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PRESIDENT'S COLUMN

With the reversal growth of mineral sectors since last few years we, the mining professionals are facing lots of challenges. This has also become a global phenomenon. Most of the mining professionals are also unemployed. Attempts shall be made to bring positive reforms of this sector as we all are aware of the fact that the country's GDP growth and economic setup are greatly influenced by the overall developments of Mineral Sectors. All stake holders should honestly try to achieve positive development of mineral resources. This will naturally bring certain set backs on the associated existing environmental set ups. But adoption of modern sustainable mineral development technologies can overcome this predicament. A positive approach for this development should be adhered to by all the stake holders which would bring positive socio economic development of the locality. In the absence of such activities the nation will face lots of negative challenges in its economic growth. In a view to render raw material security for most of the mineral based industries we are depending on import of raw materials draining lots of Foreign Exchange resources. This should be prevented by facilitating overall growth of country's mineral sectors. Our Society is no doubt very much concerned on this debacle and trying to send these messages to all the stake holders suggesting few redressal measures through conduct of workshops/Seminars/Press meets. SGAT is also actively interacting with both central and State Governments while suggesting various corrective guidelines while implementing different Acts and Rules newly formed. The steps taken by SGAT to bring environmental and mineral awareness among the peoples of mineral belts since last few decades are praiseworthy.

I take this opportunity to request all the mining professionals and stake holders for exemplifying their positive attitudes and bring a sustainable mineral development of the Country.

Save Mining & Save Country

DR. S.K. SARANGI
PRESIDENT & EDITOR

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CUTOFF GRADES (ASSAYS) MODELLING FOR OPTIMAL ORE EXTRACTION: ESTIMATION THEORY

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ABSTRACT

Determination of maximum profitable cut-off grade (assay) for mining operations of any ore body is a complex problem for the company geologist, mine engineer, investment analyst and mine owner. A high cutoff value induces decrease in overall profits in the long run whereas a very low cutoff may yield non-maximal profits as a large quantity of waste materials have to be mined, processed and disposed. A static model assumes the geological, spatial assay distributional, probability density function (pdf) of (fractional) assays (x) measured on independent REV (or larger volume) samples (cells or blocks), and mine operation to be time-invariants. These parameters are treated as time-varying random variables in dynamic models. The extraction rates of marketable ores must be profitable for each time units of operation but also to conserve the high grade marketable ores for the life-time of mines and for future generations. The probability distribution of assay values are approximately log-normal (that is; ln(x) has a Gaussian density, , n (mean ln(x)) = μ, Variance (ln (x))= σ^2 or, that z (ln(x)) has a unit Gaussian n(0,1) density whose cumulative distribution is denoted as N(0,1))(Ahrens, 1954).

Cutoff grades (assays), x(C), are shown to vary from (0, x(B)) where x(B) is the break-even grade at which profits equal the production cost of marketable ores. The optimal cut off grade (assay), x (C,O), lies within the range (0, x(B)) and can be easily estimated at the mine office using standard Cumulative Unit Normal (Gaussian) distribution, N(0,1), with z values given by z =(ln (x) – μ)/σ). High priced ores(diamonds, platinum, gold, REE, uranium, etc.) would have x(C,O) in the lower 1/3 of the range (0, x(B)) ; low priced ores(iron, aluminium, clays) have x(C,O) in the upper 2/3 of this range whereas medium priced ores (base metals, Cr, Ni, etc.) would have x(C,O) in the middle third of the range (0, x(B)). Actual estimation of x(C, O) for an ore body is mine specific and depends on the model (Static/Dynamic) used as well as on the pdf of assay distribution in the mined blocks. The upper and lower bounds for the cutoff grades are given for selected sales to cost price ratios (s/c) in Tables (1-3) for general guidance.

KEYWORDS: Cutoff grade x(C), optimal cutoff grade x(C,O), break even grade x(B), spatial assay distribution, parameters of assay pdf, risk and profit optimization, static/dynamic optimization models, optimal extractions under static/dynamic models.

INTRODUCTION

With continued rapid rate of utilization of minerals and metals for societal growth and explosive rise in world population it has become imperative to mine minerals with lower grade and at greater depths which induces increased costs of extraction and processing to make these marketable. Hence, there is greater need for conservation of these invaluable non-renewable finite mineral resources as well as for preservation of fragile ecology and environment. Balancing these two opposing concepts of maximal utilization of ores and sustainable societal growth is the critical need of the hour (see, Sahu, 2012, 2013, 2014, 2015, 2016 submitted).

Mineral resources are characterized by their unique geological setting and genesis, as well as their spatial distribution which greatly influence the optimal extraction of these non-renewable resources. Mining industry becomes sustainable with consistent long-term profit accruals over the life span of the mine. This dictates that extracted ores can be marketed with reasonable profit, with sale price (s/ton) exceeding the cost of production (c/ton). Cost of production includes many factors such as: mining, blending, beneficiation, transport of ores and wastes for their marketing and safe disposals, respectively. Sale price(s/ton) of marketable ore is highly unpredictable due to volatile demand and supply of ores, government policy, technological innovations and substitute products, etc.

The cutoff assay, x(C), is defined as the fractional assay (x) of resource above which the extracted product is marketable (x(M)) and above the break-even assay(x (B)) defining the equality of sale(s/ton) and cost (c/ton) prices of the produce. Unfortunately, break-even assay, x(B), is not very useful as a cutoff grade since at this mining strategy profits become nil and mine becomes unsustainable. However, x(B) does provide the upper bound to the cutoff grade x(C) for ore extraction. Profits accrue if the extractable grade is reasonably above the marketable grade x(M) with the sale price (s/ton) greater than the production cost(c/ton) and with an extraction rate that maintain long-term sustainability of mine (at least till the end of mine-life or ore exhaustion). This strategy would induce a cutoff grade, x(C), much lower than the x (B) assay value but should be equal to the minimum assay value, x min, or near zero assay value or waste materials. The lower grade materials with assays less than the assigned cutoff grade, x(C), are not mined and left in situ as un-mined blocks and pillars. The optimal cutoff assay, x(C,O), therefore, must lie satisfying the following sequence: $0 < x \min < x(C,O) < x(B,R) < x(B)$ or $x(M) < x$ maximum < 1.0. Although x(C,O) variation has a high range of assays (between x min and x (B)), it can be optimally estimated, under a static model, using two factors of pdf of ln (x) which is Gaussian and ratio of sales to cost prices (s/c). Under a dynamic model, however, these parameters are time-varying and hence have to be estimated after each time period of mining extractions and hence the procedure of estimation of x(C,O) becomes more complex.

Sales prices are known to be more volatile compared to cost of production as it depends on supply and demand position, vagaries of technological innovations, market substitutions, government interventions and management policies must account for these dynamic changes for optimizing the profits and future expected profits. All profits must be brought to a comparable level using the standard techniques of reduction using net profit value (NPV)(see, Sahu,2012,2015) to the present state of time origin.

Characterization of pdf of fractional assays in the ore body can be made by measuring assays of a large number ($N > 50$) of independent REV (see, Bear, 1972) samples/cells/blocks collected in the 3D space over which the resource exists. From, these sample data using the standard statistical methods the arithmetic mean, median, variance or standard deviation etc. can be easily obtained/computed. However, it is well-known that the fractional assay pdf is log-normal (Ahrens, 1954, Sahu,2003,2005, 2013) and hence all statistical parameters and hypotheses test must be made on the transformed Gaussian random variable, ln(x), where~ ln~ stands for natural logarithm of assay value, x. Computing on ln(x) basis, we obtain the mean(u) which is ln(x median), and standard deviation of ln(x) (σ) for cutoff, x(C) and optimal cutoff, x(C,O) estimations. Relations between fractional assay, x, and the probability density function (pdf) of its

Gaussian transformation, ln (x), have been dealt with at greater details in another paper (Sahu, 2016, submitted) and is largely omitted here.

In case of high-valued ores like Diamonds, U, REE, Au, Ag etc., the optimal cutoff grade lies in the lower one-third range of x(C) (x min< x(C) < x(B)) , and in low-valued ores like Fe, Al, Mn, Clays, etc. the optimal cutoff grade would lie in the upper two-thirds of the cutoff range. In case of medium-valued ores, the optimal cutoff, x(C,O) would lie in the middle one-third of this cutoff range(that is , x min to x(B)). In static analysis the geologic, assay distributional and economic factors are assumed to be constants over time while in dynamic analyses, these parameters are time-varying and have to estimated after each time-unit of ore extraction (say, quarterly, half-yearly or yearly as felt necessary). Dynamic modeling, although more involved, would yield much greater profits compared to the simpler static analysis.

Relation between break-even, x(B), and cutoff, x(C), assays:

Break-even assay, x(B) is very important in mining industry as it delimits the profitable ores from non-profitable mineral resources. This concept largely depends on the ratio of sales (s/ton) and cost (c/ton) prices of ore extraction of the marketable ore grade, x(M). Thus, using the pdf of fractional assays, x, if x(C) is zero or x min, we obtain,

$(1- x(B))\, s = c$ …. (1A) ,

or, $x(B) = 1 – (c/s)$ .. (1).

