delimit mineable zones and this may be achieved through a computer system. The associated risk factor for mining should also be computed as indicated above.

C. Spatially correlated samples on log(c/(1-c)) basis.

This situation often arises in development and production stages when a large number of geochemical data becomes available. The data is having signal (mineralized assay) and noise (random errors) and time (spatial) series model separated the signal needed for average assay computation from the Gaussian noise giving the confidence limits to the average assay. Models may be non-stationary (ARIMA (p,d,q) which is made stationary (ARMA(p,0,q) by differencing d times. Integration of location data over the spatial domain gives the total volume and of signal gives the average assay. Such integration can be done blockwise to obtain block reserves and block average assays. More details of general time series modeling are given in Sahu (2003). Geostatistical models are special case of time series models belonging to the ARIMA (p,1,q) but are generally non-linear since log(c/(1-c)) pre-transform of fractional concentrations is not preformed to make the pdfs of assays Gaussian as needed for linear statistical models.

Example 2: Identification of Pathfinders:

Pathfinders include minerals, molecules, elements and isotopes and are very useful for exploration of uni- and multi-metal ores. These are characteristically easy to recognize, have higher concentrations than sought element, higher occurrence frequency, and can be analysed cheaply and easily at much less time. Correlation matrix, R, of pre-transformed fractional constituent data is then computed using R-mode analysis (cheaper and faster than Q-mode). The correlation coefficients could be strongly +ve ($r>.50$), strongly –ve ($r < -.50$) and weak ($-.50< r < +.50$). Factor analysis (FA) of R (without weak r s), provides rotated factors that are statistically significant to yield pathfinder (s) loaded strongly on high positive and/or negative correlations on constituents.

Pathfinders can also be identified through use of partial correlations but this method is computationally more intensive and decision may be confounded (non-unique).

Multi-element or multi-mineral ores would require Canonical Correlation Analysis with the mineable metals/minerals taken as criterion vector and other sets as predictor and/or control random vectors. FA in such cases may not be useful unless criterion vector has only one random constituent which is mineable. More details on finding geochemical pathfinders can be obtained from Sahu (2005).

Example 3: Mine feasibility:

Mineability depends on five static geological and ten dynamic economic factors which interact among themselves complexly and nonlinearly. Whereas highly valuable minerals can be mined at lower assays but need large waste disposals, medium valued minerals can be mined at trace to major amounts but need much beneficiation and waste disposal. However, rocks and soils can be mined without beneficiation and waste disposals as their value is extremely low. Sustainable mining operations must insure that the expected profits/yr is positive, which is discussed below.

Mining operations with profits depends on high sale value of high-grade and beneficiated low-grade ores to marketable grades. Mining costs include mine operation, transportation, beneficiation and disposal of mine wastes with remediation. Main geological factors are: (i) total reserve (W tons), (ii) proportion of high-grade, W(H),(iii) proportion of low-grade W(L), (iv)proportion of gangue W(G) = 1-

W(H)-W(L), (v) assay for high grade ore A(H). Of these five, three factors are independent but (iv) factor W(G) is not independent of W(H) and W(L). A(H) and A(L), assay of low-grade ores are two additional independent factors (Total Five factors).There are TEN economic factors include Profit per year, P which must be positive, life of mine (L = W/ (production rate per year in tons), sale price per ton of marketed ore S(H), capital cost of mine operations C(M), capital cost of beneficiation plant C(B), rate of interest, r,; efficiency of beneficiation, e; per ton running costs of mine R(M), beneficiation R(B), waste disposal R(D).

Economic analysis for mine operations having beneficiation processing results in, P:

P = [W (W(H) +W(L)) S(H)/L) – (C(M) + C(B) (1+r)/L) – (W R(M)/L) – (W-W(H).A(H) – W(L) e (A(H) – (A(L)/L) R(D) – (W R(B)/L)

Above equation is a complex nonlinear one which cannot be linearised. If W(L) is negligible (zero), then mine-site beneficiation would be unviable and associated costs C(B) and R(B) would become zeros. Smaller mines with less low-grade ores would need pooling of nearby small mines for establishing a combined beneficiation plant to be operated jointly by these mines with proportional cost and profit sharing per year.

Example 4: 3D Modeling and Mine Planning:

Fast, efficient and up-to-date computer systems having links to end-users are essential for this purpose.

Following items seem to be useful:

a. Fast transmission of databases, maps, sections to central processor online and/or offline
b. Preparation of 3D maps using GIS technology and generation of desired sections for planning and mine operations. Offline transmission of this to all sub-centres
c. Optimal plans for mine transport, blending and beneficiation and timeframe of works
d. Marketing plans, expected profits vs. actual profits, doubling of assets in < 5/6 years
e. Planning for new biddable targets and for extensions to present mines
f. Monitoring environmental damage and plan mitigation of such damages
g. Optimal computer architecture on faster transfer ratio is several separate computer systems acting in parallel to yield distinct outputs from a single input to the whole system
h. Mine closure plan, settlement of personnel, equipment disposal, mitigation of ground- and surface-water damages, corporate social responsibility (CSR) in the locality including mine closure operations.

Example 5: Mine Sustainability:

Environmental hazards and associated mitigation costs are site-specific and hence, will depend on local geology, topography, and climate. Mineralogy and geochemistry would affect emissions on metallurgy, pollution by toxic metals, leakages from dumps/tailings. Environmental degradation is due to poor production efficiency, and poor innovations.

We can achieve sustainability in mining industry through the following:

a. Market incentives with pollution-prevention, focus on management system (MS)
b. Mine closure plans with EIA and SIA (S is social) at different stages
c. Bonds issued to clean up pollution after mine closure
d. Obtain environmental and social performance indicators, risk assessment for environmental management (EM), and use of LCA for technology choice and EMS

CONCLUSIONS:

a) Mineral resources are fast depleting due to intensive industrialization and urbanization during the last three centuries. It has created high pollution in ecology and high temperature rise in the atmosphere with climate change which creates additional problems.
b) Statistical and computer technology are necessary to achieve greater efficiency in exploration, mining, processing, beneficiation and marketing of minerals/metals. This would attain sustainable development of society and is absolutely required conservation of ecology and environment.
c) Mathematical pre-transformation of fractional constituents (c; $0< c <1$) by $\log(c/(1-c))$ in ore and rock samples, yields the required Gaussian pdf for further statistical analysis and inference by univariate, multivariate, and time(spatial) series methods to give optimal results with minimum risks and maximal profits.
d) Five examples are given to demonstrate the practical utility of statistical technology at different stages of mining and mineral industries. These examples provide the versatility of statistical and related computer technologies to solve current problems faced by mineral industries.

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RESEARCH AND DEVELOPMENT IN ALUMINIUM ELECTROLYSIS – AN OVERVIEW

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ABSTRACT

The Hall-Haroult cell technology for aluminium smelting by electrolysis in a molten cryolite bath is in practice since more than a century without any major modification. Until recently the research and development in this field was concentrated on increasing the cell capacity, improvement in anode quality, cathode lining, emission control etc.. However, in very recent years innovative developments have taken place in terms of inert anodes, wettable cathodes, various newer cell designs etc. which may revolutionize the existing aluminium smelters. Cost of production, energy consumption and environment issues are some of the important features that have significant impact on primary aluminium production. The paper attempts to make a critical analysis of all these parameters in the present context.

Key words: Aluminium, smelting, inert anode, wetted cathode, vertical electrode cell

1. INTRODUCTION

Aluminium has played a key role in the technological development that the society has witnessed in the last century. It is the sole medium of large-scale transmission of electricity and because of its light weight, low cost and corrosion resistant property it has emerged as an important structural material in various applications especially in the air craft industry.

Aluminium is the most abundant of all metallic elements. It is the third abundant element in the earth's crust, constituting 8.13% of it, preceded by oxygen (46.60%) and silicon (27.72%) [Fleischer 1953]. In spite of its abundance in nature, aluminium could not have found use to the extent it is at present, without the technological revolution brought about by the development of the electrolytic method, independently by Charles Martin Hall in USA and L.T. Heroult in France in 1886 [ACS Hall Brochure 1997]. The commercial production of aluminium metal by this method started in 1889 and since last more than 120 years this technology is in practice without any major change, although there are continuous attempts to upgrade the technology.

2. ALUMINIUM ELECTROLYSIS-STATE OF THE ART

Aluminium cannot be produced by an aqueous electrolytic process because hydrogen ion, being electrochemically much nobler than aluminium, would be reduced at the cathode instead of aluminium ions [Siva Sankar 2008]. Primary aluminium is produced through molten salt electrolysis in a Hall-Heroult electrolytic cell termed as smelting pots. The sides and the base of the pot which act as cathode are lined with partially graphitized anthracite in coal-tar pitch and pre-baked carbon blocks respectively whereas the anode, which is either pre-baked or continuous baked (Soderberg), is carbon composed of petroleum coke and pitch [Shiva Prasad 2000]. In a modern smelter, purified aluminium oxide produced from bauxite ore by the Bayer's process [Habashi 1995], is mixed with cryolite - a mixture of sodium fluoride and aluminium fluoride. The mixture is heated to about 980 °C to melt the solids and the hot molten mixture is electrolyzed at a voltage of 4-5 V, but a current as high as 50000-150,000 amps. Aluminium ions are reduced to metal at the cathode and metallic aluminium is deposited at the bottom of the pot.

Oxygen gas is liberated at the anode resulting from the discharge of oxide ions.

$$1/2\ Al_2O_3\,(s) = Al\,(l) + 3/4\ O_2\,(g) \qquad (1)$$

The liberated oxygen reacts with the carbon anodes at that temperature and is released as carbon dioxide.

$$C\,(s) + O_2 = CO_2\,(g) \qquad (2)$$

The overall cell reaction is

$$1/2\ Al_2O_3\,(s) + 3/4\ C\,(s) = Al\,(l) + 3/4\ CO_2\,(g) \qquad (3)$$

The smelting process is continuous. Periodically, molten aluminium is siphoned from the cell. The alumina consumed in the bath by reduction and the aluminium fluoride depleted through volatilization, combination with residual soda in the alumina and hydrolysis by moisture from the air is adequately compensated to maintain the bath composition.

Hall's first electrolytic cells (pots) were of cast iron, 24" x 16" and 20" deep, with a 3" baked carbon lining [Beck, 2008]. Six to ten carbon anodes, 3" in diameter and 15" long were suspended in the electrolyte from a copper bus bar above. The pots had arrangements to be heated from below by a gas flame. It is interesting that the present-day cells have qualitatively the same design but of considerable larger size. On the average, cell size has doubled every 18 years in the 20^{th} century. As a result of increasing cell size and better process control, energy consumption has improved with time.

3. R & D SCENARIO IN ALUMINIUM SMELTING

In view of the rise in the demand of the metal attempts were primarily made to enhance the production as well as to bring down the cost. Thus, the R & D activities mainly concentrated on bringing about improvements in (i) cell capacity and performance (ii) cathode lining, (iii) anode technology, (iv) layout of reduction units and (v) environmental aspects. A concise review of the important progress made on these aspects in the twentieth century is presented by Tarcy et al. [Tarcy et al. 2011]. R & D efforts were also directed towards developing alternative processes such as carbothermic reduction of alumina [Balomenos et al. 2011], Alcoa chloride process involving molten $AlCl_3$ electrolysis [Sverdlin 2003], Toth process involving reduction of $AlCl_3$ by manganese [Sverdlin 2003], and Alcan process or sub-halide process [Gasik and Gasik 2003]. Some of these alternatives have been developed almost up to industrial scale, but then abandoned because of technical problems and lack of overall economic advantage over the Hall-Heroult process. However, the most challenging R & D activities during the last few decades are the attempts for some major modifications to the Hall-Heroult process. These are **inert anodes, wetted cathode** and **vertical electrode cell**. If successful, this will bring a revolutionary change in the aluminium production technology. This paper attempts to make a critical analysis of the possible benefits as well as drawbacks of these ensuing technological modification and the various challenges that confront the adoption of the changes. Some of the critical issues addressed are energy and environment benefits, materials for inert anodes, cell operation challenges, use of vertical electrodes and economic analysis of inert anodes and wettable cathodes.

3.1 INERT ANODES

Hall-Haroult cell uses consumable carbon anodes, which are prepared from petroleum coke by forming, baking and rodding operations. In the anodic process the carbon content of the anode gets used up as per reaction (2) generating carbon dioxide, thus limiting the anode life and requiring its periodic replacement. Moreover, the anodes typically contain 1-4% of sulfur originating from the petroleum coke used in anode fabrication so that sulfur gases particularly COS and SO_2 are also emitted [Hey et al. 2004]. Inert anodes, on the other hand, are not consumed during electrolysis and the cell reaction (3) changes to reaction (1). The consumption of anode and the emission of green house gases and most of the sulfurous gases are eliminated. The idea of using inert anodes, also called non-consumable or oxygen producing anode, is not new and dates back to1889 in the name of one of the inventors of Hall-Haroult cell [Hall 1989].

For efficient use an inert anode should possess favourrable properties such as 1) low solubility in the electrolyte, 2) high resistance towards oxygen produced at the anode, 3) high electric and negligible ionic conductivity, 4) low oxygen overvoltage, 5) resistance towards electrolytic decomposition of the oxide material, 6) adequate mechanical strength, 7) easy electrical connection, 8) non-polluting in manufacture, use and disposal, 8) acceptable contamination of the aluminium produced 9) economically attractive and 10) ready availability (Sadoway 2001).' Despite intense research efforts no materials have yet been found that meet all these requirements. The materials that have been tried are classified as **ceramics**, **cermets** and **metals**.

3.1.1 Ceramics

Under this category come many fully oxidized materials, especially metal oxides, because of their resistance to chemical attack by pure oxygen at 960°C (the operating temperature of the Hall cell) [Pawlek 2002]. Examples are tin oxide based ceramics [Yang and Thonstad 1997], some semicondcuting oxides such as ferrites [Olsen and Thonstad 1999], spinels and certain perovskites [Yamada et al. 1977]. But most oxides exhibit unusually low electrical conductivity and high solubility in Hall bath. Tin oxide was considered a good material for inert anode because of its high conductivity and reasonable stability in cryolite-alumina melt [Liu and Thonstad 1983]. Some other examples are CeO_2 [Dewing et al. 1995], $Cr_2O_3 - NiO - CuO$ [Augustin et al. 1993] and Ni_3O_2, NiO [Wu and Mao 1999]. All these oxide materials exhibit a finite solubility (corrosion) problem [Xiao et al. 1995] and to prevent the anode from corrosion a protective coating like cerium oxide (CeO_2) has been attempted [Gregg et al. 1993].

Use of additives has also been attempted to improve upon the properties of ceramics materials. In a recent study [Popescu et al. 2010] Sb_2O_3 and CuO were doped into it to further increase the conductivity and densification respectively. Several other metal oxides and their mixtures have also been examined as anode material. A Cu-Ni-NiO-$NiFe_2O_4$ ceramic material was prepared adding ZrO_2 (0-1.5 wt %) and the impact of ZrO_2 addition on the mechanical properties and corrosion resistance was studied [Zhang 2011]. The results showed that with the addition of 0.5 wt. % ZrO_2 the relative density decreased slightly whereas the binding strength improved remarkably. Similar studies are reported with the use of V_2O_5 [Xi et al. 2008], CaO [Tian Z, 2008] and cobalt [Singleton et al. 2011].