At some positive cutoff grade x(C) > 0 and/ or x min, we similarly get,

$(1 – x(B))\, s = (1- x (C))\, c$, ….. (2A), or,

$x(B) = 1 – (1 – x(C)) (c/s)$. …….(2)

Equation (2) can be reversed to obtain, x(C), as a function of x(B) as:

$x(C) = 1 – (1 – x(B)) (s/c)$. ----- (3).

In dynamic models forecasted values of (s/c) ratios are needed which is achieved by linearising Eqn.3 as:

$\ln (1 – x(C)) = \ln (1 – x(B)) + \ln (s/c)$. --------(3A)

The predicted values of ln (1- x(C)) = Y (hat) from time series model equation can, then, be inverted to obtain x(C) as { 1 – Exp(Y(hat))}. But in this paper dynamic models are not investigated in details, and hence not pursued further. From Eqn(3), it is obvious that x(B) is the upper limit to cutoff grade, x(C) and if (s/c) is 1.0, then x(C) is same as x(B). We can obtain the lower bound to cutoff grade x(C) as the minimum assay in the resource, x min, since fractional assay always lie above x min for any log-normal pdf. Thus, x(C) lies in the range x min to x(B) in the following sequence: 0< x min < x(C)/ x(C,O)<x(B,R)< x(B)<x(M)< x max<1.0; (x(M) being the marketable grade and x(B,R) the break-even grade for mining with risk factor at alpha confidence level). The optimal cutoff grade, x(C,O) will lie in the range from 0 or x min to x(B)/(x(B,R) or x(M)) ; and x(C.O) strongly depends on the (s/c) ratio as well as the lower- , (x min or 0) and upper-, x(B,R) or (x (B)) bounds of x(C). Table 1 indicates some typical values of lower and upper bounds of x(C) for various (minable/economic) sale to cost price ratios (s/c) for a log-normal assay pdf , x, (that is ln(x) is Gaussian).

Table 1: Feasible break-even grade, x(B), and x min or zero grade < x(C)/ x(C,O) assuming log-normal (log-Gaussian) pdf for ln (x) with mean, μ, and standard deviation, σ. Standardized random variable, z, can be calculated as z = [ln(x) – μ]/σ; hence we obtain, x min = Exp[μ – σ. z min] and x max = Exp(μ + σ. z max) . The values, x(B) and x min/ zero grade, form the upper and lower bounds of cutoff grades, respectively. However, the upper bounds to x(C) given in Table 2 would be more useful, in practice, rather than those listed in Table1.

(s/c) ratios	1.15	10	100	1000	10000	Remark
x min or zero	0.3	0.01	0.001	0.0001	0.00001	Lower Bound
x(B)	0.84	0.99	0.999	0.9999	0.99999	Upper Bound

The above calculations can easily be extended to two or more marketable grades, x(M 1), x(M 2), x(M 3), if required. For two marketable grades x(M 1) and x(M 2) with x(M 2)> x(M 1) and having sale prices s2 /ton > s1/ton, respectively, and production cost of c/ton, the break even grade x(B) can be calculated as:

x(B) = ((s2- x(M2) (s2-s1))/ s1) - (c/s1) , … (4)

which reduces to Eqn(1) in case of one marketable grade x(M) with a single sale price(s/ton) as required. The corresponding cutoff grade x(C)> 0, when mining of minerals resources is made from zero assay value, would be given as:

x(C) = 1 - (1- x(B)) (s 1/c), ---- (5)

where x(B) is now given by Eqn(4) for the two-marketable ore grades situation. Such type analyses can be extended to more than two marketable grades as well.

Geologists and mining engineers were using cutoff grade empirically and without the concept of pdf of assay distribution being log-normal. Considering Eqn(2)developed here and without using pdf of assays, we can obtain a much simpler upper and lower limits to cutoff grades based on economics (s/c ratios greater than 1.0) as shown in Table 2.

Table 2: Values of upper bounds, (x(B)), and lower bounds, x (min) or Zero, to the cutoff grade, x(C), for different economically feasible (s/c) ratios, greater than 1.0, as obtained by Eqn.(2).

(s/c)	1	2	3	4	5	6	10	Remarks
x(B)	1	0.5	0.33	0.25	0.2	0.167	0.100	Upper Bound
x(C)	0	0	0	0	0	0	0	Lower Bound

The optimal cutoff grade, x(C,O) would lie between these upper and lower bounds. However, the lower bounds to x(C) that is x min, given in Table 1 using the pdf of assays will be more useful and better than those given in Table 2.Thus, in practice, the upper limits to x(C) values as given in Table 2 (x(B) values) and the lower limits to x(C) values as listed in Table 1(x min values) are really to be used. The optimal cutoff grade, x(C,O) would then lie between these upper and lower bounds as in Tables 1 and 2,respectively.Table 3 gives the cut off grades, x(C), computed as per Equation(3)for different values of (s/c) ratio and corresponding break even grade, x(B), for direct application and for reference.

TABLE 3: Fractional cut off grade (assay), x(C), for different ratios of sales to cost prices, (s/c) ratios, and corresponding fractional-break even grade, x (B),as calculated by Equation 3. Beyond (s/c) ratio of 2.0, the x(C) values will be essentially x (minimum) or Zero; hence has not been given in this table. The optimal cut –off grade (as given by Eqn. 8) , x (CO), lies between x(min) or zero and x (B) values.

(s/c)	1.0	1.1	1.2	1.25	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
x(B)		------	------	x(C)	values	given	by	Eqn3	------	------	-----	-----
.005	.005											
.010	.010											
.015	.015											
.020	.020											
.025	.025											
.030	.030											
.035	.035											
.040	.040											
.045	.045	.000										
.050	.050	.000	0									
.100	.100	.010	0	0								
.150	.150	.070	0	0	0							
.200	.200	.120	.040	0	0	0						
.250	.250	.175	.100	.060	.025	0	0					
.300	.300	.230	.160	.120	.090	.020	0	0				
.350	.350	.285	.220	.190	.145	.070	.025	0	0	0		
.400	.400	.340	.280	.250	.220	.160	.010	.040	0	0	0	0
.450	.450	.395	.340	.310	.285	.230	.175	.120	.065	.010	0	0
.500	.500	.450	.400	.370	.350	.300	.250	.200	.150	.100	.050	0
.600	.600	.340	.280	.250	.220	.160	.100	.040	x	x	x	x
.700	.700	.230	.160	.125	.090	.020	x	x	x	x	x	x
.800	.800	.120	.040	x	x	x	x	x	x	x	x	x
.900	.900	.010	x	x	x	x	x	x	x	x	x	x
1.00	1.00	x	x	x	x	x	x	x	x	x	x	x

PROFIT MAXIMIZATION

Assuming sufficient proportion of marketable ores, (1 – x(B)), with sale price (s/ton) greater than the production cost (c/ton) exists for mining until exhaustion (mine life), economic viability is obtained if:

W. (1- x(B)) s > w. c . …..(6)

The optimal cutoff grade, x(C,O), should be searched for in the range of profitable cutoff grade range (that is between x min and x(B)), which can be equivalent to z (C,O) value within the range of z(x min) to z (x(B)) calculated on basis of log-normal mean(μ) and standard deviation (σ) of the ln (x) pdf. .Then the total profit, P, can be calculated as:

P = W. (1 - z (x(C)). (s - c). ….(7)

The optimal cutoff grade, x(C,O), would be less than x(B) and can be obtained through risk analysis (sale price of material in range x(B) to x(C,O) equals the cost of mining up to this lower optimal grade, x(C,O)) (see, Sahu,2005,2016). The resulting new break even grade, x(B,R) with taking risk at alpha level, would be less than the original break even grade, x(B) without taking any risk, that is, x(B,R) < x(B). Using cumulative unit normal, N(0,1), statistical tabular values, we then obtain (see, Sahu, 2005,2016):

[N(z (x(B)) - N(z(x(C,O))] / [N(z(x(C,O)) – z(x min) or z (-∞)] = (c/s), … (8)

which can be easily computed at the mining office for static or dynamic modeling to obtain x(C,O) value, as required by the mine management. Compare equation (8) with equation (3) under x(C) calculation assuming mining of ores at zero assay value as the cutoff grade.

Dynamic model calculations must be updated from time to time after a fixed time period of mining operations. In addition, forecasting techniques can be used to predict future sale price(s/ton) and future cost price (c/ton) using time-series modeling parameters estimated from corresponding past time-series data(see,Sahu,2003) to obtain c/s or s/c ratios as needed. These forecasting techniques are complex and model parameter dependant, and hence not pursued here.In case of large mines, blending and/or ore beneficiation processes are usually employed to upgrade lean ores to marketable grades for profits as well as for waste utilization to protect ecology/environment. Dynamic optimization of profits is mine and ore specific and cannot yield general optimal cutoff grade for any specific ore type (say, iron ore, copper ore, gold ore etc.). Hence, dynamic optimization must be done periodically in every large mine and for every block as is needed. In addition, mining company must adhere to National Mineral Policy and Mining Laws to have safe and un-interrupted operations.

CONCLUSIONS

Estimation of cutoff grade (fractional assay value), x (C), involves many complexly related geological, spatial assay distributional, probability density function (pdf) of assay in ores, and several economic factors such as sale price (s/ton) and production cost (c/ton). Estimation is simpler for static model where these parameters are assumed to be time-invariant constants, but highly complex for dynamic models where these parameters must be updated from time to time at short intervals of ore production. For static analysis, optimal cutoff grade, x(C,O), lies within the range of x minimum to x (B) (the break-even grade of no profit-no loss). Calculation of actual value of x(C,O) is more involved but can be made at mine office using standard unit-normal (Gaussian) statistical tables of N(0,1) where the parameters of fractional assay pdf is log-normal(see, Eqn.8). Dynamic modeling is more complex and time-consuming, as these calculations must be updated after each short periods of ore extraction. However, dynamic analyses of ore-extraction would yield much higher profits compared to ore-extraction policy predicted from a static model. Hence, a dynamic model is recommended for precious metals (like Pt, Au, REE, and U) which have very volatile sale prices.

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MINERAL EXPLORATION IN INDIA: A NEW APPROACH

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INTRODUCTION

A dedicated, involved, systematic and appropriate approach by an expert, well versed in mineral exploration can only locate new mineral resources anywhere in the world and more so in India where mining over 3-5 millennium has exhausted the more visible , easily accessible, near surface, richer deposits of ore. Three critical parameters need attention in any exploration programme with a view to achieving success in today's context in our country.

1) Experienced and serendipitous mineral exploration professionals.
2) Sufficient funds to the tune of hundreds of crores of rupees for each exploration project to meet the high cost of exploration.
3) Modern inputs by capable assistants if various allied technologies, like geomorphology, geochemistry, geophysics, remote sensing, spectroscopic analysis upto ppt level of all elements of the periodic table, study of altered haloes in the weathered zones.

Mineral exploration techniques are now very sophisticated and there is a lot of scientific (both laboratory and field) input to ensure success in most impossible conditions and that too with speed, accuracy and good economics. Exploration is very different from prospecting done during 16th to 19th century when the search was for visible near surface ores. The prospectors of early years lacked systematic approach and often their finds were due to chance. Today's mineral exploration follows a logical and scientific approach and more often the discoveries are due to logical computation of data collected very precisely with this objective to locate unseen, buried deep-seated resources which often need special mineral processing technologies to be usable. In the early days most prospected areas were virgin and the ore had direct surface expression. Today the exploration is in used up areas and special inputs from geology, geophysics, geochemistry, drilling, sampling and analysis are needed. Core recovery in drilling has to be 100%. It is now necessary to study the near-surface weathered cover rock and soil which may have a genetic link with the main buried ore body. Therefore, mineral exploration needs expert supervision and intelligent, dedicated and involved participation of all types of assistants. The exploration geologist must not only be senior, but also should be fully conversant with basic fundamental knowledge of all his assistants' subjects and be capable of guiding all operations of the exploration project with a view to getting success.

Modern exploration is not only expensive but also involves risk and therefore is necessary that the exploration is guided by 'exploration models' formulated in line with 'mineral deposit models'. If we have exploration models we can ensure better success and economics of exploration. In such a model the underlying principle are:

1) Identify target areas for different kinds of deposits adopting principles of economic geology.
2) Cut down unnecessary field work by studying mineral deposit models.
3) Help collect minimum but truly representative samples. This can be achieved by both theoretically and practically by assessing the basic data and that by an expert.

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4) Analyse all samples spectroscopically to find total ions, individual concentrations and their inter-relationship so as to ascertain and assess the resource as well as realign exploration strategies keeping in mind trace element studies and their relationship to the primary mineralisation.
5) Compute the data to arrive at conclusions related to the genetics of the deposits and their temporal and geographic entities.
6) Follow up with essential minimum drilling including single hole combined with or without multiple inclined boreholes to assess the dimension and quality of the deposit.
7) And do all these operations in the shortest possible time and with least expenditure this will ensure the readiness of a prospect for mpt.
8) During prospecting, some development be done to partly or fully pay for the cost of exploration. (Exploratory Development)

Some of the more important aspects of the Mineral Exploration Modelling are discussed in the text that follows.

1) Geological Targeting: Mineral deposits' formation and localisation is controlled and guided by economic geological principles and are therefore, not found everywhere and every time. In fact there are different geological and geographical provinces for different kinds of ores. An experienced geologist either knows this or can learn about this by a reconnaissance survey (e.g., chromite, nickel and platinum with ultrabasic rocks, gold and copper with acid volcanics, bauxite with aluminous rocks)

2) Study of weathered profile: The study of chemistry, physics and geomorphology of any weathered profile which contains the altered products of the ore and associated minerals, but not the actual mineral gives enough indications about the original minerals and the rock. The study of the alteration hallow indirectly leads us to the deposit. Such study can only be done by intelligent field work by an expert and with excellent laboratory back up. Physical and optical studies together with spectroscopic analysis give us a complete picture of the deposit for further exploration by geophysics, geochemistry and drilling. The altered minerals' genetic connection, when established , becomes a very important factor in locating the deposit. For such studies it is important to analyse for all elements in the periodic table up to PPT level to find the path finding element or element combination.

3) Sampling: A sample is a small unit which is as far representative of the whole as possible. In order to be a successful geologist, one has to be an expert sampler. The more representative the sample the more nearer your exploration will be to the actual set up of the deposit. A perfect sampling programme will tell us about the quality and quantity of the deposit and forewarn us about its MPT requirements.

4) Analyses of samples: This now no longer the conventional gravimetric chemical analysis. It is now more of spectroscopic analysis. The NIR spectroscopy is now found to be more suited for mineral exploration as it is speedy, less cumbersome, and economical. It is also non-destructive. The method has many applications in laboratory and field. In situ material can also be studied. The chemical assistant has to be a competent in spectroscopic analysis.

WHAT IS NIR SPECTROSCOPY?

It is near infrared spectroscopy in the range of 700-2000 nm discovered in 19 th century by William Herschel, but industrial application started in 1950 in pharmaceutical applications like blood sugar and pulse oximetry. It is based on molecular overtone and combination variations. Its penetration is farther than MIR and even though it is not very sensitive this is now extensively applied in mineral exploration because it is non-destructive, because little or no sample preparation is needed and it can be applied to bulk samples and has in situ applications in field. Multivariate calibration technique is applied to extract desired chemical information. The spectrum is studied in reflection or in transmission.

5) Geophysical studies: As geophysical properties are fairly good indicators of the underlying concealed material a proper geophysical survey will give us (without drilling which costs a lot) indirect information through study and measurement of gravity, magnetic , seismic and electrical, gas emission parameters information about the deposit. A proper geophysical modelling prior to actual mineral deposit modelling will be a valuable tool in the hands of the exploration geologist. This geophysical modelling will eliminate the non-applicable surmises from among the multiple possible geological set ups that can give a set of geophysical anomalies. Only an expert can do this elimination and find the actual fit and predict correctly about the true geological set up.

6) Drilling: Drilling will give us more information as the geologist will compute all available data to prepare a drilling model which may vary from deposit to deposit and from place to place. He will decide the drill plan so that a minimum of drilling is done without compromising data acquisition. A drilling model for each area and each deposit has to be arrived at by the geologist to ensure minimum drilling. Any competent and experienced geologist can ascertain a lot of information even from single borehole (e.g. oil exploration). The information obtained is extremely useful for future exploitation and extraction. The drilling personnel have to be very good. They must ensure 100% core recovery. Three shift drilling can be done if the machine maintenance is top class. It is a tragedy in India that such jobs are performed by incompetent, unskilled to semiskilled workers. Drilling, a very sophisticated job cannot be done by the untrained and the uneducated. Even in organisations where they have engineers, the drilling is rarely done by them as they are busy in routine administrative work. The drilling programme must not only ensure deliverance of what we are looking for but also what we are not counting on. Geologist heading the exploration project must get full support from his drilling assistant.

Keeping in view all that has been said so far India now needs a sound 'Mineral Exploration Policy'.

MINERAL EXPLORATION POLICY

This has to be a National Policy and should at least ensure the following.

1) Deploy genuine experts for the jobs
2) More funds for government agencies
3) More private participation
4) Proper training for all workers
5) Incentives to all
6) Private participants must have a stake in later mining if a deposit is established
7) All data on mineralized areas be compiled and readily available to any entrepreneur. The exploration policy should encourage finding resources irrespective of their geographic location, because this is not manipulatable. So exploration programmes need to override forest laws. Afterall exploration does not affect environment.
8) Even though mining has some effect on environment, it can be reduced to near zero level by suitable sustainable operations. Besides the area under mining is hardly 0.03 % of total land area of the country and possibly only 0.1% of total forested area.
9) The exploration policy will earmark areas as suitable for exploration and such areas need to be specially identified.
10) Officers from GSI as per their charter were authorised to enter any property for geological survey and this has been in force for nearly more than 170 years. This still is in force. Then how can any rule framed afterwards do away with this authority. Obviously the later forest and environment law which forbids a GSI official from entering a forest is a bad law.

11) The country cannot progress to a developed status without minerals. So the exploration policy should be conducive to mineral search. Exploration can be done without cutting trees.
12) Quantification of different jobs done for mineral exploration is illogical and should never be done in any rule. The latest directive of the MMRD act to restrict drilling to 16 bore holes per sq. Km. is silly. I wonder how such an idiotic provision has found place in country's law. Modern exploration can be done with near zero modification of geomorphology.