3.1.2 Cermets

Cermets used as inert anodes predominantly consist of a metal dispersed within a ceramic matrix. The attractiveness of cermets is their ability to combine the features of ceramics and metals; the ceramic matrix provides inertness i.e. chemical stability and the metal provides good conductivity and strength [Sadoway 2001]. Different combinations of ceramics and metallic phases have been tested and evaluated as anode material [Pawlek 2008]. Examples are: Al-Ni-Cu-O [Wen et al. 2005], Al-Ti-Fe-O [Cao et al. 2007]. More attention is being paid to nickel ferrite ($NiFe_2O_4$) as inert anode material. A cermet material containing a metallic dispersion of 17 % copper in a ceramic matrix of nickel ferrite, was developed by Alcoa who have reported the successful operation of laboratory cells using such inert anodes [Ray et al. 1986]. Mixture of $NiFe_2O_4$ and NiO are also being studied and a number of studies are reported where the properties of the electrode are evaluated against the NiO content of the material [Tian et al. 2009, Li et al. 2009]. An extensively studied material is a Cu-NiO-$NiFe_2O_4$ matrix containing different metallic phases such as Cu [Tian et al. 2007], Ni [Tian et al. 2008] and CuNi [Tian et al. 2008].

Problem of solubility in the Hall bath also remains with the cermets. Saturating the electrolyte with alumina has been suggested as one solution to this since oxide solubility decreases with increase in alumina concentration. However, operating a cell with an electrolyte saturated with alumina is cumbersome. Even then, in such an electrolyte, the cermet's electrical conductivity is still lower than that of the conventional carbon anode. Other problems associated with cermets are:

i) Carbothermic reduction of the ceramic phase due to contact between the anode and the carbon block at high temperature.
ii) Failure of the dual-phased microstructures to withstand high direct current at elevated temperatures.
iii) Coarsening and electromigration that can lead to destruction of the metal dispersion in the long run, thereby degrading the electrical and mechanical property of the material.

3.1.3 Metals

Of the properties mentioned earlier, metals possess most of them to satisfactory level for use as anode material. In addition, metal anodes are easy to fabricate and present fewer problems in service. An example of this type of anode material is aluminium bronze: copper containing 7-15% by weight of aluminium [Sadoway 2001]. The free energy of formation of alumina is much more negative than that of copper oxide so that in a Hall bath the metal anodes get coated by a film of alumina whose thickness is large enough to prevent the anode from attack by the electrolyte and small enough to create any electrical conductivity barrier. At the Massachusetts Institute of Technology, a laboratory cell fitted with anodes of various copper aluminium alloys ran for hours producing Al and O_2. The cell voltage also remained constant. In a study by Glucina and Hyland [Glucina and Hyland 2005], however, it was reported that aluminium bronze material containing ~ 10% Al but varying amounts of Cu, Ni and Fe, performed adequately as anodes providing steady voltages. However, the anodes sustained a high degree of material loss. Moreover, oxide formation at the anode surface, both before and during electrolysis, did not passivate the anode resulting in the oxidation of Cu to Cu_2O. Nickel bases alloys such as Ni-Al, Ni-Cu and Ni-Fe [Simakov et al. 2007] and super alloys Cu-Ni-Al, Cu-Ni-Fe, and Cu-Ni-Cr have also been studied [Shi et al. 2003] as anode material. The alloys were tested for corrosion in acidic electrolyte molten salt and for oxidation in both air and oxygen. The Cu-Ni-Al anodes were found to possess excellent resistance to oxidation and corrosion, and the oxidation rates of Cu-Ni-Fe and Cu-Ni-Al anodes were slower than those of pure copper or nickel. During electrolysis, the cell voltage of the Cu-Ni-Al anode was affected most by the concentration of alumina in cryolite molten salt. The Cu-Ni-Fe anode exhibited corrosion resistance in electrolyte molten salt. Comparatively, the Cu-Ni-Cr anode showed poor resistance to oxidation and corrosion. The testing found that further study is warranted on the use of Cu-Ni-Al and Cu-Ni-Fe as inert alloy anodes. Coating of the anode surface with a protective material has also been tried. The DeNora group of companies, Eltech and Moltech, has experimented with cerium oxyfluoride anodes [Sadoway 2001]. Subsequently a material with Ni-Fe alloy base structure and an active semiconductor Ni-Co mixed oxide coating was developed [Nguen and deNora 2006]. The anodes exhibited excellent electrochemical characteristics with low oxygen over potential and a good electronic conductivity of the oxide scale. In some recently reported studies [Chapman et al. 2011] Ni-Fe alloys having Ni content of 50-60 wt.% have been shown to be adequately resistant to corrosion in a Hall bath when the electrodes had a protective cover of $Fe_2O_3Ni_xFe_{3-x}O_4$ and $Ni_xFe_{1-x}O$ formed in a prior oxidation step. It was found that the pre-formed oxide scale was effective in reducing anode wear and fluoridation. In the absence of a pre-formed scale, anodes were shown to undergo appreciable internal corrosion and/or passivation due to metal fluoride formation.

Besides solubility, there are other important factors which affect the SnO_2-based anode prospects in the context of degradation and environmental pollution [Thonstad 2001]. Hence chemical modifications in the SnO_2 based anode material are being attempted to improve upon the properties of the anodes. An example is the use of tin antimony ferrite solid solution [Govorov et al. 2005].

3.1.4 Challenges for inert anodes

The ceramic materials fail to exhibit adequate electrical conductivity in spite of the efforts to improve their electrical properties. Their high solubility in the Hall bath leads to contamination of the aluminium metal product beyond acceptable quality. For example, the solubility of tin in cryolite-alumina melt is among the lowest compared to other elements (150-500 ppm SnO_2) [Xiao et al., 1995]. When used as anode in Hall electrolyte the tetravalent tin, being reduced at the cathode, produces more soluble Sn(II) and metallic tin. The accumulation of the latter in aluminium (ca. 0.4 wt. % Sn at an anode wear rate of 1.7 cm/year) [Keller et al. 1997] lowers the quality of produced aluminium even more than a higher content of less poisonous metals, such as Fe.

The challenges that cermet materials face in being adopted as anode materials are in the area of plant operation which also reflect in the economy of aluminium production and also with respect to electrical and mechanical properties resulting from low structural stability.

In the case of metallic materials the main concern is the stability of the alumina films formed over the electrode surface in the Hall bath. If it is too thin or disappears, the underlying metal will be attacked. If the film grows too thick, its electrical resistance will increase and cause the cell voltage to rise beyond acceptable values.

In case of coating there is a chance of mismatch between the substrate and the coating, which can result in cracks that allow electrolyte penetration. Various barrier layers have been suggested to prevent this problem. The contamination of the product aluminium with cerium introduces another unit operation for purifying the aluminium to make it acceptable in the market. To date, no industry has shown its willingness to bear the cost of this additional step.

3.1.5. Energy benefits of inert anodes

The energy in aluminium electrolysis has two main components: electrical- and heat energies. Details of various energy components in terms of voltage/power for the conventional carbon anode and future inert anodes are presented in Table 1 [Kvande 2001]. The data presented in Table 1, help analyzing various energy effects associated with changing of carbon anodes to inert anodes.

In a Hall cell, the heat generated by the burning of the carbon anodes as per reaction (2), contributes to the heat requirement in the cell, saving electrical energy indirectly. The reversible potential for the reduction reaction of alumina to aluminium as per reaction (3) is 2.248 V. The standard Gibbs energy of reaction (2) at 960 °C is equivalent to 1.026 V. Because of the contribution of carbon anode, the reversible potential corresponding to reaction (1) actually comes out to 1.222 V. This, coupled with various over voltages, makes the polarization voltage (back emf) 1.756 V. Two other energy demanding factors included in the total standard heat of reaction (reaction enthalpy) to reduce alumina to aluminium are: $T\Delta S^{o}$ and the heating of the system. The theoretical voltage equivalent of this energy is 2.016 V

Table 1 show that half the voltage saved by using carbon is lost in the anode over voltage. However, this over voltage generates heat necessary for the reaction in the cell, as well as balance of the heat losses of the electrolytic process. Hence, a net anode carbon consumption of 400 kgC/t Al would give a carbon-mass consumption efficiency of 80%. Thus, from the point of view of both energy and mass consumption, the present Hall-Heroult cells use carbon anodes efficiently.

Table 1 Various energy components of the conventional carbon anode and future inert anodes.

	Anode	
	Carbon	Inert
Reversible potential of Al_2O_3 reduction, V	2.248	2.248
Advantage due to anode burning, V	−1.026	–
Over voltage, V		
Anode	0.502	0.10
Cathode	0.032	0.032
Back emf (bemf)	1.756	2.380
Voltage drop, V		
External	0.15	1.1
Cathode	0.35	1.1
Anode + rod and clamp	0.35	1.1
Bubble induced	0.25	1.1
Electrolyte	1.344	0.72
Heat requirement corresponding to reaction enthalpy, kWh/kg Al	6.323 (Reaction 1)	9.174 (Reaction 3)
Voltage equivalent of the above, V	2.016	2.925
Heat loss, kWh/kg Al	6.382	3.533
Voltage equivalent of the above, V	2.034	1.126

In case of inert anodes the cell reaction would be reaction (2) and the benefit due to contribution of carbon would not exist. The reversible potential would then be 2.25 V, which is 1.03 V higher than for a cell with carbon anode.

As seen from Table 1, the voltage equivalent of enthalpy to make aluminium increases by 0.908 V (from 2.016 to 2.924), which means that in the absence of any reduction in the other components of the cell voltage, cells with inert anodes will consume more energy.

3.2. WETTED CATHODE

In the conventional Hall-Heroult cell a molten metal pool at the bottom practically acts as part of the cathode system since it is in contact with carbon lining cathode. Difficulties in cell operation include accumulation of sludge or muck on the cell bottom beneath the aluminium pool forming insulating regions thereby causing voltage drop. Another serious drawback of the carbon cathode is its non- wetting by aluminium necessitating the maintenance of a substantial height of pool or pad of metal in order to ensure an effective molten aluminium contact over the cathode surface. Electromagnetic forces create standing waves on the molten aluminium giving rise to the possibility of short circuit. This has become a constraint to manipulate with the anode cathode distance. An approach in this direction was to replace this electrode by a drained and wetted cathode which possesses favourable mechanical and chemical properties.

The most promising candidate, first proposed in the 1950s, has been titanium diboride TiB_2 [Welch, 1999] as it has a low solubility in aluminium , is resistant to attack by molten electrolyte , has good electrical conductivity and more significantly is wetted by aluminium , thus potentially lowering interfacial voltage drops. Because it is expensive as well as difficult to make a cathode from TiB_2 tiles alone, attention has focused on using TiB_2 as a composite or a coating material on a carbon base and a variety of methods have been adopted to prepare such materials. The different routes examined are: applying a coating from a suspension of TiB_2 powder and binders and drying [Mirchi and Bergeron, 2000], compaction and partial sintering [Rapp, 2001], plasma spraying [Lu et al., 2005], coating of carbon cathode block surfaces with TiB_2/C compound layer by vibration moulding [Ren et al., 2007], electro-deposition [Simakov, 2008], using furan resin and pitch blend as binders [Hou et al., 2011], pressure-less sintering using Ti and Fe additives [Heidari et al., 2011] etc..

Commercial cells have been evaluated where the TiB_2 is employed either as mushrooms, protruding above the metal pool to form the cathode surface or as a coating applied to a sloped substrate and draining to a central sump [Tabereaux et al., 1998, Keniry, 2001]. Comalco [Brown et al., 1998] has reported important results with drained cell development. In these studies the energy saving resulting from the use of drained cathodes has been estimated to be in the order of 9% compared to the conventional Hall-Heroult cell.

A wetted cathode will bring in advantages like increase in production capacity while maintaining a low anodic current density and will lower the anode cathode distance, reducing cell energy consumption. However, cost of titanium diboride and problems like metal penetration, expansion of titanium diboride composite and attack by discharged oxygen and are matters of concern. It was reported [Dorward, 1986] that relatively porous titanium diboride (~96% dense) is penetrated with aluminium metal when used as a cathode in aluminium reduction cells operating at 970°C. Metal penetration changes the predominant fracture mode and has potentially important ramifications on mechanical properties. A study on expansion of titanium diboride/C composite cathode and sodium penetration reported by Yaowul et al. [Yaowul et al., 2007] showed that expansion of TiB_2/C compound cathode decreased with the increase of TiB_2 content in TiB_2/C and Na expansion happened both in TiB_2/C cathode and in normal cathode, the Na expansion rate in TiB_2/C cathode being less than that in normal cathode under same conditions. The expansion of TiB_2/C compound cathode decreased with the increase of TiB_2 content in TiB_2/C.

4. VERTICAL ELECTRODE CELLS

The non-consumable oxygen-generating anodes require additional free energy for electrolysis compared to conventional technology. In order to maintain the overall economy of production this additional energy requirement must be compensated for somewhere else in the process. One approach currently being under study is vertical electrode cells [Brown 2001] which employ both inert anodes and wetted cathodes in a vertical arrangement. A series of electrodes, anodes and cathodes alternatively, are suspended vertically in the molten AlF_3, NaF_3 slurry electrolyte. All the cathodes and all the anodes are at equal potential. The advantages associated with vertical alignment of the electrodes are:

1. The cathodes allow the anode-cathode distance (ACD) to be kept small and fixed so that the voltage drop within the electrolyte across the electrodes is minimized.
2. The oxygen bubbles generated on the anodes are quite small in comparison to the ACD.

Through this modification in the cell design reduction in the voltage drop across the electrodes can take care of the additional energy requirement.

4.1 Low Temperature Electrolysis (LTE)

In principle the vertical electrode system cell can be operated with any inert anode material. However, anode corrosion at the operating cell temperature in the conventional technology still poses a limitation on the choice of electrode material. LTE is being studied as a solution to this.

LTE is based on changing the electrolyte composition to one that is much more acidic than what is used in conventional smelting and that exhibits a much lower liquidus temperature [Thonstad and Olsen, 2001]. The lower temperature opens the scope for more number of materials to succeed as inert anodes. In LTE system the electrolyte exhibits a low solubility for alumina for which operation at high current density is not possible. This limitation is overcome by maintaining an excess of un-dissolved alumina suspended in the electrolyte. In order to avoid settling of alumina in the slurry, it is kept suspended by exploiting the bubbles produced at the anode. The anodic bottom liner helps oxygen formation from the bottom that prevents alumina from settling.

The LTE system has three main components: LT slurry electrolyte, Non-consumable metal anodes and wetted cathodes. The VEC concept allows the LTE conditions to be put into practice. Potassium cryolite (KF-AlF_3) -based baths are widely investigated [Hryn et al., 2005]. In KF-AlF_3 based electrolytes aluminium production is reported to be achieved at around 700°C using inert anodes [Yang et al., 2006]. Behaviour of TiB_2-C composite cathode materials in [K_3AlF_6/Na_3AlF_6]-AlF_3-Al_2O_3 melts has been studied and reported [Fang Zhao, 2010].

4.2 Challenges for VEC

A good number of challenges may come in the way of practical implementation of the vertical electrode LTE cell. The challenges belong mainly to three classes namely **fundamental, process control and engineering.**

The fundamental challenges can be summed up as:

1. Choice of anode: For anodes the choice of material and determining a suitable chemistry for it may be a challenge of fundamental nature. In addition, understanding the passivation and corrosion behaviuour of the anode lining is also a task to be reckoned with.
2. Understanding the VEC alumina feeding with respect to the type of alumina, equipment for alumina

feeding, which is ultimately related to the physical and chemical behaviour of the alumina in the slurry cell.