There has to be separate provisions for exploration of 'CRITICAL MINERALS'. A critical mineral is that which is essential for country's need and because of short internal supply we take recourse to import. For example, nickel, cobalt, antimony, bismuth, cadmium, sulphur, mercury, gold , oil coking coal , fertilizer minerals, gemstones etc. Other minerals like copper, lead, zinc, tungsten, tin, etc. are near critical. For such minerals it is necessary to find resources within the country to help save foreign exchange and to free us from the idiosyncrasies of countries willing to export these. So all rules which go against finding such resources should be changed to make them exploration friendly. I very strongly feel that any law which restricts exploration is anti- national. After preparing a list of critical minerals including those belonging to fuel group, rare earths' group and alloy steel making group , the list may be revised from time to time depending on the latest position and need.

Despite these problems related to internal resources, as per today's laws a orester can stop a geologist from carrying out his legitimate rights of doing exploration and it is a sad fact of the day that stopping a geologist is anti-progression. After all a geologist ,who understands environment better than others is blamed for degrading environment , while the truth is diametrically opposite. Let us develop the nation and stop all silly laws which go against the nation's future progress to well being. Further it is not necessary to play with environment to conduct any exploratory survey anywhere.

EXPLORATION MODELLING VS. MINERAL DEPOSIT MODELLING

A mineral deposit model gives us comprehensive information about any deposit including its dimension, grade, genetics, and amenability to mineral processing technology. But this model remains only a model till it is explored to find how far correct our model is. Post exploration remodelling takes us nearer to the truth and tells us where we went wrong before the deposit was explored. In fact it helps us to be more precise in future and helps us to avoid errors in postulation. An appropriate 'Exploration Model' tells quite early and much before actual exploitation of the deposit about all that is needed to know about it before it is exploited. An exploration model will not only help us finding the deposit but also tell us about its development ability. Like we need experts for mineral deposit modelling we need greater experts for Mineral exploration modelling.

CREATION OF A CADRE MINERAL EXPLORATION EXPERTS AND MINERAL VALUERS

This needs to be a statutory provision (of Chartered Accountants and Mine Managers). The emergency recruitment can be made to form the base of the cadre from among experienced retired willing officers from different government agencies like GSI, IBM, and PSUs like MECL, ONGC, OIL, SAIL, COAL INDIA, State DGM as well as private companies. All exploration and mine evaluation can be done by these experts and this has to be in the statutes. Any pre-evaluation exploration suggested by them has to be undertaken under their supervision by identified exploration agencies. This will help the government fix correct base price for auction. It will also help all to avoid unnecessary evaluation. Periodic revaluation of mineral property must also be a part of the statutes to ensure that any new valuable association located during mining is not excluded from the evaluation process. These experts can also be empowered to suggest eco-friendly, sustainable mining methods for extraction of ore. There need be no age bar for such experts if his capability is unquestioned and if he is fit to take up the responsibility. Later entries to the MEE & MV cadre can be done through an examination route. The cadre strength and annual intake can be decided on the basis of work load by a core group of experts.

Apart from need based expertise the explorer must be aware of the political and socio-economic environment of the business and its impact on people and ecology. One must not forget the fact that an exploration geologist's work can create a resource which can be developed into a mine which will provide a new avenue for the country's development by,

1) Creating new jobs
2) Compensating those who might be displaced
3) Provide suitable rehabilitation for shelter as well education, health care and productive job
4) Advise corporate responsibility to locals
5) Read the mood of the people to create awareness about the pros & cons of the activity in the area

As geologists deal with earth and have a great love for it their serendipity will help create a very congenial atmosphere in the mineral belt while creating new resources. He can play significant role in search of truth and not be carried away by myths and half truths. The science of geology has no assumptions nor are there any limiting factors as in other subjects. As and when new data is available a geologist accepts new interpretations. The facts of earth and the truths of geology are often not understood well by others because we are steeped in traditions, myths, and superstitions. All allied technologists must give up their traditional and irrational thinking and behaviour and accept logic and predictability of geology.

A successful explorer in geology observes all types of scientific data with care and attention so that he can analyse the phenomenon under the most diverse and different perspective. He questions himself regarding any assumptions made, though this is rare, to check if they fit to the entire theory. He rarely postulates hypothesis and arrives at any theory after considering all pros and cons. He accepts that his serendipity which can note all serendipitous events can generate important ideas and discoveries. He is always ready for the unexpected and he can encourage his assistants to observe and discuss the unexpected events. He helps to develop serendipity among the members of his group and he does not suffer from zemblanity. His serendipity never suppresses the serendipity of his younger colleagues.

MINERAL EXPLORATION TRUST

This seems to be good idea. Let the money be spent in acquiring modern equipment for physical, optical and chemical studies and acquiring high speed deep drills. Some fund needs to be used for training. Please set up the laboratories in mineral districts and not in big cities. The management be in the hands of experts who know mineral exploration and not in the hands of politicians and bureaucrats who donot even know the ABC of mineral exploration.

Finally let all the committees and core groups be managed by experts and for heaven's sake let us recognise their merit.

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SPATIAL VARIATION OF PREMONSOON GROUNDWATER CHEMISTRY OF ANANDAPUR SUBDIVISION, KEONJHAR DISTRICT, ODISHA

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ABSTRACT

The ionic concentrations of the pre-monsoon groundwater of the Anandapur subdivision show wide variation with multiple centers of maxima and minima. Trend surface analysis reveals the presence of weak regional trends. The first-degree trend surfaces depict westerly increase of Ca^{2+}, northerly increase of Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-}, Cl^{-} and southerly increase Fe^{2+}, HCO_3^{-}, NO_3^{-} and F^{-}. The second degree trend surfaces, on the other hand, illustrate centrifugal increase of Ca^{2+} and Fe^{2+}, centripetal increase of SO_4^{2-}, increase of Mg^{2+}, Na^{+} and Cl^{-} concentrations towards southeast and northwest, increase of HCO_3^{-}, NO_3^{-}, F^{-} concentrations towards southwest and increase of K^{+} concentration towards north. The weak regional trends may be due to high degree of heterogeneity of aquifers due to large scale lithological variations, diverse recharge systems, anthropogenic activities and other factors which control the groundwater chemistry.

Keywords: *Ionic concentration of groundwater, Trend surface analysis.*

INTRODUCTION

Water is one of the essential requirements for sustenance of life on the earth. The fresh surface water, which is limited to 2.8% of the total water resource (Raghunath, 1987) is very often polluted to large extent, as a result of which, more and more attention is being paid to utilise groundwater now a days. The chemical composition of groundwater depends upon several factors including chemistry of aquifer materials, amount of rainfall, extent of industrialization, interference of human beings etc. Thus, the groundwater is likely to show considerable variation in chemistry across the length and breadth of an area comparable with the size of a subdivision of a district. The Anandapur subdivision is the most populous part of the Keonjhar district of Odisha. Though the Iron ore Supergroup forms the basement, thick alluvial cover in the floodplains of Salandi and Baitarani rivers and their tributaries favour intense cultivation. Keeping pace with rapid industrialization of the country, sporadic industrial units have come up in the subdivision. In view of increasing importance of groundwater for different purposes, attempts have been made in the present work to study the spatial variation of the premonsoon groundwater chemistry of Anandapur subdivision of the Keonjhar district.

STUDY AREA

The study area is bounded by 21° - 21° 30′ north latitudes and 85° 58′- 86° 20′ east longitudes covering an area of approximately 950 Km^2 in the eastern part of the Keonjhar district (Fig.1). The Iron ore Supergroup comprising different varieties of quartzites and granites forms the basement. It is overlain by laterite of Tertiary age and alluvium of recent origin. Ultrabasic rocks hosting chromite and associated PGE group of elements have intruded into the Iron ore Supergroup in the northeastern part of the study area. A number of minor and major water harvesting structures have been constructed to meet the water need of the