3. Choice of cathode. While TiB_2 is judged as a suitable material for wetted cathode, it may not be the best for VEC application and alternative materials are to be examined.
4. Removal of product metal from cell. The liquid product metal formed on the cathode may cause short circuit if the anode-cathode distance is not critically maintained.
5. Measurement of physical parameters. Since the electrolyte and cell temperature in LTE system are quite different from the conventional system, proper data base with respect to physical parameters such as alumina solubility, diffusion co-efficient, densities etc. are not available and need to be generated.

As far as process control is concerned the major deviation of the process condition arises from the use of slurry electrolyte and low temperature bath. Identification of crucial process parameters that are needed for successful cell operation is a challenge for this technology. The final set of challenges leading to a commercial smelting process is the engineering challenges, which involve incorporation of the specifications given by the fundamental and process control challenges in cost-effective and practical ways. The conditions for successful LTE differ significantly from the conditions for conventional electrolysis. Establishing the limits of these conditions and maintaining them in practice will be a challenge in successful commercialization of the technology. The traditional cell geometry cannot sustain LTE. The concept of VCE emerges as an alternative.

5. ENVIRONMENTAL ASPECTS

The quality of emission from the Hall's cells is a matter of great concern from environmental point of view. The anodes in the present Hall cell burn a huge quantity of carbon, producing equivalent amount of carbon dioxide which contribute to global warming. In addition, CO, CF_4 and C_2F_6 are also formed which are established environment pollutants. Moreover, the anodes typically contain 1-4 wt. % of sulfur origination from the petroleum cokes used in anode fabrication particularly in Soderberg anodes. [Hay et al, 2004]. When the anode is consumed sulfur gases, particularly COS and SO_2 are emitted. The frequent anode changing operations expose the plant operators to fluorides, dust and heat.

The industry has largely solved the fluoride emission problem with the introduction of dry scrubbing, on demand dual duct system and anode cooling boxes [Tarcy et al., 2011]. Introduction of on demand dual duct system has achieved almost a twofold increase in the extraction flow rate of fluoride emission during anode change operations. The first two industrial applications of the dual duct system were at the Alcoa Deschambault smelter in the fall of 2002, which increased the duct flow from 864 to 1,584 Nm3/h during anode change operations [Broek et al., 2011], and the Hydro Sunndal smelter in Norway also in 2002, which increased the normal duct suction of 5,000 Nm^3/h to 15,000 Nm^3/h [Haugan et al., 2003]. Emissions from hot anode butts and crust account for 35% of the total fluoride emission in pot rooms the majority of which occur during the first 20 minutes of cooling. The solution to this environmental problem was through introduction of anode cooling boxes which was implemented in 2000 at the Alcoa Deschambault smelter in Quebec, Canada [Gange et al., 2006].

The spent carbon cell linings contain highly alkaline bath, aluminium carbide, cyanides and other materials. Economic disposal of used carbon cell lining remains a problem. A small part is ground and added to cement kilns as a source of fluoride, but most of it now still end in landfills.

The use of inert anodes and other modifications discussed above is expected to eliminate the gases emitted caused due to carbon anodes. However, it is not correct to say that inert anodes will eliminate all environmental problems from the electrolysis process. The fluoride-containing electrolyte will still generate HF (g) and vaporization of cryolite will continue. Emission of CO_2 from making and burning of pre-baked carbon anodes may be reduced; but that originating from other steps of alumina production such as bauxite mining and power generation source will not be affected.

6. ECONOMICS

The economic impact of the technological change over is reflected in material cost, energy consumption and environmental benefits. A concrete economic analysis is only partially accurate since the technology is not yet commercialized. A cost analysis made by Keniry [Keniry, 2001] suggests that replacing the existing prebake anode cells with inert anodes does not yield sufficient economic advantage to justify the objective. Energy saving and increase in production may be accomplished through use of drained cathode provided that the cell life is greater than three years. Inert anodes and wetted cathodes can more effectively used in vertical electrode cells whose technical and economic viability will require much lower wear rates of the electrodes than achieved till date.

7. CONCLUSION

The R & D activities during last several years on industrial aluminium production by the Hall Heroult process have focused on energy saving and reduction as well as control of environmental pollution through studies on inert anodes, wettable cathodes and vertical electrode cells as alternative to those in practice in the conventional technology. There has been considerable progress in the study of inert anodes and wettable cathode materials with respect to their mechanical and chemical properties. Other aspects such as bath penetration to cathode and retrofitting the conventional cell are also being widely examined. Though a commercial shift in adopting such changes has not yet taken place, it seems imminent. In this context wettable cathodes appear to be in a favourable situation compared to inert anodes. As observed so far, the retrofit of conventional cells does not seem to offer conclusive advantages. Suitably modified or radically new cell designs are required to achieve the potential energy benefits. It may not improve the energy consumption, but will lead to a better environmental status for the technology with marginal to moderate cost advantage.

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THE ROLE OF RAW MATERIALS IN PROMOTING FERRO ALLOY INDUSTRY IN ODISHA

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ABSTRACT

Minerals are the most important raw materials for development of ferro-alloy industry. During a few decades of industrial development, most of our high grade mineral resources have been mined extensively for internal consumption and export. In this way most of the high grade minerals have been exhausted. As these resources are nonreplensible in nature, it has been necessary to conserve these valuable natural resources and develop various technologies to process the low grade and complex ores and minerals to sustain the existing industries in the country. To make the mineral based industries sustainable, we have to manage the raw materials in a very scientific manner using environmental friendly technology. In this paper emphasis has been given on the importance of ferro alloys industry in contest of iron and steel scenario, the raw material management and the some recent developments in ferroalloy production and proposed Research and Development programs for promotion of ferro-alloy industry. The efforts have been made to highlight the developed R&D required to minimize the energy source for the production of ferro alloys.

Key Words: Ferro alloys, Raw materials management, Energy conservation.

INTRODUCTION

Ferro-alloys are essential ingredients, used for alloying, refining, deoxidation, desulphurization in the production of different types of steel and hence ferro alloy industry forms the backbone of iron and steel in the world. Ferro alloys industry in India plays a vital role in steel industry to produce various types of steel. The present capacity of ferroalloys industries is about 5.15 Mt per annum. Our planners envisage that these industries should produce larger qualities of basic alloys, which are required for the growth of steel industries at home as well as to cater to the international market. This is only possible when the management of raw materials and energy required for the production of ferroalloys is properly done. This paper deals with the utilization of low grade ores as well as the wastes produced during processing of raw materials in ferro alloy industries. The efforts have been made to highlight the developed R&D required to minimize the energy source for the production of ferro alloys.

Production of ferro alloy started in India about 62 years ago with setting up of the first ferro manganese plant by M/S TISCO at Joda, Keonjhar, Odisha. After this, with rapid development of the country's steel industry, the demand for ferro-alloys increased considerably. Number of firms were set up for the production of different types of ferro alloys. Today India has adequate capacity for the primary ferro alloys not only to meet the entire demand of the country but also surplus for the export. As the quality of ferro alloy affect the steel quality and yield at various stages, they have great impact on the profitability of the steel industries. Hence value addition is essential by production of ferro alloys and stainless steel with a view to conserve our mineral ore sources instead of exporting.

The past, present and future of ferro alloys is linked with the steel production. The planners in India envisaged an ambitious development programe for the iron and steel in the early fifties. They aimed to achieve a target of 20 million tonne of steels within 25 years. Accordingly to make this development possible ferro-alloys industry was set up in late fifties and early sixties.

In India by the year 1963, seven plants: 2 in Odisha, 1 in Andhra Pradesh, 2 in Karnataka and 2 in Maharastra were established. These plants have 18 furnaces and have a total installed capacity of approximately 130 MVA monthly for the ferromanganese. During 1966-67, 10 more furnaces were added with combined capacity of 143 MVA.

During this period, IMFA, IDC, Nav Bharat Ferro-Alloys, Sandur Metal and Ferro Alloy Plant, and Maharashtra Electrosmelt Ltd. came up. In addition to increased capacity for ferro-manganese, they aimed for silicon and chromium alloys. After 1979, three more new plants VIZ OMC charge chrome and Ispat alloys in odisha and VBC ferro-alloys in Andhra Pradesh came up.

In India, most of the Ferro-alloys units have been set up in Andhra Pradesh, Chhattisgarh, Jharkhand, Karnataka, Madhya Pradesh, Maharastra, Odisha and West Bengal because of availability of the raw materials. The industry has further spread to North-Eastern region of India. In Meghalaya, a number of small units producing ferro-silicon and ferro-silicon-manganese have come up.

Ferro-alloys may be classified as per the carbon in alloys like low, medium and high carbon ferro alloys. The most significant and important class of ferro-alloys are low carbon ferro-alloys, which are produced with great difficulty and primarily used in the production of special steels. The other classification is based on the consumption aspects of ferro-alloys. They are (a) based on tonnage alloys and (b) specialty alloys. The tonnage ferro alloys are of manganese, silicon and chromium. The specialty alloys were developed recently to fulfill the specialized quality requirement of steel technology.

As per Indian Ferro-Alloys Producers Association (IFAPA) of present the total installed capacity of bulk ferro alloys industry in India is 5.10 million tones per annum and noble Ferro-alloys is 50,000 tones per annum. The industry is reported to be working at about 60-65% capacity utilization. The capacity of ferro-alloys of India is given in Table 1. The production of various Ferro-alloys as reported by IFAPA is given in Fig. 1 to 4. Figure 1 shows the production of high carbon ferro-alloys during 2008-09 to 2011-12. The production of low carbon ferro-alloys and noble ferro-alloys have been shown in Fig. 2, 3 & 4 respectively.

Table 1: Capacity of ferroalloy industries in India (in tones per annum)

Ferro-alloy	**Installed Capacity**
(a) Bulk Ferro-alloys	
(i) Manganese alloys	3160000
(ii) Chrome alloys	1690000
(iii) Ferro-silicon	250000
(b) Nobel Ferro-alloys	50000
Total	**5150000**

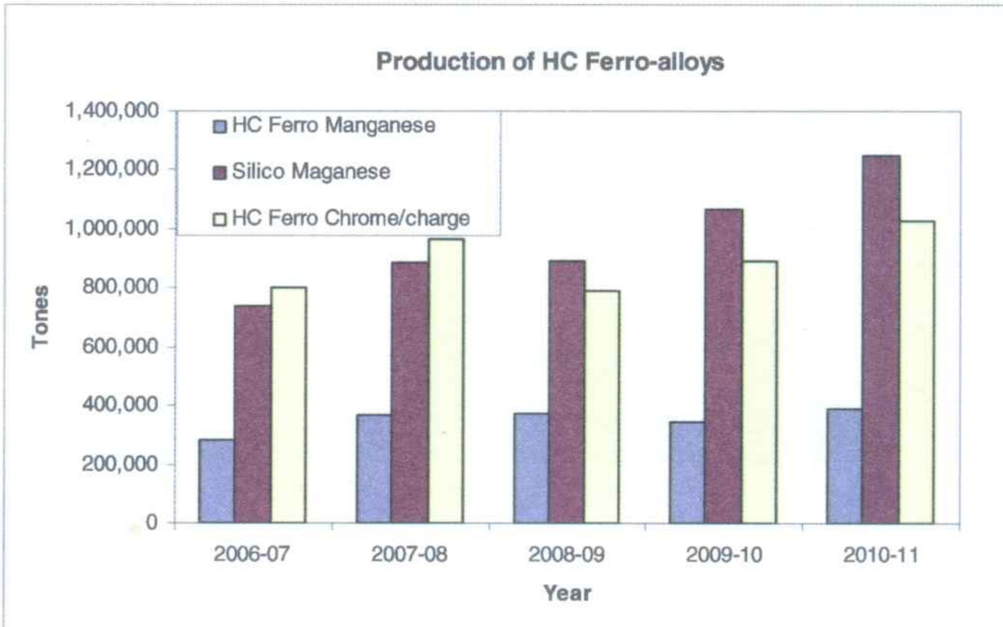

Figure 1: Production of high carbon ferro-alloys during 2008-09 to 2011-12 (Tones)

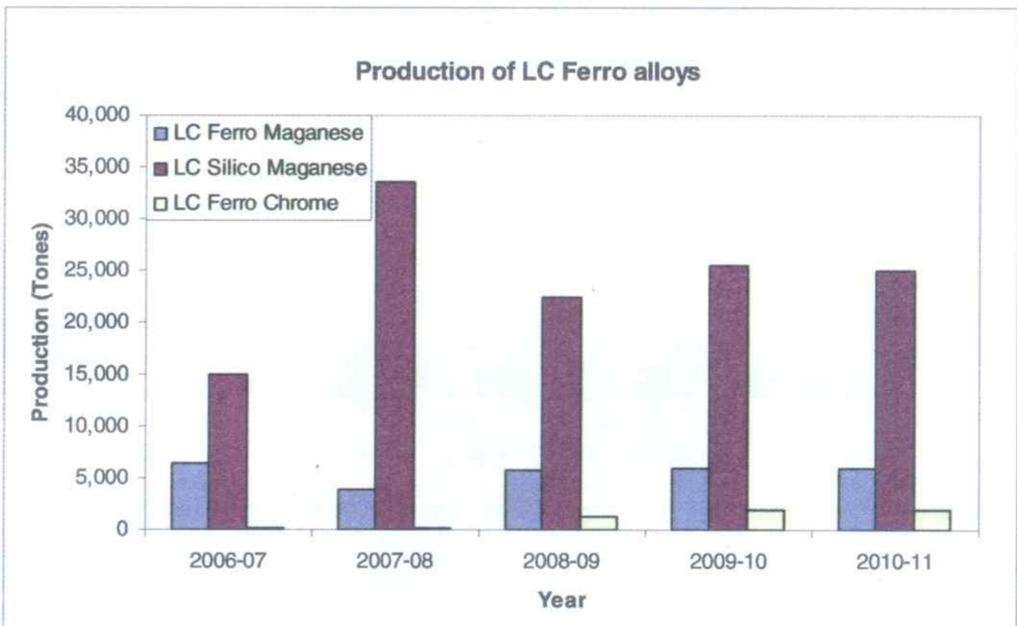

Figure 2: Production of low carbon ferro-alloys during 2008-09 to 2011-12 (Tones)

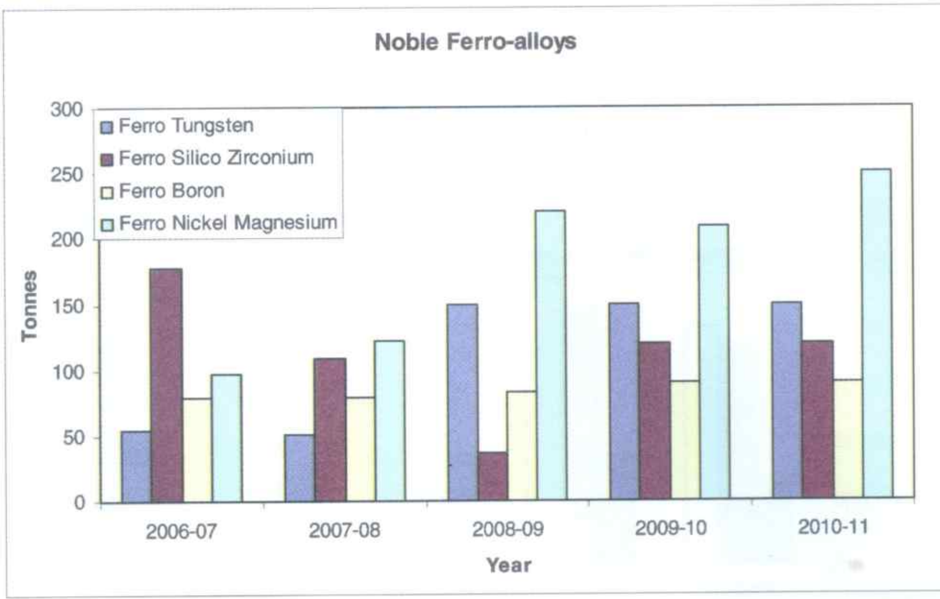

Figure 3: Production of Noble ferro-alloys during 2008-09 to 2011-12 (Tones)

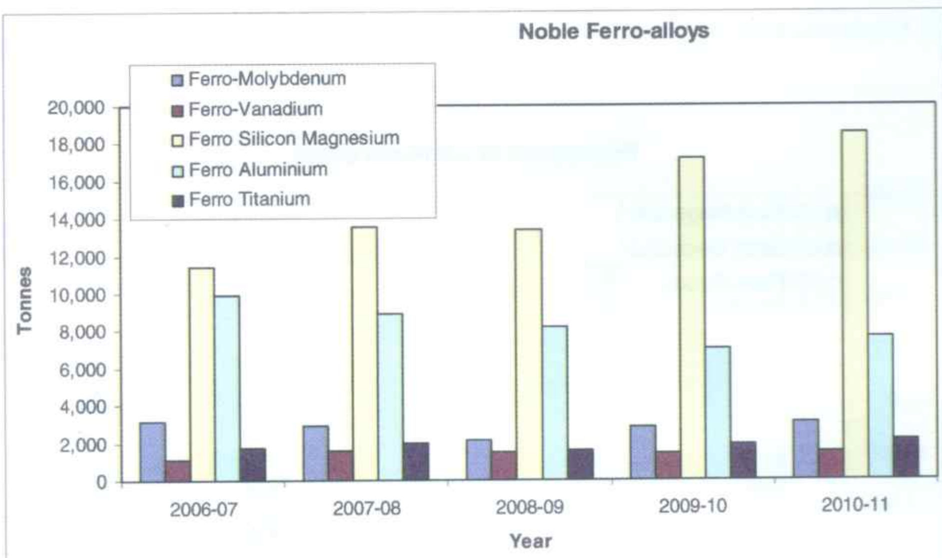

Figure 4: Production of Noble ferro-alloys during 2008-09 to 2011-12 (Tones)

RAW MATERIALS FOR BULK FERRO ALLOYS:

Our country has reasonable resources of Manganese Ore and Chrome Ore to meet the requirement of Bulk Ferro Alloys Industry, if the policy of conservation of minerals by using beneficiated low grade ores is followed.

MANGANESE ORE:

As per the Indian Bureau of Mines Survey Report of April 2010, the total resources is 429,980,000 tonnes out of which about 141,977,000 tonnes is reserve as shown in the Table 2. Out of total reserves BF grade Manganese ore is 49,894,000 tonnes and Ferro manganese grade is of 12,869,000 tonnes. The present production of Manganese Ore is around 3.00 Million tones per annum. Based on the IBM's Report of April 2010, the requirement of Manganese ore for ferro-alloy industry, will be available domestically for 20 years (excluding the inferred reserves). The production of Manganese Ore in India for last five years has been given in Table 4.

Table 2: Reserve of Manganese Ore in India(Provisional, in '000 tonnes)

Grade	Reserves	Remaining Resources	Total Resources
BF grade	141,977	288,003	429,980
Ferro Manganese grade	49,894	95,961	145,855
FERRO manganese and BF	2,425	13,902	16,327
Ferro Manganese, Medium & BF mixed	34,541	31,162	65,703
Low ≤ 25% Mn	1,647	7,505	9,152
Medium	8,694	40,034	48,729
Medium & BF mixed	12,263	32,024	44,287
Mixed	1,763	11,617	13,380
Not Known	2,731	6,702	9,433
Others	7,871	6,053	13,923
Unclassified	7,167	20,216	27,383

Source Indian Bureau of Mines

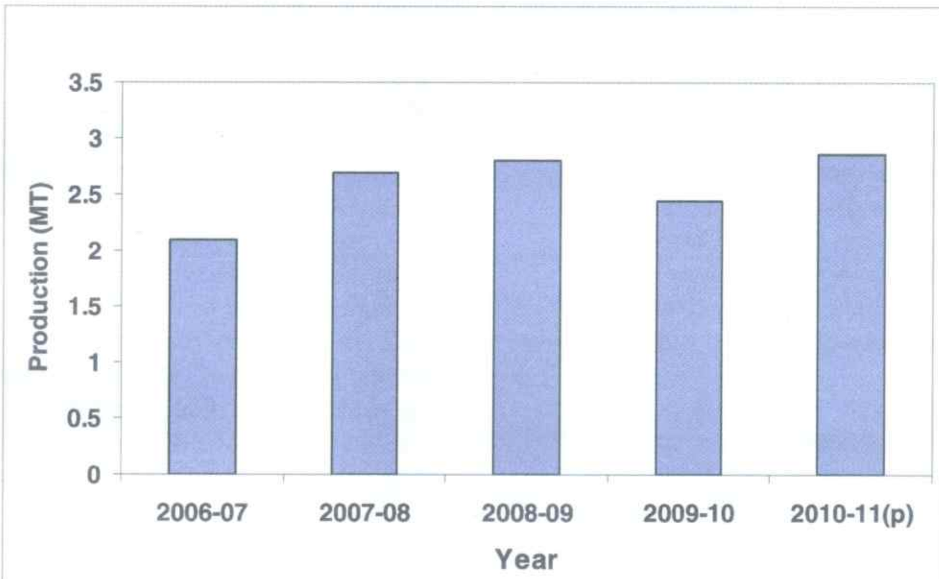

Figure 5: Production of Manganese Ore during 2006-07 to 2010-11

CHROME ORE:

Reserves / Resources:

As per United Nations Framework Classification system (UNFC), total resources of Chromite in the country as on 1.4.2010 are estimated at 203 million tones, comprising 54 million tones Reserves (26%) and 149 million tones remaining resources (74%). Sukinda Valley in the State of Odisha, has 97% of Indian Chromite Ore deposits and it has one of the largest Chromite Ore deposits in the World. Minor deposits are scattered over Manipur, Nagaland, Karnataka, Jharkhand, Maharashtra, Tamil Nadu and Andhra Pradesh. Grade wise, Charge-Chrome grade accounts for 35%of the Resources, followed by Ferro Chrome grade (19%), Beneficiated grade (17%) and Refractory grade (5%). Low, others, unclassified and not known grades together account for 24%. Grade wise Resources of chromite as on 1.4.2010 are given in Figure 6.

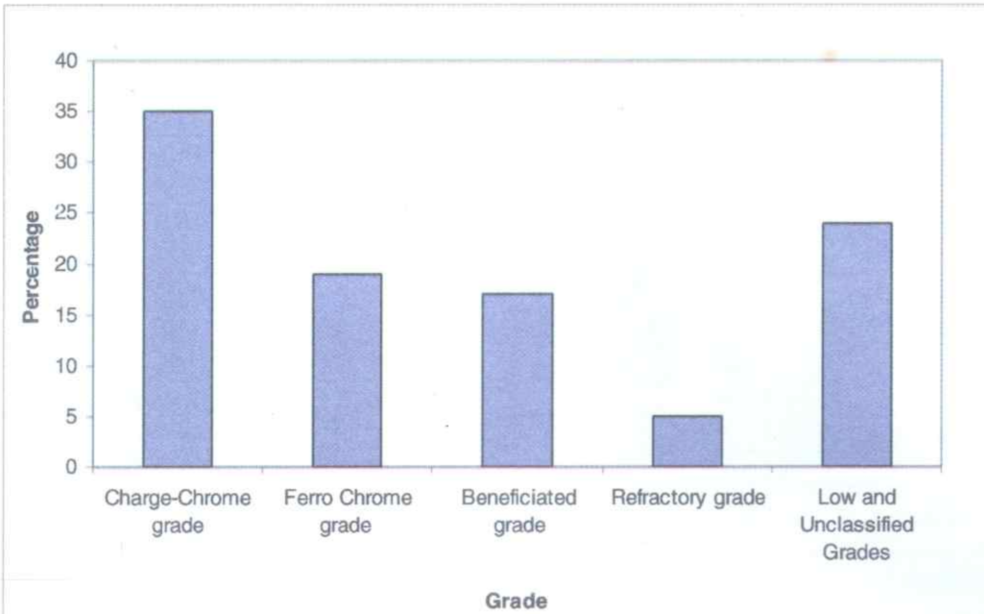

Figure 6: Grade wise Resources of Chromite as on April 2010

Based on the Survey report of Indian Bureau of Mines, the requirement of chrome ore will be available domestically for next 15 years (not including inferred) for Ferro Chrome Industry. The Industry has also started to use Chrome Concentrate (Beneficiated product from Low grade chrome ore). Since the year 2000, the domestic demand of Ferro Alloys is increasing.

REDUCING AGENTS

The high ash and volatile matter contents in the reductants have marked adverse affect on the ferro alloys produced and furnace operation. The resistivity and reactivity of the reductants also has very significant effect on productivity of the furnaces. The high sulphur and phosphorous contents of the reductants adversely affect the quality of ferro alloys produced.

Charcoal is considered as the most ideal reductant in the manufacture of silicon alloys.

- Metallurgical coke from steel plants and other coke making plants along with non-coking coal are used for the production of manganese alloys.
- Imported low ash & low phos. coke along with non-coking low phos. coals and Anthracite coals are used in the production of chrome alloys. In India coal reserves are about 202 billion tones but only about 15% of this is coking coal. Most of the coals are very high in ash and not amenable to known methods of washing because the shale rock is finely distributed in coal. In the absence of low ash & low phos, coking coal/coke in the country, production of chrome alloys has to depend on imported coke. The Indian ferro alloy producers have substituted 50 to 70 percent of the requirement with low phos. non-coking coal though high in ash and imported low ash anthracite coal from Vietnam and recently from Russia and Ukraine. The production and imports of coal for 2009-10 and 2010-11 are shown in Table 3 and 5 respectively. The production of raw coal in our country increased from 493 MT to 533 MT during 2008-09 to 2010-11 and our country imports 69 MT of low ash coal worth of Rs.4154 crores.

Table 3: Production of Raw Coal in India

(In million tonnes)

Year	Production from open-cast mines (% share)	Production from under-ground mines (% share)	Total production
2008-09	433.79 (88%)	58.97 (12%)	492.76
2009-10	473.52 (89%)	58.52 (11%)	532.04
2010-11	477.84 (89.7%)	54.85 (10.3%)	532.69

Source: Coal Directory of India, 2010-11, Coal Controller's Organisation, Kolkata

Table 4: Imports of Coal for 2009-10 and 2010-11

Country	2009-10		2010-11	
	Qty ('000 t)	Value (₹ '000)	Qty ('000 t)	Value (₹'000)
All Countries	**73257**	**391798228**	**68918**	**415494801**
Australia	22837	183802972	17273	181449036
Indonesia	32165	115473599	35944	134788133
South Africa	14492	62269478	11214	57272632
USA	1400	13303028	1770	19829296
New Zealand	1059	9976882	795	7703847
Russia	146	1382492	424	4216902
Vietnam	188	1694285	241	2580766
China	45	235500	242	1752587
Philippines	671	2235122	261	801774
Unspecified	–	–	333	1783374
Other countries	254	1424870	421	3316454

FERRO-ALLOY MAKING

The production of Ferro Chrome, Ferro Manganese and Silico Manganese etc is done in three phase Sub Merged Arc Furnaces. The Oxides of respective ores of these ores are smelted with carbon. The carbon as reductant comes from coke, coal, char and in some cases wood chips. The fluxes like lime stone, dolomite, quartz, bauxite and magnesite are used to slag to desire composition. The raw materials are continuously fed into the Submerged Arch furnace and hot metals are tapped at regular intervals through tap hole of the furnace. The tapped alloy and slag are separated by de-canting process or by adopting gravity using skimmer blocks. The metal is collected or cast into cast iron pigs. After solidification, the same is crushed, sized and later packed duly in drums or bags with chemical assay to make it ready for dispatch.

In our country the total infrastructure and supplies i.e., power supply, transport, and communications, oil supply, coal, ores supply are in control of Government. So the Ferro Alloy industry is dependent for almost 80% of the total input on supplies from public sector and have no control on cost of these inputs. These costs are much higher as compared to the cost of similar inputs borne by producers in other countries. For example power costs are 4-5 times higher than the power cost abroad. Hence, with such high input costs, the industry can not survive to compete in the global market. The Government has to make some policies to assist the industry for production.

In the same time ferro alloys industries have to put their main thrust towards modernization and reengineering of existing facilities considering application of possible areas of energy conservation since power tariff in India is higher as compared to other countries. The energy conservation measures can be adopted right from raw materials selection to disposition of final products which can be taken by the ferro alloy industries is given in Fig.7. The continuous Research and Development in the process and products, Energy conservation, utilization of by-products, pollution control etc is must to compete in the global market.

RECENT DEVELOPMENTS

The increase in production of ferro-alloy depends on minimizing the energy consumption, for which it is required to (i) use high grade raw materials (ii) to adopt better furnace design, durable refractory lining and efficient operation (iii) to utilize ferro-alloys scraps and recovery of alloy values from the slag and rejects and (iv) to develop new technology. In recent years, all over the world various R&D work have been taken up in these lines. Further, special types of ferroalloys like those of refractory metals and rare earths have also been developed.

A new ferro-chrome production route with higher production capacity was developed and commissioned at the Tornio Works of Outokumpu. This new process was specially designed to process soft and friable lumpy ores which was subsequently smelted in a closed electric furnace. In this route, besides increase in production, there was substantial decrease in energy consumption.

Shcherbin et al. have carried out some laboratory scale studies for producing low carbon ferro-chrome. They have found that the rate of considerable. In a view to manufacture low carbon ferro chrome one can use highly calcined lime having a carbon dioxide content of less than 2 % unlike the previous practice where this gas content was used to be 3 to 5%. In this manner it has been possible to produce ferro chrome having a carbon content of not more than 0.019%. The highly calcined lime can be used for producing medium carbon ferro-chrome.