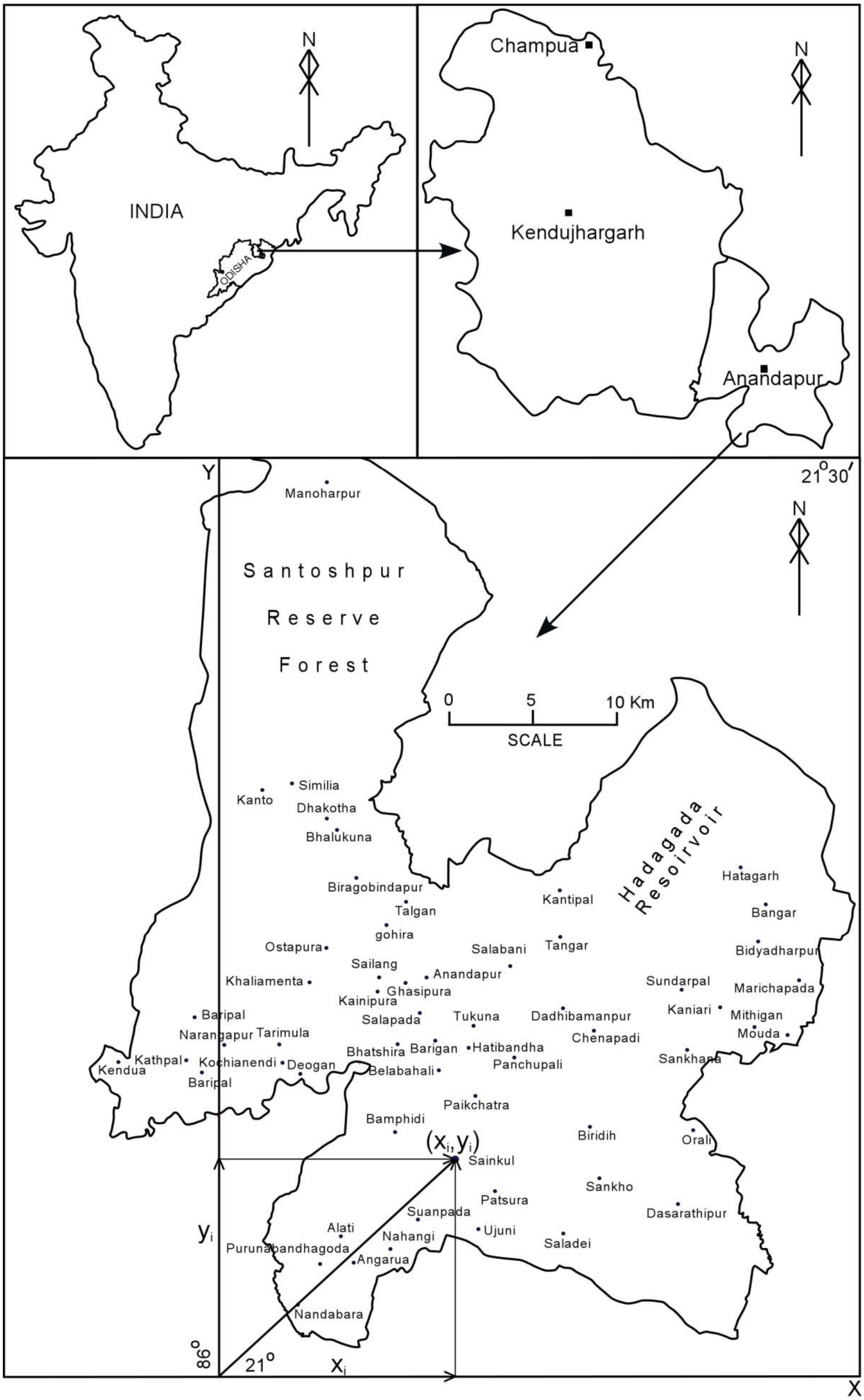

Fig.1. Location map of the study area showing villages from which groundwater samples were collected and x- and y-axis for trend surface analysis

subdivision. Hadagarh project is the largest among them that spreads over an area of about 65 Km^2.

METHODOLOGY

Fiftyeight tube well water samples were collected during premonsoon season of 2013 from different parts of Anandapur subdivision (Fig.1). Concentrations of major cations (Na^+, K^+, Ca^{2+} Mg^{2+} and Fe^{2+}) and anions (CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^- and F^-) of the water samples were determined following standard analytical procedures (Trivedy and Goel, 1984; Gupta, 2004, Jaiswal, 2004; Gray, 2005; APHA, 2005 and Hota, 2011). Ca^{2+}, CO_3^{2-}, HCO_3^- and Cl^- were determined by volumetric titrations. Na^+ and K^+ were estimated by flame photometer and SO_4^{2-}, Fe^{2+}, NO_3^- and F^- were estimated by spectrophotometer.

Spatial variation of major ions of the groundwater samples were determined by trend surface analysis following the methods outlined by Davis (2002) and Hota (2014). This method is an effective technique in separating the regional or large-scale component (signal) represented by trend from the local or small-scale component, which is residual (noise) (Rimmer and Davis, 1990). In this analysis, a variable (concentration of an ion) at a place is regarded as the function of the abscissa and ordinate (in kilometers, in the present case) of that place. In the present case 21° north latitude and 86° east longitude were taken as the x- and y-axis respectively (Fig. 1). The concentration of any ion in groundwater sample collected from village "i" is related to the abscissa (x_i) and ordinate (y_i).

In mathematical expression: Concentration of an ion in mg/l (z_i) = $f(x_i,y_i)$

The degree of the trend surface depends on the degree of the equation.

The general form of first-degree (planar) trend surface is $z = a + bx + cy$

Second-degree (quadratic) trend surface is $z = a + bx + cy + dx^2 + ey^2 + fxy$ ....etc

The coefficients (a, b, c etc) of the trend surface were determined by solving a set of simultaneous equations. Trend surfaces were fitted by least square criteria in the increase order of their degrees i.e. initially the first-degree surface was fitted followed by second-degree. After determining the values of the coefficients of first-degree trend surface, expected or trend values were determined for each locality. Total sum of squares (SS_T), total and mean sum of squares due to trend or regression (SS_R and MS_R) as well as total and mean sum of squares due to deviation (SS_D and MS_D) were computed. Statistical significance of the trend surface was determined by analysis of variance (ANOVA) using the F-test by comparison of MS_R and MS_D at appropriate degrees of freedom and 5% significance level. In addition, 95% confidence interval about the trend surface was determined to ascertain the range of variation of the population.

RESULT AND DISCUSSION

The groundwater samples show wide variation of concentration of different ions but all the parameters are within the limits of drinking water standard of World Health Organisation (WHO, 2004) and Bureau of Indian Standards (BIS, 1991) (Mohanty and Hota, 2015). In the present case, first- and second-degree trend surfaces were fitted to the Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^- and F^- by least-square criteria. The first- and second-degree equations along with the 95% confidence intervals are presented in Tables 1 and 2. Analysis of variance was performed in three instances *viz.* to test the significance of the fit of first- and second-degree trend surfaces and increase in the degree of trend surfaces (Table 3). The computed values of 'F' in all cases are less than the critical values at 5% significance level. This leads to acceptance of the null hypothesis (H_0) that the variance about the trend surface is not different from the variance in the observation. Thus, both first- and second-order trend surfaces fitted to

Table 1. First-degree trend surfaces fitted to the ionic concentrations of premonsoon groundwater of Anandapur subdivision

Parameter	First-degree (planar) trend surface	95% confidence interval
Ca^{2+}	52.1526 - 0.0719x - 0.0052y	± 49.3918
Mg^{2+}	19.9471 - 0.0861x + 0.0416y	± 25.2819
Na^{+}	3.1543 - 0.0372x + 0.0340y	± 3.3944
K^{+}	0.9900 - 0.0003x + 0.0061y	± 1.5578
Fe^{2+}	0.7448 - 0.0005x - 0.0020y	± 0.5322
HCO_3^-	100.4875 - 0.3086x - 0.6844y	± 57.8559
SO_4^{2-}	45.4366 - 0.1748x + 0.0774y	± 50.0025
Cl^-	61.5922 - 0.2505x + 0.3782y	± 44.0212
NO_3^-	1.3640 + 0.0057x - 0.0163y	± 1.1963
F^-	0.4307 - 0.0004x - 0.0034y	± 0.2148

Table 2. Second-degree trend surfaces fitted to ionic concentrations of premonsoon groundwater of Anandapur subdivision

Parameter	Second-degree (quadratic) trend surface	95% confidence interval
Ca^{2+}	$43.27996 - 0.29700x + 0.97773y + 0.03802x^2 - 0.01095y^2 -0.04910xy$	± 48.54476
Mg^{2+}	$11.83365 + 0.46855x + 0.50672y + 0.00026x^2 - 0.00370y^2 - 0.02617xy$	± 25.07971
Na^{+}	$4.88613 - 0.20937x - 0.04025y + 0.00450x^2 + 0.00114y^2 + 0.00111xy$	± 3.24214
K^{+}	$0.88330 + 0.02662x + 0.00109y - 0.00091x^2 + 0.00011y^2 + 0.00017xy$	± 1.54538
Fe^{2+}	$0.83690 + 0.00099x - 0.01372y + 0.00039x^2 + 0.00039y^2 - 0.00063xy$	± 0.51125
HCO_3^-	$78.80350 + 1.76665x + 0.17226y - 0.00822x^2 + 0.00182y^2 - 0.08217xy$	± 56.77670
SO_4^{2-}	$50.66165 - 1.57323x + 0.39092y + 0.03988x^2 - 0.00899y^2 + 0.00195xy$	± 49.15662
Cl^-	$39.12419 + 0.12641x + 2.32545y + 0.05400x^2 - 0.01962y^2 - 0.10204xy$	± 41.33981
NO_3^-	$0.61261 + 0.04898x + 0.03221y + 0.00009x^2 - 0.00052y^2- 0.00217xy$	± 1.16630
F^-	$0.34106 + 0.00129x + 0.00458y + 0.00009x^2 - 0.00012y^2 - 0.00023xy$	± 0.21124

the ionic concentrations of premonsoon groundwater are not statistically significant. However, the second-degree trend surfaces explain greater percentage of sum of squares than the corresponding first-degree surfaces and thus are better suited to demonstrate the geographical variation of ionic concentrations of premonsoon groundwater. The two-dimensional projections of the trend-surfaces along with isoconcentration maps of different ions are shown in Figs.2 – 12.