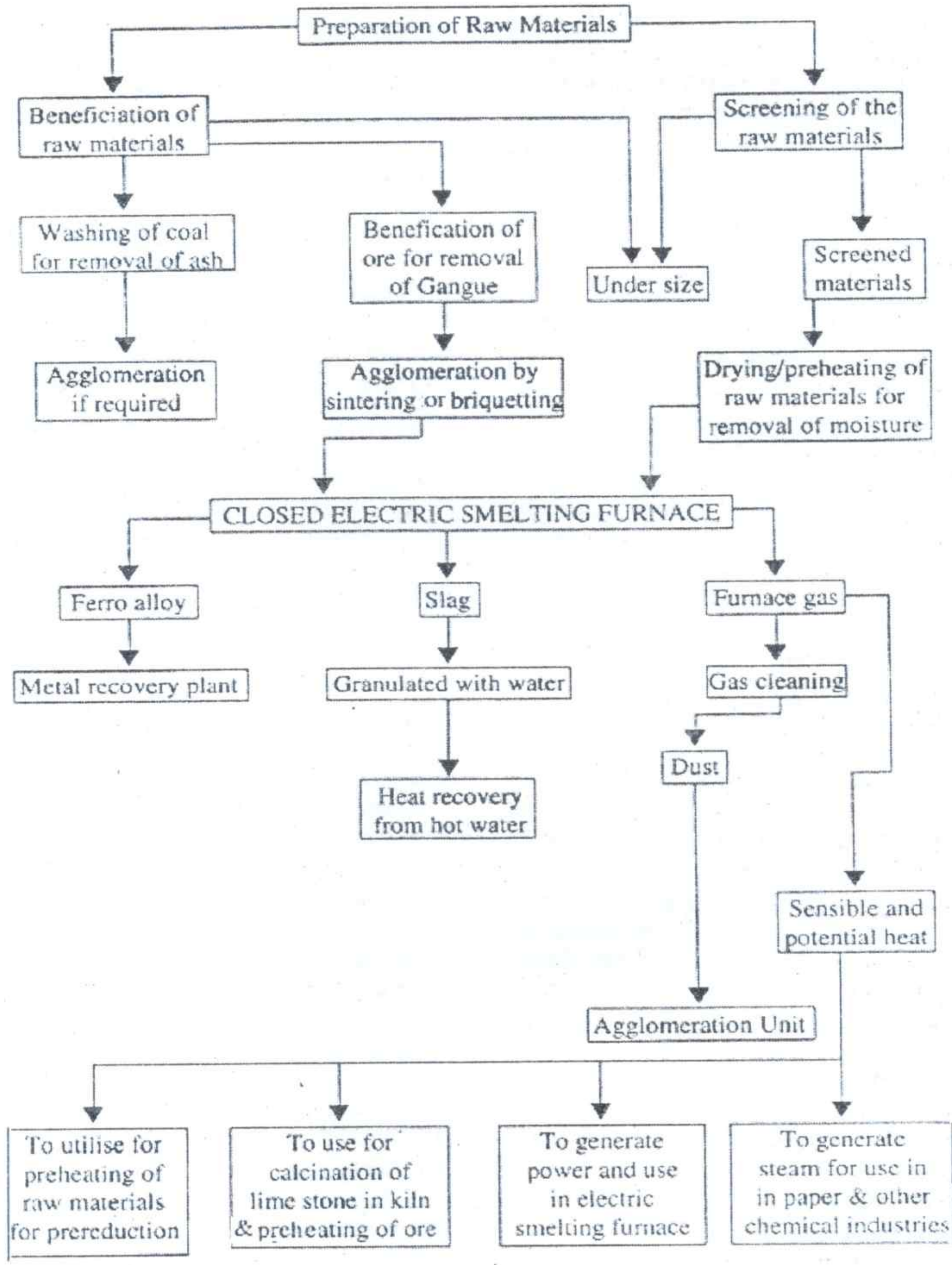

Figure 7:Possible areas of energy conservation in production of Ferro Alloys

A process was developed by Kawasaki Steel Corporation Limited developed a process where reduction of chromium ore in a fluidized bed reactor using a hydrocarbon instead of oil, was carried out. The behavior of melting, reducing foaming and dripping of chromite in a packed coke bed was examined and the viability of the smelting reduction process was established. However, the pilot scale results have to be examined prior to any commercialization.

CSIR-Institute of Minerals and Materials Technology, (CSIR-IMMT) Bhubaneswar is involved on smelting reduction of chromite to optimize slag composition to reduce loss of chromium in slag thus improving the chromium recovery in alloy. It has been possible to reduce Cr_2O_3 in slag to a level of 1.3 to 4.0% with 90 to 95% chromium recovery in alloy. Experiments to reduce electrical energy consumption have also been conducted simulating oxy-coal process in induction furnace. With 2l/min oxygen injection on top of the molten slag covered with 25 to 50g coke for a duration of 5 to 10 minutes, it has been possible to reduce electrical energy by 30% without affecting chromium content in alloys as well as recovery of chromium.

For producing manganese alloy, preheating and pre-reduction of the smelting furnace charge, has been carried out successfully on bench scale because of the encouraging results, Outokumpu did carry out pilot tests at its metallurgical Research Centre in 1983 in order to optimize the conditions for scaling up the process.

The smelting reduction of manganese ore has been studied in CSIR-IMMT, Bhubaneswar. It is possible to reduce manganese loss in slag to a level of 15.97% with 80% Mn recovery in alloy. The effect of slag basicity on foaming of the slag, reduction of manganese ore and the loss of manganese in slag has been studied in detailed. The effect of temperature on reduction of MnO in slag and the kinetic studies has been made. Efforts have also made to reduce the electrical energy consumption by oxy-coal process in induction furnace. With 5l/min oxygen injection on the top of the molten slag covered with 25 to 50g coke for duration of 2-10 minutes, it has been possible to reduce electrical energy consumption by 30% without affecting manganese content in alloys as well as recovery of manganese.

Recently, a number of developments for producing ferronickel from lateritic ores, have been made in Japan. Studies on concentrating nickel in lateritic ore up to 50-60% with a low nickel content by segregating process has been reported to be successful. As the process takes place below 950°C, compared to about 1600°C in the conventional smelting process. A 25-30% energy saving is expected on commercial scale.

There is reported production of ferro-nickel 2200 tons Ni per month scale at Hyugu Smelter in Japan by rotary kiln and electric furnace. The development made in the areas are (i) improvement in ore sizing, (ii) substitution of heavy oil and anthracite by bituminous coal, pelletization of rotary kiln dust and (iii) energy saving in electric furnace.

A process for producing ferro-nickel by direct reduction of garnierite ore has been developed by Nippon Yakin Kogyo Corporate Limited, at their Oheyan using a rotary kiln after pretreatment of raw materials and this crude ferronickel can be used has the raw material in the AOD stainless steel making process. A simplified mathematical model has been developed for the production of ferronickel from lateritic ores by the electrical reduction furnace reduction process(ERF process) and the same has been applied satisfactorily at the plant of LARCO ,at Larymna in Greece.

Studies on ferro-nickel making from Sukinda chromite overburden materials have been undertaken by CSIR-IMMT, Bhubaneswar sponsored by M/S Tata Iron & steel company Ltd, Jamshedpur. The experiments were carried out to enrich nickel from Sukinda chromite overburden materials by reduction roasting in pan sintering unit followed by magnetic separation. Further experiments were carried out on smelting of nickel concentrate to make ferro-nickel. Trial runs were carried out on in 50kg scale using sintering pot grate furnace of 400×400×430 mm cross section with 400mm bed height and 500 WG suction pressure below the grate bars. It has been possible to get a nickel rich concentrate containing up to 1.4% Ni from the feed containing 0.74% Ni by using the above process. When this concentrate was subjected to smelting studies, it was possible to obtain ferronickel containing up to 4.1% Ni with 90% metal recovery.

In recent years, with the development of plasma generating system and the design and fabrication of large size plasma furnaces, various efforts are being made to produce metals and alloys by using such facilities. Plasma Furnaces are being used for direct reduction of iron oxide, chromite, manganese oxide, ilmenite etc. to produce the metals and their alloys. Plasma systems are also used for dissociating metal halides, in slag refining as well as various gas phase reactions.

The installation and commissioning of a (500lb) 220 KVA DC transferred arc plasma furnace at the mineral Resources Research Centre of University of Minnesota. The furnace is based on a hollow electrode designed with a 10cm graphite cathode and tilting lip for sample pouring.

In early seventies, SKF steel started a long range research and development programme to produce metals and alloys by applying plasma technology. As a result of these efforts, it has been possible to develop commercial processes for producing iron, steel and ferroalloys. Simultaneously they have also developed plasma generators in the range 1-10MW

In New Zealand, plant studies have been made to produce ferro-alloys by plasma as alternative to fossil fuels and electrical energy. These include the production of ferrovanadium from New Zealand Steel Works slag; treatment of steel plant dusts, ferrosilicon, enrichment of titanium value in ilmenite etc. The council for Mineral Technology has embarked on a programme to produce ferrotitanium containing 30-40% Ti, and also Ti-Al-Fe alloy from a high titanium slag by using DC transferred arc plasma system.

Various R&D activities on titanium has been carried out at CSIR-IMMT, Bhubaneswar. The studies on recovery of ilmenite and sillimanite from beach sand concentrate has been sponsored by M/S TATA Steel, Jamshedpur. Another beneficiation studies on beach sands of srikakulam district, Andhra Pradesh has been sponsored by M/s Trimex Industries Ltd, Hyderabad. A number of other projects on plasma smelting of illimenite has been undertaken. A detailed study was conducted on the separation of titanium rich slag and iron from pre-reduced consumption. The studies were conducted with static bed plasma smelting reactor as well as moving bed plasma smelting reactor, which was designed and fabricated based on the static bed data.

A detailed report was submitted to M/S Indian Rare earth Ltd. Chattrapur. The results clearly indicate that by varying various plasma processing parameters, it is possible to minimize the energy consumption significantly. The degree of metallization also plays an important role in minimizing energy consumption and improving slag quality.

THE PROPOSED R&D PROGRAMS

The Proposed R&D Program can be directed in to the following areas:

1. Recovery of potential and sensible heats in off gas by implementation of closed submerged arc furnace
2. Decrease in slag production which can save about 60-70 units of power per ton of product.
3. Utilization of tapped molten ferro-alloy directly in steel making to conserve about 10-15% heat equivalent to electrical energy inputs in steel making.
4. Application of computer control system for process control and raw materials handling system which helps to bring down 5-10% of specific energy consumption. And

5. Implementation in furnace design and electrical parameters which help to save the electrical losses in the system and reduces the specific consumption.
6. Agglomeration of Ore fines to utilize the fine ores
7. Beneficiation of low grade Ores
8. Beneficiation of high ash coal which can be used as reductant in production of ferro alloy.
9. Utilization of plasma smelting for direct feed in form of fines of ores and reductant.
10. Refining of Ferro alloys outside the furnace.
11. Development of new Ferro alloys.
12. To find out the cheaper sources of power generation for captive use like solar energy, wind energy, hydel energy or captive power plant based on DG sets/ gas turbine/thermal power station.

CONCLUSIONS

During 1950 to 1970, our industrial development was in its infancy and to meet our foreign exchange requirement. Iron ore, chrome ore etc were exported. In the subsequent period the ferroalloys and sponge iron industries were set up to add value. In this century the metal price in the international market has gone up substantially and therefore the conversion of semi product to finished product is extremely important from National point of view.

The production of Ferro Alloy in larger quantities of basic ferro alloys which are required for the growth of steel industries at home as well as to cater to the international market is only possible by proper management of raw materials and energy required for the production of ferro alloys. The mineral like chrome ore and nickel ore are non renewable assets and our country has got limited reserve. Therefore it is very important on our part to make judicious use keeping in view our long term requirement. For this purpose chrome ore and chrome alloy export to be limited and all efforts should be made to convert charge chrome to stainless steel and special steel to meet domestic and export need.

Beneficiation plants to upgrade our medium and low grade chrome ore and nickel containing chrome ore overburden should be installed for charge chrome and ferro- nickel production. The charge chrome and ferro-nickel are basic input for stainless production.

Value added products (Engineering and other technological items) are to be produced for meeting domestic demand and export with a view to conserve our mineral resources. In the past we have already suggested to Govt. of Odisha that processing of raw materials which are being wasted during mining are to be scientifically utilized to produce value added product. This will be promoted by a company as an auxiliary of OMC/IPICOL entitled "National Innovative Mining and Metal Limited" to look after the promotional effort establishing pilot demonstration and commercial plant in our state. These valuable raw materials can provide the base for manufacturing of Fe-V, Fe-Ti, Fe-Ni etc which our country is importing for production of special steels. We understand this is under consideration by Govt. of Odisha as a special case

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MASS EXTINCTIONS OF ORGANIC LIFE ON EARTH'S SURFACE

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ABSTRACT:

Since the origin of earth some 4.6 billion years back there have been constant changes in many aspects of the Earth, e.g. distribution of land and sea, climate, sea level, composition of the atmosphere diastrophic movements (mountain building, volcanic activity) and the impact of space bodies (bolides, meteorites etc.).

Earth is the only known planet which provided environmental inputs for development of life. It developed initially as unicellular bacteria which diversified into many complex forms based on Darwin's theory of evolution.

During the long history of Earth many forms of life have appeared and disappeared in response to the mega changes on Earth's surface. Based on fossil records, five mass extinctions of organic life have been noted. Now the earth is heading for the sixth mass extinction where most mammals, it is feared, would disappear. The present mass extinction is believed to be due to the destructive human activity on the Earth's surface.

INTRODUCTION:

From records of fossil remains preserved in rocks all over the Earth it has been observed that there has been disappearance of large groups of life in certain periods of geological time which have never appeared again. Earlier disappearance was related to marine life only since the landmass was not congenial to the development of life but later it related to both plants and animals inhabiting both on land and in sea. The life forms which disappeared later were large and complex, The earlier life was only invertebrates while later it was both invertebrates and vertebrates. Now one does not see the great *Trilobites* of the Cambrian, the *Productus* of the Permian, the soft bodied plant *Gymnosperms* which gave rise to *Gondwana* coals – during the Mesozoic, the great *ammonites* and huge *dinosaurs* of the Cretaceous and the wooly mammoths of the Pleistocene. Five mega extinctions have occurred during end of Ordovician, Devonian, Permian, Triassic and Cretaceous Periods. Now mankind is facing the sixth mass extinction and it is due to the activities of man only. The present article describes the different main extinctions and their possible causes.

Geological Time Divisions

Since the formation of planet 'Earth' around four thousand six hundred million years ago it has witnessed many mega changes such as : (1) development of land and sea and their quantitative distribution, (2) the development of atmosphere and its change in composition of oxygen, carbon dioxide, methane etc., (3) the organic evolution from azoic to protozoic and extensive visible life with their remains as fossils, (4) diastrophic activity such as plate tectonics, mountain building and volcanism, (5) climate change, (6) glaciations and (7) space impactors such as smaller meteorites to major asteroids. Based on such mega changes affecting Earth at different times, the Earth's age (4.6 Billion years) has been divided into several mega divisions (Eons) and smaller divisions (e.g., Era, Period, Epoch etc.) The standard geological time divisions are stated below for the benefit of the common readers as below.

(1) At 4600 million years (my) back (approximately) the Earth is believed to have its independent identity mostly in gaseous state developed either from sun as a daughter or from the same parent Nebula as a sister body.

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(2) 4600 my - 4000 my : From gaseous state the planet changed into a hot liquid state. On loosing temperature it gave rise to the formation of minor hard solid rock crust with hot sea and an anoxygenic atmosphere rich in CO_2, CH_3 etc.

(3) 4000 my – 3800 my : The Earth further solidified to give rise to the protocrust, warm seas, with very little of oxygen in the atmosphere and no life. This is referred to by some as the *Hadean* age.