Table 3. F-test results of analysis of variance of trend surfaces fitted to the ionic concentrations of premonsoon groundwater of Anandapur subdivision

Parameter	*First degree trend surface	**Second degree trend surface	***Increase of the degree of trend surface
Ca^{2+}	0.02313	0.37515	0.61016
Mg^{2+}	0.14808	0.22529	0.28065
Na^{+}	2.07707	1.86105	1.66668
K^{+}	0.11218	0.21067	0.27932
Fe^{2+}	0.1111	0.91346	1.44655
HCO_3^-	1.30600	0.91187	0.66503
SO_4^{2-}	0.15253	0.42069	0.60167
Cl^-	0.90677	1.78175	2.32150
NO_3^-	1.62008	1.18726	0.90434
F^-	1.84976	1.07638	0.58847

*$F_{\nu1=2,\nu2=55,\alpha=0.05} = 3.17$; **$F_{\nu1=5,\nu2=52,\alpha=0.05} = 2.39$; ***$F_{\nu1=3,\nu2=52,\alpha=0.05} = 2.78$

Relatively high values of confidence intervals of trend surfaces (Tables 1 and 2) are due to wide variations of the concentrations of ions in the study area. Different ions have multiple centers of maxima and minima. The first-degree equations are divisible into three categories. In the equations for Ca^{2+}, Fe^{2+}, HCO_3^-, and F^- both the coefficients are negative, while in case of Mg^{2+}, Na^+, K^+, SO_4^{2-} and Cl^- the coefficient of abscissa is negative and that of ordinate is positive. In case of NO_3^- the coefficient of abscissa is positive and that of ordinate is negative. The first-degree trend surfaces suggest westerly increase of Ca^{2+} (Fig.2b), northwesterly to northerly increase of Mg^{2+}, Na^+, K^+, SO_4^{2-} and Cl^- (Figs. 3b, 4b, 5b, 8b and 9b). Fe^{2+}, HCO_3^-, NO_3^- and F^-, however, increase towards southerly directions (Figs. 6b, 7b, 10b and 11b). The second degree trend surfaces, which satisfy higher percentage of variance, depict the variation of ionic concentration of groundwater to greater extent. These surfaces are divisible into five categories. Ca^{2+} (Fig. 2c) and Fe^{2+} (Fig. 6c) show centrifugal increase while SO_4^{2-} (Fig. 8c) shows centripetal increase of concentrations. Concentrations of Mg^{2+} (Fig. 3c), Na^+ (Fig. 4c) and Cl^- (Fig. 9c) increase from northeast and southwest directions towards central part of the study area and subsequently increase towards southeast and northwest directions. HCO_3^- (Fig. 7c), SO_4^{2-} (Fig. 8c), NO_3^- (Fig. 10c) and F^- (Fig. 11c) concentrations increase towards west-southwest. K^+ is the only ion, whose concentration steadily increases towards north in case of both the trend surfaces (Fig. 5b and 5c).

SUMMARY AND CONCLUSION

Concentrations of different ions of the premonsoon groundwater of the Anandapur subdivision show wide variation with multiple centers of maxima and minima. Trend surface analysis of ionic concentrations reveals the presence of weak regional trends and consequent predominance of residuals (noise). The first-degree trend surfaces suggest westerly increase of Ca^{2+}, northerly increase of Mg^{2+}, Na^+, K^+, SO_4^{2-} , Cl^- and southerly increase Fe^{2+}, HCO_3^-, NO_3^- and F^-. The second degree trend surfaces, on the other hand, give a picture of centrifugal increase of Ca^{2+} and Fe^{2+}, centripetal increase of SO_4^{2-}, southeast and northwest increase of Mg^{2+}, Na^+, Cl^-, southwest increase of HCO_3^-, NO_3^-, F^- and northward increase of K^+. The weak regional trends may be attributed to high degree of heterogeneity of aquifers due to large scale lithological variations, diverse recharge systems, anthropogenic activities and other factors which control the groundwater chemistry.