(4) The Period from 3800 my to 2500 my

This vast time period is known as the *Archeozoic* (Archean) Eon. During this period the protocrust increased in volume and gave rise to continental fragments. The sea water became cooler and the atmosphere became more oxygenic and less of carbon dioxide etc. There was development of the amino-acids, the building block of life. The primitive life began. These were microscopic unicellular blue green algae, prokaryotes and euro-karyotes bacteria which developed in warm sea waters of the time. Their fossil evidence is found not as individual fossils but as a rock product known as the '*stromatolite*'.

(5) The period from 2500 my to 600 my

This is another Eon referred to as Proterozoic. During this mega period there was further cooling of the Earth, enrichment of Oxygen in the atmosphere and more land mass development either through volcanic activity and sedimentation in the marine basins. Numerous soft multi-celled organisms proliferated in the seas. Many small continents moved together to form a supercontinent known as *Rodinia* to the later part of Proterozoic. By 600 my some animals started developing a skeleton. The remains of life during this period were preserved as impressions in rocks where the individuals could not be identified. By around 800-700 my the mega continent, Rodinia, started breaking away and later tried to assemble together to give rise to another mega continent, the *Gondwanaland* in the southern globe and Laurentia-Baltica-Siberia in the northern region of the globe. These continents were surrounded by many seas e.g. Panthlasea.

(6) The Period from 600 my to Present

This is referred to as Phanerozic Eon. This period is characterized by extensive life forms with hard part development, skeletons which were easily preserved as fossils in the sedimentary rocks of the time. The sedimentary rocks deposited in different time periods were like pages of Earth's history and fossils in them as photographs and diagrams in each page representing life forms that developed during that period. During the initial periods, the fossils represented sea-living animals but later they were both sea and land creatures.

Within the Phanerozoic many large scale visible changes took place in respect of life, in paleo-geography, plate tectonics, mountain building, glaciation, climate change, and changes in atmospheric composition of 0_2, $C0_2$, CH_3 etc. Many old things have vanished and new things appeared. The continents such as Gondwanaland, Laurentia, Baltica and Siberia joined together to form a great landmass *'Pangea'* which later fragmented and gave rise to present day continents and ocean basins. There was tremendous change in organic development in consequence of mega changes. Proliferating animals and plants of a geological period got affected by the environmental changes and perished never to appear again. New forms evolved which could manage in the new environmental set up. Among the notable changes are the development of various mountain chains like Himalayas, Alps, Rockies, Andes; the Tethys sea vanished; the dinosaurs disappeared, the gymnosperms, coal bearing plants, vanished, so also the wooly mammoths and the *Neanderthal* man which appeared before the present man.

Because of extensive changes at different intervals of time during the Phanerozoic it has been further divided into shorter time intervals of Era, Periods etc as shown below.

Table showing divisions of Phanerozoic EON

S.l. No.	Era	Periods	Age
1	Paleozoic Era 600 my to 248 my	Cambrian Ordovician Silurian Devonian Carboniferous Parmean	600my-490my 490my-443my 443my-417my 417my-354my 354my-295my 295my-248my
2	Mesozolc Era 248 – 65 my	Triassic Jurassic Cretaceous	248my-205my 205my-144my 144my-65my
3	Cenozoic Era 65 my – present	Tertiary (Paleocene Eocene, Olgocene Miocene, Pliocene)	65my-1.8 my
		Quarternary (Pleistocene, Present Last 10, 000 years)	1.8my-Present

Mass Extinctions of Organic life

It is observed that at certain periods of geological time in the Phanerozoic Eon a large percentage of organisms, which were most prevelant around the globe, vanished from the Earth's surface permanently and never reappeared later. New forms of life appeared, proliferated and occupied the space left by the older life. This type of mass disappearance of organic life is termed as Mass Extinction. Mass extinction is recognized from complete lack of fossils of such extinct species in subsequent geological periods. Mass extinction could be identified in the Phanerozoic time because life during this period developed hard parts such as bones, skeletons and protective covers which could remain as fossils in the sedimentary rocks.

There have been a few remarkable mass extinction episodes, for example, at the end of Ordovician, Devonian, Permian, Triassic and Cretaceous Periods. Mass extinctions in a lesser extent have also been noticed at the end of Cambrian and Pleistocene Periods. Brief details of mass extinction at different geological periods are discussed below.

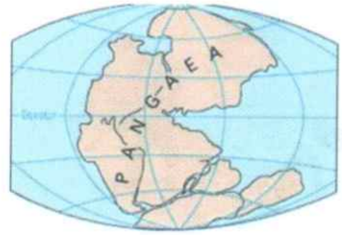
Till end of Proterozoic Eon there was no proper record of fossils because the animals which developed during 3500 million years till 600 million years were microscopic, soft and without hard parts, hence proper fossil record was not possible for study and research. It is only during the 600 (my) period (before present) when hard protective cover and bony skeletons developed which were preserved. During Cambrian Period, i.e. the beginning of Phanerozoic there was great explosion of life in marine environment which were well preserved as fossils in rock records of the entire globe. After the initial Cambrian explosion, conditions became adverse and many species could not survive and became extinct during 495-490 million years ago. The cause of this mass extinction has been assigned as due to extensive sea level fluctuation disturbing the marine habitat in which marine species could not exist. This is however not taken as a major mass extinction, as several existing species survived into the next geological period i.e. the Ordovician. The Cambrian Period is known as the age of the Trilobites, a marine invertebrate, now completely vanished.

Trilobite

The first major mass extinction was during the end of Ordovician Period (445-443 my ago). The cause has been assigned as due to great ice age which occurred at the Ordovician and massive sea level fluctuation before and after the glaciations, one due to formation of ice and the other due to melting of ice. There was also volcanic activity which altered the composition of the then atmosphere which did not favor life in the seas.

The second major mass extinction occurred at the end of Devonian Period (354-350 my ago). During the Devonian Period new life, both plants and amphibians appeared on the Earths land surface and fishes developed a vertebra in their skeleton. This period is known as age of fishes. The cause of this mega extinction is due to change in atmospheric composition (Oxygen and Carbon dioxide), fluctuation of sea levels and formation of the great single landmass, the Pangea.

The third and biggest of all recorded mass extinction was during the end of the Permain Period (250-248 my ago) During this mass extinction as much as 96% of species disappeared from Earth's surface, both land and sea animals and plants. The causes have been assigned to fall in sea level restricting sea area which once was home for many shallow water sea animals. The great volcanic activity which produced the Siberian traps caused great changes in atmospheric composition which had its impact on the extinction. 0_2 was drastically reduced and CO_2 increased in the atmosphere which affected life seriously.



PANGAEA
225 million years ago

The fourth major extinction occurred at the end of Triassic Period during which 33% sea animals, 32% land based vertebrates and 90% land plants disappeared. The cause has been due to green house effect with possible meteorite impact changing the atmospheric condition.

Ammonite

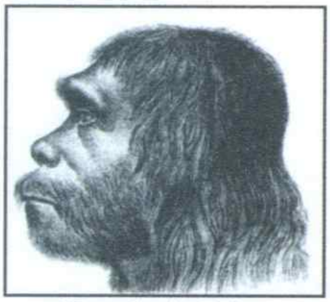
The fifth major extinction at the end of Cretaceous Period also known as K-T event, wiped out most land animals especially the dinosaurs. This is believed to be due to extensive volcanic activity (such as the Deccan traps of India) and major meteorite impact, both causing great changes in climate during that time.

Dinosaurs

A minor extinction occurred towards the end of the Pleistocene Period where great mammalian animals like the Wooly mammoths were wiped out. This was due to the impact of the great Pleistocene Ice age.

Wooly Mammoth

Around 18000 years back a species of humans 'Neanderthal man' appeared in west European area but they were later wiped out by the present species, the Homo-Sapiens sapiens.



Neanderthal Man

Thus we see four episodes of mass extinction in the Paleozoic Era, at the end of Cambrian, Ordovician, Devonian and Permian Periods, two episodes in Mesozoic Era at the end of Triassic and Cretaceous Periods. In the Cenozoic only one extinction episode has been registered during the Pleistocene Period which is a minor one. Of these episodes, the mass extinctions at the end of Ordovician, Permain and Cretaceous could be major events of mass extinctions.

Holocene Mass Extinction (6th Extinction)

Holocene represents the last ten thousand years of Earth's history but appears to be the most eventful. It is the age of Homo Sapiens sapiens, the man with intelligence and settled life. Man appears to be the greatest consumer of Earth's natural resources and polluter of the environment. There are tremendous changes in atmospheric composition, chemistry of the sea water, deforestation and degradation of land making organic life unstable. Many species are permanently disappearing and several are threatened and this goes on and on. The lush green Earth is fast changing to brown. We are in the midst of climate change, global warming, melting of ice, changes in sea level, rise in CO_2 in atmosphere, acidification of sea water and etcetera. If this continues the Earth would be uninhabitable for mankind. This is believed to be the beginning of another mass extinction, and the sixth in the series after the earlier five mega extinctions, such as during end of Ordovician, Devonian, Permian, Triassic and the Cretaceous Periods, The earlier extinctions were taking million years interval to happen but the present one is taking a few hundred of years and solely due to the activity of human beings, the Homo-Sapiens sapiens.

CONCLUSION:

Great changes on Earth have occurred during the geological periods such as: from no continents to the supercontinents, their disintegration and movements to form new ones, from anoxygenic atmosphere to present stage of oxygenic, changes in volume and spatial distribution of land and sea, diastrophic movement associated with mountain building and extensive volcanic eruptions; climate changes, glaciations, impacts of various space bodies e.g. comets, meteorites bolides and asteroids etc. Life which was unicellular and began at around 3500 million years ago, evolved and diversified into large and complex forms based on Darwin's theory of "Origin of species" and 'Survival of the fittest', have suffered great mass extinctions at certain intervals of geological time due to its inability to cope with the changes in the environmental conditions. New sets of environmental condition brought new life forms and their diversification to fill the space left by the old sets.

Thus environmental changes during the history of Earth controlled evolution of life, its diversification and extinction. Mankind is now facing similar situations such as population explosion, industrialization, mass consumption of Earth's resources leading to environmental degradation, climate change, global warming etc. Many species are vanishing before our eyes and many are in danger. This is a red signal to the existence of mankind itself. Who knows, it is not unlikely that Earth may meet the same fate as planet Mars as we see it now. While earlier mass extinction was taking millions of years to come; now it is a few hundred years when the mass extinction is being witnessed.

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ADDRESS BY PROF. S. P. BANERJEE, FORMER DIRECTOR-IN-CHARGE, INDIAN SCHOOL OF MINES, DHANBAD ON THE MINING DAY CELEBRATIONS 2013: A REVIEW OF THE MINING SCENARIO IN THE COUNTRY

Dismal production scenario leading to increased import and declining export

Mining industry in India is going through a bad phase as the production of major minerals has shown near stagnancy during the last three years. This unsatisfactory situation has arisen inspite of the Indian economy growing at a CAGR of 7.8 % during the last decade. The steel, electricity and cement sectors have grown at a CAGR of 6.5, 5.5 and 8.0 per cent respectively during the last five years and the growth rates for these sectors have been projected to be higher during the twelfth Plan.

It is an irony that in spite of the expansion of the energy and industrial sectors, the index of mineral production (base 2004-05) has decreased from 131 in 2010-11 to 128.4 (2011-12) and 122.2 in 2012-13. The decline in mineral production continues in 2013-14 and in April-August 2013 period, it has come down to an average value of 118.1.

The same story is illustrated in the Table below giving production figures of seven most important minerals in the country.

Mineral/ year	2009-10	2010-11	2011-12	2012-13
Coal (Mt)	532	533	540	549
Natural Gas, Bm^3	47.5	51.2	43	40.7
Crude oil, (Mt)	34	38	38.1	37.9
Iron ore, (Mt)	218.6	207.2	167.3	140
Bauxite, (Mt)	14.1	12.7	12.9	NA
Manganese ore, (Mt)	2.49	3.06	2.35	NA
Limestone, (Mt)	233	246	257	NA

The Table shows that except for that of limestone, the production of other minerals has decreased or only marginally increased in the past three years.

India traditionally imports huge quantities of petroleum, natural gas, coking coal, gold and copper concentrate but to that list is now added non-coking coal of which the country has adequate resources (approximately 100 Mt imported last fiscal).There is also great reduction in export of minerals and mineral products such as iron ore and alumina.

The impact on the CAD and consequent depreciation of the rupee is well known.

Obviously a stage has reached when corrective action must be taken and on an urgent basis.

Against this backdrop it is proposed to delve into the reasons for the slow growth of the mineral sector and examine the provisions mentioned in the National Mineral Policy and the recommendations of the Working Group of MOM for XII Plan to discuss the ways of changing the situation.

National Mineral Policy1993

The first requirement for a planned mineral development for any country is a Mineral Policy suiting its needs and the prevailing circumstances. The Mineral Policy followed by India had evolved over many years since Independence and a written down Policy was adopted some

20 years ago in the form of the National Mineral Policy 1993.

The first Para of the preamble of NMP 1993 states- "Minerals are valuable natural resources being finite and non-renewable. They constitute the vital raw materials for many basic industries and are a major resource for development. Management of mineral resources has, therefore, to be closely integrated with the overall strategy of develop- ment; and exploitation of minerals is to be guided by long-term national goals and perspectives."

Four of the basic objectives mentioned inNMP 1993 are:

- Exploration both on-shore and off-shore,
- development of mineral resources to ensure their adequate supply,
- promotion of necessary linkages for smooth and uninterrupted development of the mineral industry and
- to minimise adverse effects of mineral development on the forest, environment and ecology through appropriate protective measures.

At present we often find some tussle between the Central Government and some of the State Governments in matters relating to grant of mining lease. NMP 1993 mentioned the joint responsibility of the Central Government and the State Governments for Management of mineral resources in terms of Entry 54 of the Union List and Entry 23 of the State List of the Seventh Schedule of the Constitution of India. The Mines and Minerals (Development and Regulation) Act enacted by the Parliament in1957, lays down the legal framework for the regulation of mines and development of all minerals other than petroleum and natural gas.

National Mineral Policy 2008

After 15 years of operation of NMP 1993, it was felt necessary to revise the policy and make provisions for greater share of the benefit from mineral resource development going to the state in which the mineral resources occur.

The National Mineral Policy 2008 states-

"India is a federal structure with a single economic space. Nevertheless, the legitimate fiscal interests of States which are mineral rich need to be protected. The revenues from minerals willbe rationalised to ensure that the mineral bearing States get a fair share of the value of theminerals extracted from their grounds."

In addition, NMP 2008 deals with many current issues. It mentions the problem of illegal mining and covers in great detail forestry and environment issues by observing that a significant part of thenation's known reserves of some important minerals are in areas which are under forest cover.Further, mining activity is recognized as an intervention in the environment with potential to disturbthe ecological balance of an area.

However, it recognizes that the needs of economic development make the extraction of the nation's mineral resources an important priority. It desires that a framework of sustainable development will be designed which takes care of bio diversity issues and to ensure thatmining activity takes place along with suitable measures for restoration of the ecologicalbalance.

For many decades the Mining Industry has been blamed for not taking adequate care of the people it displaced for carrying out mining operation. In 2006 the Forest rights Act was enacted. NMP 2008 states that "Special care will be taken to protect the interest of host and indigenous (tribal) populations through developing models of stakeholder interest based on international bestpractice. Project affected persons will be protected through comprehensive relief andrehabilitation packages in line with the National Rehabilitation and Resettlement Policy (2007).