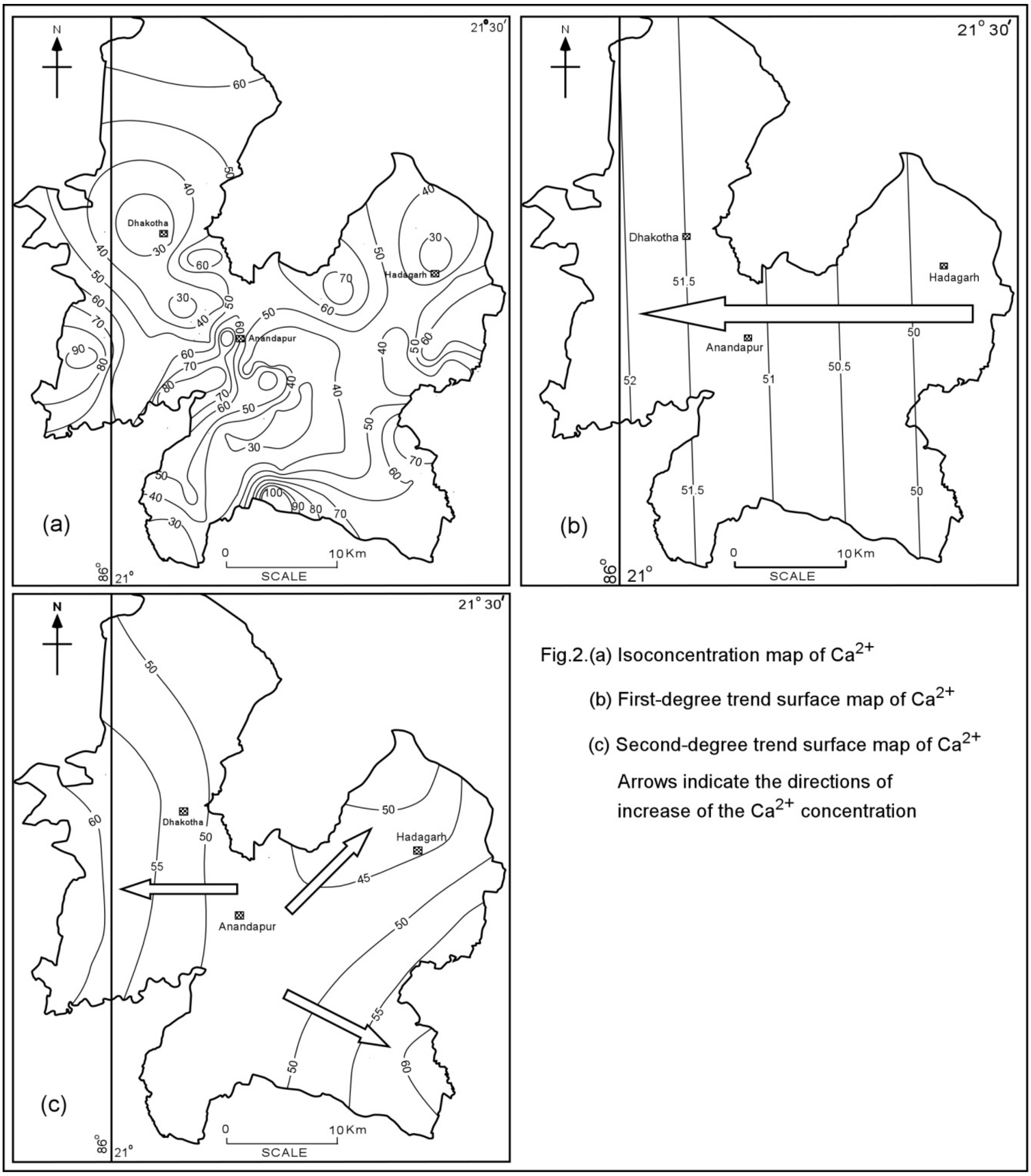

Fig.2.(a) Isoconcentration map of Ca^{2+}

(b) First-degree trend surface map of Ca^{2+}

(c) Second-degree trend surface map of Ca^{2+}

Arrows indicate the directions of increase of the Ca^{2+} concentration

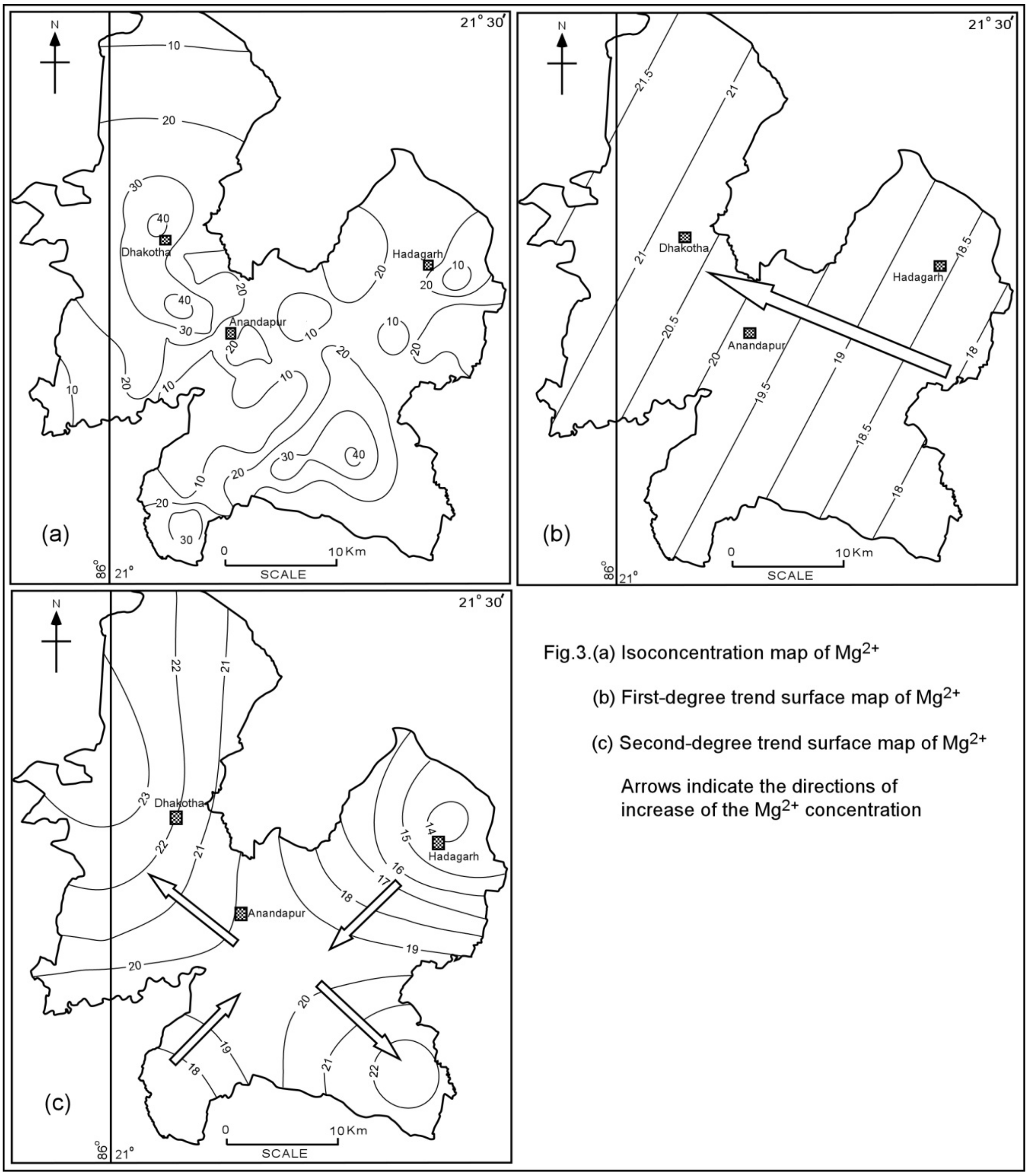

Fig.3.(a) Isoconcentration map of Mg^{2+}

(b) First-degree trend surface map of Mg^{2+}

(c) Second-degree trend surface map of Mg^{2+}

Arrows indicate the directions of increase of the Mg^{2+} concentration

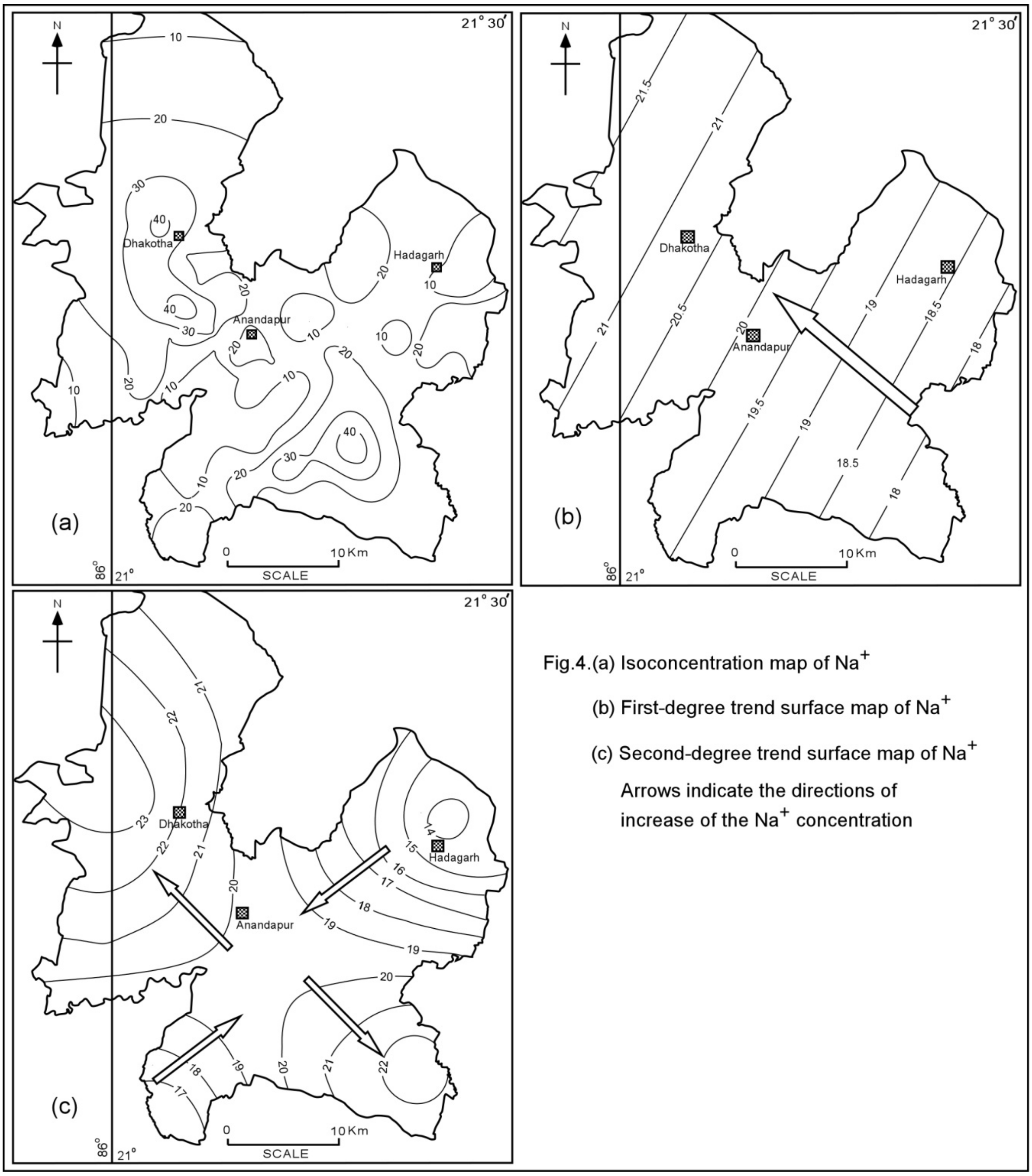

Fig.4.(a) Isoconcentration map of Na^+

(b) First-degree trend surface map of Na^+

(c) Second-degree trend surface map of Na^+

Arrows indicate the directions of increase of the Na^+ concentration