By 2008 the debate on banning mineral exports to encourage value addition and conserve mineral resources for the benefit of domestic sector has gained momentum. NMP 2008 struck a balanced approach by stating that while value addition will be actively encouraged suchvalue addition should go hand in hand with the growth of the mineral sector as a stand-aloneindustrial activity.

The Working Group on minerals for the XIIth Plan

Because of the similarity of geological setting of parts of Australia, India, South Africa and Canada, many experts believe that India has good geological potential for many metallic minerals but the results obtained by our exploration agencies so far have been disappointing. The Working Group on mineral exploration and development of the Ministry of Mines for the XIIth plan has commented that Investments in exploration are grossly inadequate in the country.

These days illegal mining has become a major issue for the mining industry and many of the regulatory and judicial orders restraining mining and transport of minerals owe their origin to complaints of illegal mining. Justice M. B. Shah Commission of Inquiry instituted by the GOI is working on the subject for over two years now. The Working Group on minerals of the Ministry of Mines for the XIIth plan deals with the subject of illegal mining in some details. It states that Illegal mining and unscientific mining, are symptoms of a failure of the regulatory system in all its aspects, including proper exploration, scientific mining in accordance with Mining Plans, adoption of beneficiation practices, royalty accounting etc. The WG mentions that although Section 23C of MMDR Act, 1957 empowers the State Govts. to frame rules to prevent illegal mining, illegal mining is still rampant in the country.

According to the WG, the major causes of illegal mining are –

- Poor detection and enforcement procedures – ineffective Directorates of Geology and Mining with poor information gathering and coordination capability, poor mobility and communication, poor investigation and prosecution mechanism, corruption, connivance and interference.

- Inefficient concession grant process including delays and inefficiencies in concession system, forest and other clearances

- Lack of awareness among those adversely affected including environmental consequence of unregulated mining, loss of State revenue, promotion of lawlessness

The WG recommends that causes of illegal mining need to be addressed. The nation is also waiting for the final report of the Justice Shah Commission on the subject.

Problem of the coal sector

Coal is the most important mineral mined in the country and along with lignite accounts for 52.9%ofits commercial energy consumption. Approximately 70 % of the electricity generated in India comes from coal fired power stations. The installed capacity for generation of electricity has gone up from 101.6 GW in 2000-01 to 236 GW in 2012-13 with approximately 55 % of the installed capacity being coal based thermal power stations. The coal demand for the terminal year of XII Planhas been estimatedby the Planning Commission as 980.5 Mt. Even if Indian domestic coal production increases from 549 Mt in 2012-13 to 715 Mt in 2016-17, a gap of 265.5 Mt has to be met by import. Such large scale import of coal would not only further exacerbate the balance of trade problem but also result in considerable increase in average electricity price leading to higher input cost for the industry.

Domestic coal production can be raised to match the rising demand but for that the impediments faced by the coal industry as listed below needs to be removed:

1. Acquisition of land and Resettlement and Rehabilitation of Project Affected Persons
2. Getting forest land diverted for mining (forestry clearance)
3. Getting environmental clearance for the new and expansion projects
4. Inadequate rail capacity for evacuation of mined coal
5. Poor Law and order situation in some coal belts

The land acquisition problem may be eased to a great extent by employing innovative mine closure methods and converting mined land to agricultural land in suitable cases.

Iron ore mining sector in India

The iron ore mining sector has undergone rapid expansion in the past decade. From a moderate production of 80.6 Mt in 2000-01, the production went up to 218.6 Mt in 2009-10. Quantity of iron ore exported went up from 15.7 Mt in 2000-01 to 101.5 Mt in 2009-10. After 2009-10, there has been a great decline in production as well as export of iron ore (as low as 140 Mt and 18.4 Mt respectively in 2012-13).

The reasons for the dramatic decline comes from imposition of 30 % export duty on iron ore and court orders banning iron ore mining in important iron ore producing states of Karnataka and Goa due to complaints of environmental degradation and illegal mining.

Many iron ore mine owners in the private sector greatly increased production from their mines in the boom period of 2003-08, reworked their reject dumps and reaped the windfall profit from high international prices of iron ore.

In the process, however, many of them violated the Environmental Clearance conditions accorded to their mines and in general the environmental quality in the major iron ore mining regions in Goa, Karnataka, Jharkhand and Odisha States greatly deteriorated in this period.

The local communities got agitated and the media highlighted the environmental degradation. Many unscrupulous mine owners worked illegally outside their leaseholds and didn't report the correct production or dispatch data to the Government to evade payment of royalty and export duty on the ore. Hence the industry must share a major part of the blame for the present mess in the iron ore mining sector.

Bauxite Mining Sector

Till 1970 the known bauxite resources of India were of the order of 345 million tonnes only. Then appeared the discovery of the massive hill top deposits in 'East Coast Belt' in Odisha and Andhra Pradesh and now the country's inventory of bauxite resources has been put at a massive 3480 Mt.

Aluminium metal is of great importance to Indian economy as the country is short of base metals like copper and tin, and the country's rapidly growing power, transportation and infrastructure sectors need more aluminium.

The working group on mineral exploration and development for the XII Plan has projected major expansion of the aluminium sector in the country and has estimated "that aluminium production capacity in India at the end of the 12th Plan period would be about 4.7 Mt" and the demand for alumina and bauxite in 2016-17 would be 13.3 Mt and 40 Mt respectively. The working group has not elaborated as to how they arrived at such astronomical demand figures and considering the near stagnancy in bauxite production at 13-14 Mt in 2008-2012 period, it is extremely unlikely that the bauxite production in the country can be raised to such a high level of 40 Mt in just 5 years.

The experience of Vedanta in failing to get ML in Niyamgiri hills after so many years of efforts and massive expenses is an example of the impediments in expanding bauxite production in the country.

The mining industry has to increase its CSR budgets manyfolds and greatly improve its R&R work, especially amongst the tribal and forest dwellers. The perception of the mining industry as insensitive to the needs and aspirations of the tribal community has to be corrected. Many NGOs appear to be committed against mining par se and in most cases they provide leadership to the anti-mining movements in the tribal belts. In case of the agitation against the Kudankulam nuclear power station in TN in 2012, the Prime Minister suspected a hand of foreign NGOs with some hidden agenda to fuel the agitation. Whether foreign funded NGOs with some hidden agenda are active in the case of agitation against bauxite mining of East Coast deposits, should be investigated by the State Governments.

Concluding Remarks

Mining is a very important component of the National economy. The need for increased production of minerals will be there for many years to come. In many countries, especially in the erstwhile Soviet bloc countries, miners were held in great esteem amongst the general society. President Herbert Hoover of USA was a mining engineer by profession. In India, unfortunately, recent events have tarnished the image of the mining profession.

The mining engineers and earth scientists of today must carry out their task with competence and sincerity and pay heed to the modern day aspirations of environmental protection, bio diversity conservation, social justice and equity. Only then the social licence for doing mining can be obtained in future.

JAI HIND.

➢ SGAT NEWS

- **Environment-cum-Mineral Awareness Programme (EMAP) – 2013:**

24th State Level EMAP was conducted on 2 & 3 February 2013 at Bhubaneswar. Altogether, 10 schools participated in the programme from 10 regional centres. Delhi Public School of Damanjodi, represented by S/Shri Sankar Sahoo and Sumit Kumar Pradhan was adjudged the overall best team. DAV school, Unit-8, and DAV Public School, Noamundi emerged as the 2nd and 3rd best teams respectively.

The regional programme and State Level Programme were supported by Tata Steel, JSPL, Rungta Mines, SAIL, OMC, OCL India, NALCO, Sarada Mines, M/s G.S. Mishra, OSCOM, MGM Group, M/s S.N. Mohanty, EMIL, Patnaik Minerals, Misrilall Mines, Balasore Alloys, FACOR, IMFA, EZMA.

- **Mineral Development Awareness Quiz (MDAQ) – 2013:**

MDAQ Programme – 2013 was held on 23-25 Aug'2013 in Joda-Jilling-Bamebari Iron and Manganese mining area of Odisha. Altogether 18 teams from geology, mining, engineering, metallurgical and materials engineering stream participated who travelled from Jharkhand, West Bengal, Andhra Pradesh and different parts of Odisha. The Geology Department of Ravenshaw University represented by Soumendra Nayak and Sanjeev Sourav Behera was adjudged the overall best team. The programme was hosted by EMIL and co-hosted by Tata Steel, Rungta Mines and Sarada Mines. From all considerations, the programme was a great success.

- **International Seminar on Developments in Mineral Exploration Techniques - Strategy and Challenges**

Society of Geoscientists and Allied Technologists (SGAT) has organized an **International Seminar on Developments in Mineral Exploration Techniques - Strategy and Challenges** which was inaugurated on 14.12.2013 by Sj. Sisir Chandra Rath, Director General, Geological Survey of India, Govt. of India in the presence of Mr. Tom Calder, Trade Commissioner for the Australia Trade Commission (Austrade), New Delhi and Sj. G. Srinivas, IAS, Commissioner-Cum-Secretary, Deptt. of Steel & Mines, Govt. of Odisha. The two days Seminar included delegates from mineral industries of India and abroad and Govt. agencies from both State and Centre along with representatives from stake holders.

SGAT President, Dr. S.K. Sarangi, welcome the delegates and stressed on the Govt. to pay attention for mineral development and he further stressed on SGAT's suggestion to take proper action on the suggestions made in VMD-2020 for Odisha submitted to the State Govt.

Mr. Tom Calder, Trade Commissioner for the Australia Trade Commission (Austrade) had made a comparative study on mineral exploration conducted in Australia and gave commitment of Austrade to develop mineral industries in India in general and Odisha in particular.

Sj. G. Srinivas, IAS, Commissioner-Cum-Secretary, Deptt. of Steel & Mines, Govt. of Odisha, appreciated the initiatives of the Society in organizing the International Seminar and requested the industry to utilize the opportunity to exploit the mineral belt of the State and assured them all possible support from Govt. He further impressed upon the delegates to take appropriate steps for erasing out the bad impression from the mining industries.

- Sj. Sisir Chandra Rath, Director General, Geological Survey of India, Govt. of India spoke on the role and achievement of 162 years old organization and stressed on marine survey using their newly acquired ship (Samudra Ratnakar). He also stressed that marine survey will continue in Odisha in Jan'2014 with the help of the ship.

  29 technical papers were presented in 4 technical sessions. The Seminar was concluded with a panel discussion. The valedictory session was addressed by Dr. R.N. Patra, CMD, IREL as the Chief Guest.

SGAT General Secretary, Shri B.C. Patnaik, proposed vote of thanks.

- Sri B.K. Mohanty, Advisor; Dr. R.C. Mohanty, former President; Sri B.C. Patnaik, General Secretary; and Sri N.R. Patnaik, met Chief Secretary, Govt. of Odisha on 01.08.2013 and appraised him the current mining scenario of Odisha.
- As the regular activities, on 02.08.2013, a group discussion was organized in SGAT hall on various issues on "Bauxite Mining and development of Aluminium industries". Shri B.S. Pani, and Shri Niladri Mohanty, former executives of NALCO, participated in the deliberations.
- Sri C.S. Gundewar, Controller General, IBM with his officials visited SGAT building and addressed the members of the Society on 06.08.2013.
- Dr. S.K. Sarangi, President and Sri B.C. Patnaik, General Secretary, participated in the deliberations of 49th State Geological Programming Board held in Hotel Mayfair Lagoon, Bhubaneswar on 18.09.2013. SGAT suggested for reassessment of iron, manganese, chromite and detail exploration of bauxite in the state.
- Shri B.S. Pani, former Executive of NALCO delivered a lecture on "Technology ownership need for development in Indian Mineral and Metal Industries" in the SGAT hall on 21.09.2013.
- The Media Management Cell of SGAT consisting of Dr. S.K. Sarangi, President; Shri B.K. Mohanty, Advisor, Shri B.C. Patnaik, General Secretary; and Shri Pravakar Rout has been constituted in the month of September 2013 to highlight the views of SGAT on mineral development through electronic and print media.
- On invitation, Sri G.C. Das, Treasurer, SGAT attended the 9th meeting of CGPB Metalliferrous Committee meeting at Kolkata on 22.10.2013 and submitted the agenda which has been accepted by the Committee.
- SGAT observed the 1st Indian Mining Day on 01.11.2013 jointly with Mining Engineers' of India, Bhubaneswar Chapter. The function was held in the SGAT building. Prof. S.P. Banerjee, former Director of ISM graced the occasion as the Chief Guest and addressed the members. Prof. Dr. G.B. Misra was felicitated as the best mining engineer. On this occasion, a Press Meet was convened to appraise the objectives of the Indian Mining Day.
- Rs. 1.00 lakh was donated by SGAT to CM's Relief Fund on 04.11.2013 for cyclone and incessant rain and flood during Oct'2013.
- SGAT felicitated Sj. Sisir Chandra Rath, the first Odia Director General, G.S.I., a premier exploration institute at SGAT building on 25.11.2013.
- 33rd Annual General Body Meet was held on 15.12.2013 at SGAT hall. Prof. M.C. Dash, Vice President, welcome the members and highlighted the achievement of the Society. Sri B.C. Patnaik, General Secretary read out the Annual Report which has been confirmed by the members present. Sri G.C. Das, Treasurer presented the audited accounts of for the financial year 2012-13 which has been confirmed by the members present. Er. N.K.

Nanda, Director, National Mineral Development Corporation Ltd. delivered his address as the K.S. Mahapatra Memorial Lecture highlighting the mining scenario of the country. On this occasion, SGAT conferred SGAT Lifetime Achievement Award-2013 to Dr. R.K. Sahoo and Er. V.S. Rao; SGAT Award of Excellence-2013 to Er. N.K. Nanda; Sitaram Rungta Memorial Award – 2013 to Dr. Deshbandhu Sikka and Best Paper Award – 2013 to Dr. Indra Deo Mall.

- Sri J.K. Nanda, former DDG, GSI, member of Society has been conferred with the prestigious B. Rama Rao Award by Geological Society of India in the A.G.M. held on 16.11.2013 at Dhanbad.

➢ NEWS ABOUT MEMBERS

- Dr. R.N. Hota, Head & Professor of Geology, Utkal University has been awarded with D.Sc. in July 2013.
- Sri S.K. Singh, member of SGAT was conferred with "Samant Chandra Sekhar" Award in Engineering & Technology by Odisha Vigyan Academy on 19.07.2013.
- The following Deputy Director of Geology, Directorate of Geology were promoted to the post of Joint Director, Geology and placed at Zonal Offices in the month of July-August 2013.

  1. Sri G.K. Bhuyan : Dhenkanal
  2. Smt. Arun Bala Mishra: Keonjhar
  3. Sri Jagat Pati Panda: Bolangir
  4. Sri K.C. Mohapatra: Koraput
  5. Sri M.R. Mishra: HQRS, Bhubaneswar

- Sri Mihir Ku. Senapati, Deputy Director of Geology has been posted at Koira Mining Circle as Deputy Director of Mines on 30.09.2013.
- Sri Amal Chandra Paira presented a paper entitled "Threats to Conservation of Biodiversity and their Consequences in UGC Sponsored National Seminar on Nature, Environment and Society which was held on 11.11.13 to 12.11.13 at Neela Shaila Mahavidyalaya, NiladriVihar, Jagda, Jhirpani, Rourkela-42.
- Shri S.N. Padhi SGAT member and former Director General of Mines Safety (GOI) was the Guest of Honour in the Inaugural Session of the Seminar POSTALE (Policy, Statute and Legislation) organised by the Institution of Engines (India) at Dhanbad on 30th November and 1st December 2013. Sri Padhi spoke in detail about the arduous and slow journey of Policy travels to become Legislation and statute. In June 1996, a Policy decision had been taken to amend the Mine Act, 1952. The amendment in the format of a draft Mines Bill supported with a detailed sectional Note and a draft Cabinet Note was sent by Sri Padhi, when he was the Director General of Mines Safety to the Ministry on 6th April 1998. After taking into the views and counter views of all stake holders, & examination and reexamination by a number of committees, Mines Bill 2007 was sent for consideration of the Parliament. It is still to see the light of the day. Shri Padhi also chaired the technical session on "Safety & Health" on the second. He spoke in details about the emphasis being given to "Occupational Health" in the proposed Mine Bill and recent safety conference.
- Shri Arun K. Mohanty assumed the office of Director of Geology w.e.f 1st Dec'2013.

NEW MEMBERS

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BOOK REVIEW

"Minerals, Mines and Environment in Human Life", authored by Professor Kaulir Kisor Chatterjee and published by National Book Trust, India (First Edition - 2013) is a book for everybody - geologists and mining engineers, people associated with mining and metal industries, environmentalists including protestors agitating against mining and industries and the people in general who need economic development of the country. The subject matter of the book has been presented in very simple and lucid language in seven chapters covering 179 pages, which can be easily understood even by common man not knowing about minerals, mines and environment. It analyses the root cause of all conflicts between the industries and environmentalists, though both intend to work for benefit of the society. In introduction (Chapter-1), the author hopes that the book would help in clarifying the confusion prevailing in minds of common man when development of mining and mineral sector is slowed down raising ecological and environmental concerns. In order to bridge the gap between industries and environmentalists, the author suggests for educating both, as well as the intelligentsia and common man. Dr. Chatterjee recommends to start educating the younger minds in school level explaining them the importance of preservation of environment as well as banes and boons of mining in particular and industries in general.

The Chapter 2 on "The Earth and Minerals" starts in logical order with universe and stars, then explains about origin of Earth 4.6-4.5 billion year back, followed by formation of minerals and rocks and then soil and sand, 1.6 million years back. In Chapter – 3, Beginning and Evolution of Life', author brings out that the living objects have many common elements which are present in minerals and rocks. Further, intimate relationship existed between the two during the chemical process of evolution of life from 3350 billion years back to 1.6 million years back till homosapiens appeared as primitive man. He points out that, after a long process of evolution over billions of years, the existence of man is only for 1.6 million years. In Chapter – 4 on 'Evolution of Modern Man', it is indicated that further evolution to the state of modern man, the process is of a different type. Early man developed slowly by adaptability to survive in different environments and hence could migrate from place to place when minerals found in nature played a vital role. During last 1,20,000 years, urge to grow and excel by evolution of intelligence and ability to apply intelligence creatively to acquire newer and newer knowledge and skill, played an important role in the evolution process. Important milestones are fire produced by hitting stones 31,000 years back and starting of agriculture and shelters in caves or huts around 11,000-10,000 year back. After invention of wheels 6000 years back, development of agriculture and animal husbandry took place. Slowly literature, arts and communication by language developed. Man started living in societies with socio-diversities. There have been many ancient civilizations in the history which developed and fell. The real knowledge based development has taken place from 1200 BC to 21st century.

'Man was born on minerals, has evolved on minerals and has been living on minerals" – thus starts the 5th Chapter on 'Man and Minerals' It reminds readers that entire ancient history has been divided into ages depending on predominance and nature of mineral-centric activities. During stone age from 2.5 million years back upto 4500 BC man lived in caves and used weapons and rocks to kill animals. Then lived in communities in houses made of bricks and rocks, used clay made potteries and had agricultural farming and domestic animals. Use of metal, first being copper, started around 4500 BC, when the copper age started. During this period Bronze as an alloy was developed when minerals of lead, zinc, copper and tin were used. Iron age started around 1800 BC with discovery of iron ore. Soon, iron technology and steel technology developed with use of alloying metals. Metals of gold, silver were used besides diamond, precious stones etc and stone blocks were used for constructing monuments. Glsss manufacturing also started towards 400 BC. From 1200 BC upto 250 years back though the development has been significant, the real development started after steam engine was invented in 1765AD which brought industrial revolution in England. In the subsequent years many metallic and non-metallic minerals come into use for providing various products for use of modern man. Besides iron, coal and petroleum as source of energy predominated the scenario of minerals in use, till nuclear energy from atomic minerals came into picture towards the end of 2^{nd} world war. Country having resources of atomic minerals and nuclear energy came into prominence. Later on man entered into outer space with rockets, placed satellites in orbit for communication and better understanding the nature and environmental degradation taking place.

Out of 3000 minerals reported and 2000 studied so far, only 100 or so are important for human use. As these resources are not renewable and do not occur uniformly throughout, there are regions with rich mineral deposits and there is scarcity elsewhere. Many cases are illustrated in the book to show how war and conflict have taken place for possession of minerals and new discoveries have taken place in search of minerals. While last war between Iraq and Kuwait was fought for oil towards the end 1980s, many predict that future war would be for water. Minerals would continue to play important role in the economy of a country and also international scenario.

The 6^{th} Chapter – ' The changing meaning of Environment' explains ecology, ecosystem and environment and then deals with impacts on various parameters of environment often observed in case of mining projects i.e. land and landscape, biodiversity with loss of forest, wildlife, top soil, water bodies, ground water, air and water pollutions, socio – cultural aspects of human settlements, noise, vibration and health hazardous etc. The above impacts have been analysed in details giving examples of reported cause in the past. There are specific references to impact of artificial light and pollutions due to toxic elements being carried by mine effluents. The book also indicates that these hazardous chemicals are also seen in surface and ground water coming from rocks in natural process, where there is no mining activity. Similarly impact on global warming on oceans, ice sheets, Antarctica, Greenland and other regions of world have also been dealt. Mines are not the only reason for these environmental concerns. There are various other human activities which have increased with rapid growth in population after 1950 onwards (Table-4, Chapter-7) which are also responsible for environmental degradation and global warming, for example agriculture, transport, horizontal expansion of habitational areas, pollution of urban areas by accumulated waste and sewage besides excessive use of modern gadgets.

'Man, Minerals and Environment' the last and 7^{th} chapter starts referring to previous chapters where it has been established how important minerals have been in the progress and development of human beings. The same is also true for environment which has given birth and provides sustenance to mankind till date. Man has so far exploited environment where mineral resources are one component. Man can't live without either. Man need as many as 36 meals and non-metals (21 of which are vital) for their growth and energy to carry out different functions of the body i.e. calcium, phosphorus, iron, manganese, potassium, sodium, sulphur, zinc, etc. besides most vital water and oxygen. Man gets all these from nature which are being supplemented by medicines produced from minerals. In day to day life, whatever man uses is directly or indirectly a product from minerals which have been mined. Without minerals immediate impact would be on availability of water and power, food and various items used in daily life. As such, there has to be sustainable development where preservation environment and ecosystem is most essential and mining and use of minerals should also continue simultaneously but judiciously.

Life with zero impact on environment was the one that primitive man lived. Human activities and exploitation of nature even upto 200 years back was negligible. Degradation of environment due to human activities including mining was visible around 1970s nearly 50 years back. There are 3 reasons for this which are, growth in population, development of science & technology providing conformable life style and economic growth with development taking place worldwide. This resulted in increasingly more demand for industrial and agricultural products. For more productivity agriculture was mechanized when higher production was expected from reduced agricultural areas. To meet the growing demand, mining of minerals increased to produce more metal and downstream products for direct or indirect use of people. By restricting mining and mineral sector the same people would also suffer, which many do not understand. Common mass including some of the people constituting intelligentsia know more about environment than about the indispensability of minerals and their products in everyday life. Environment entities are visible or at least felt with senses. Again, it is often observed that knowledge about environment often is biased and not scientifically correct. There are many debatable issues like predictions about future like Dooms Day which have been proof not to be correct based on scientific data. By restricting mining and mineral sector, environmental degradation can't be restricted nor damage to ecosystem and extinction of species can be saved. There have to be some concrete and substantial results for which even the products of mineral would be required. International efforts and National Legislations have not been successful over last 40 years or so. Degradation of environment has continued, through in small patches good results are seen. Hence, the author emphasizes that these has to be mass awareness involving people of all sections and professions. In this regards, he gives importance on awareness to be created amongst the future generation. Although, decrease in population at a single stroke would reduce the demand for industrial products and employment, the situation is that nobody or no institution in our political system and democracy wants to do anything in that direction for various reasons including religious and emotional. Having this observation, the author views that for sustainable development we have now to turn to our important forte, the science and technology for continuing mining and mineral production with eco-friendly operation and green products. R & D effort for new minerals and new technology is also equally essential for the future. The book deals various aspects for achieving eco-friendly operations like control of air, water and other pollutions. Mines have to be there where mineral exists in nature. Hence, there has to be scientific mining with stress for conservation, zero waste, waste utilization and recycling etc. and simultaneously restoration of mined out areas for public use. Global, national and local interests have to be taken care by the industry giving importance on development of locality, management of water resources and energy, protection of biodiversity etc. Recent policy option and benefit of eco-friendly operations can be availed for cost management. Industry for its sustenance and growth should look into all the above issues such that there is clarity and understanding between the industry and the people of the area.

While concluding the author states that "The target of environmentalists should be the greed and shortsightedness of industries who exploit workers and indulge in over exploitation of minerals in hurried, unscientific and unlawful manner without adequate care for conservation of environment, but not the mining industry as such".

On the controversial topic of the day, 'whether to continue with mining or not', the book provides excellent reading material for people of all ages and professions. It has clearly established the importance of minerals in our day to day life, to say that minerals are equally important as environment. Mining has to continue with conservation of environment for which application of advance science and technology is recommended. Though rapid population growth is indicated as the root cause of present degradation of environment endangering the life system, some facts and figures about the impact on environment by other human activities areas would have further clarified the above view that by restricting mining alone degradation of environment can be contained. Having scientific and historical information on wide range of subjects i.e. origin of earth and minerals, evolution of life and development of modern man incrementally with the development of science, the book deserves a place in institutional libraries particularly those of educational institutions.

Dr R. C. Mohanty
Former Executive Director Nalco & Former President SGAT.

Amulya Mani Garabadu

Born on 16 June 1939 at Bhubaneswar, Amulya Mani Garabadu graduated from Ravenshaw College, Cuttack with Physics (Hons). He acquired degree in Mining Engineering from B.E College, Shibpur.

Amulya Mani joined the Directorate of Mining & Geology, Government of Odisha as Drilling Engineer. He rose to the position of Director of Mines and retired on 31 July 1997. During his tenure as Drilling Engineer, he contributed significantly to mineral exploration in the State. He was largely responsible in building up of an efficient drilling outfit which did commendable job in proving of coal, chromite, bauxite, iron ore, limestone reserves of the state.

Amulya Mani Garabadu had leaning for music, social service and religion. He was President of Chinmay Mission and Bharat Vikash Parishad, Bhubaneswar.

He passed away on 4 August 2013 after a brief illness. He is survived by his wife and two daughters. Garabadu was an active member of SGAT. SGAT family deeply mourns his passing away and conveys its heartfelt condolence to the members of the bereaved family.

Sri B.K. Mohanty

Gour Hari Khuntia

G H Khuntia was born on 5 November 1936 at Cuttack. He completed post graduation in Geology in the year 1960 and joined as an Exploration Geologist in Dalmia Cement Bharat Limited. He joined Odisha Mining Corporation Limited in the year 1963 and rose to the position of General Manager (Geology). He retired in 1994. During his tenure in OMC he contributed significantly to proving of Iron ore, chromite, manganese ore, lime stone and gemstone resources in the leaseholds of OMC. Among his contributions, proving of iron ore reserve in Gandhamardhan is most notable. He was a member of Senate of Utkal University representing Science Faculty from 1968 to 1989. He was Director in the Board of GEM Corporation of Odisha.

Gour Hari was an active Rotarian and made significant contribution to the Transparency International organisation. He had traveled extensively abroad.

G H Khuntia participated in several seminars and workshops organized by SGAT during the last 2 decades and made substantial contribution to the deliberation of such events. He was a conscientious and extremely dedicated geoscientist. He passed away on 11 October 2013 at Mumbai after a brief illness.

He is survived by his wife, two daughters and one son. GHK was an active member of SGAT. SGAT deeply mourns his passing away and conveys its heartfelt condolence to the members of the bereaved family.

Dr. R.C. Mohanty

Dr. K.L. Pandya

Born on First June 1942, Dr. Krishnalal Pandya obtained his Post Graduate degree in Geology from Ravenshaw College, Utkal University in 1965. For a very brief period, he had worked as a field geologist and subsequently he joined as a member of teaching faculty in the Department of Geology, Ravenshaw College under Utkal University in 1967. Since then he pursued his noble career as Lecturer, Reader and retired as Professor of Geology. During this period, he obtained his Ph.D degree in 1985 and with his teaching proficiency and acumen as a Research Scientist, he had produced six Ph.D. students. Ten of his students also completed their M.Phil. degree under his guidance.

He was a dedicated teacher, renowned sedimentologist and had an amicable and sociable personality. He left lots of his colleagues, students, relations with sorrow and grief to mourn his eternal journey on 16th November 2013 at his house in Keonjhar. He is survived by his wife, one son and daughter-in-law.

Members of SGAT deeply mourn his death and convey its condolence to his bereaved family. SGAT pray before Almighty God to keep his soul in peace.

Dr. S.K. Sarangi

SGAT observed 1st Indian Mining Day on 01.11.2013

Dr. S.K. Sarangi, President, SGAT is giving his welcome address.

Mr. Tom Calder, Trade Commissioner for the Australia Trade Commission (Austrade), New Delhi is addressing the Inaugural Session

Sj. G. Srinivas, IAS, Commissioner-Cum-Secretary, Deptt. of Steel & Mines, Govt. of Odisha is addressing in the Inaugural Session as the Guest of Honour

Sj. Sisir Chandra Rath, Director General, Geological Survey of India, Govt. of India is addressing in the Inaugural Session as the **Chief Guest.**
Dr. S.K. Sarangi, President, SGAT; **Mr. Tom Calder, Trade Commissioner for the Australia Trade Commission; Sj. G. Srinivas, IAS,** Commissioner-Cum-Secretary, Deptt. of Steel & Mines, Govt. of Odisha; and **Shri B.C. Patnaik,** General Secretary, SGAT are in the Dias

Panelist in the Valedictory Session held on 15.12.2013

- **SUBMISSION OF PAPERS FOR SGAT BULLETIN**
(Instruction to Authors)

Research papers, review articles, short communications, announcements and letters to editors are invited on topics like geosciences, mineral exploration, 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 the same is original, unpublished and is not being considered for publication elsewhere. Two copies, complete in all respect (with copies of figures and tables) are required to be submitted. Originals of figures and tables should be enclosed separately. Each manuscript must accompany 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. The copies of manuscripts, strictly in accordance with the instructions to authors given below may be sent to the editor of the bulletin.

Journal Format: A-4 size
Language: English
Manuscripts: Manuscripts should be typed in double spacing with wide margins in one side of A-4 size paper 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 he 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
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