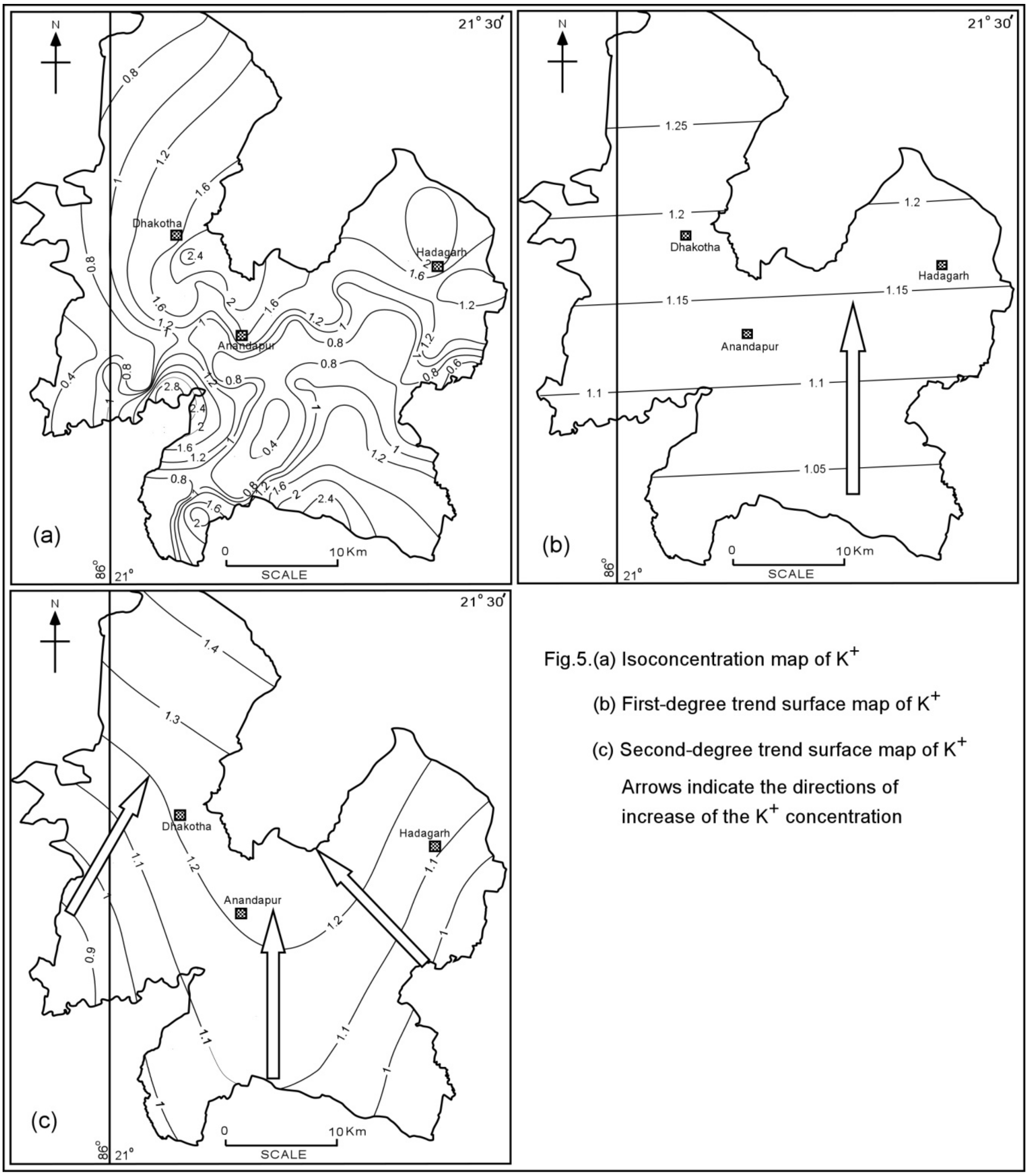

Fig.5.(a) Isoconcentration map of K^+

(b) First-degree trend surface map of K^+

(c) Second-degree trend surface map of K^+

Arrows indicate the directions of increase of the K^+ concentration

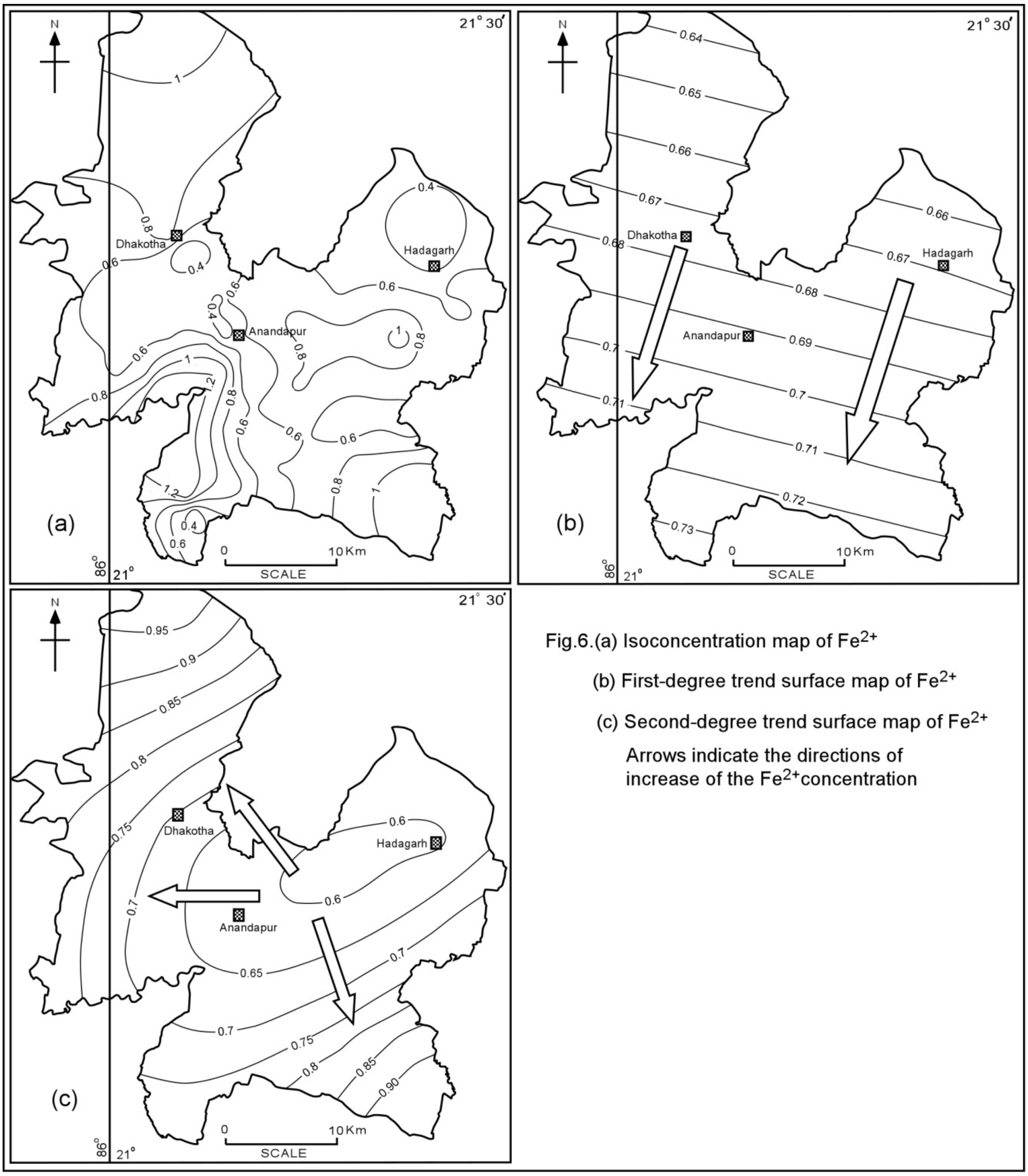

Fig.6.(a) Isoconcentration map of Fe^{2+}

(b) First-degree trend surface map of Fe^{2+}

(c) Second-degree trend surface map of Fe^{2+}

Arrows indicate the directions of increase of the Fe^{2+} concentration

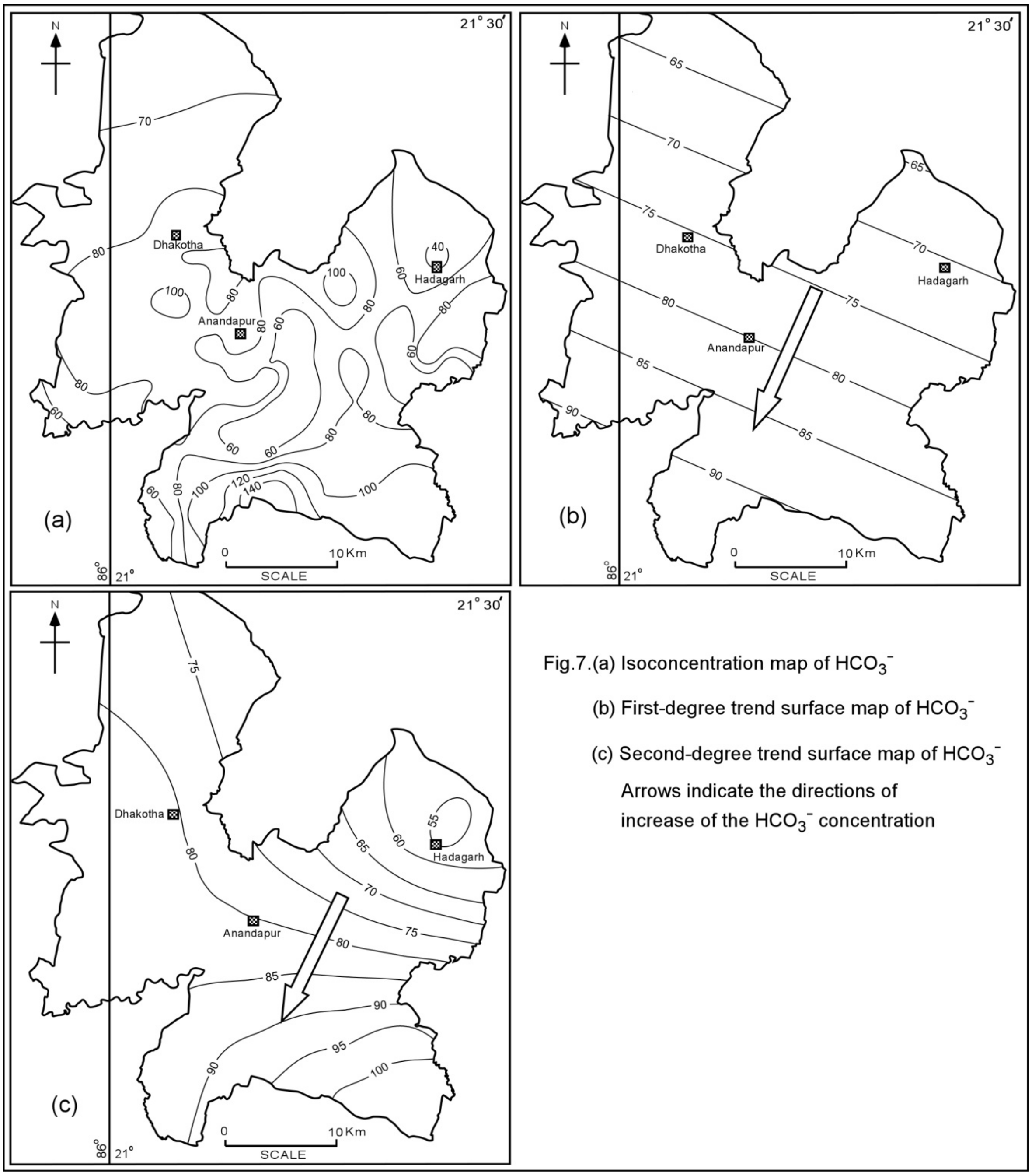

Fig.7.(a) Isoconcentration map of HCO_3^-

(b) First-degree trend surface map of HCO_3^-

(c) Second-degree trend surface map of HCO_3^-

Arrows indicate the directions of increase of the HCO_3^- concentration

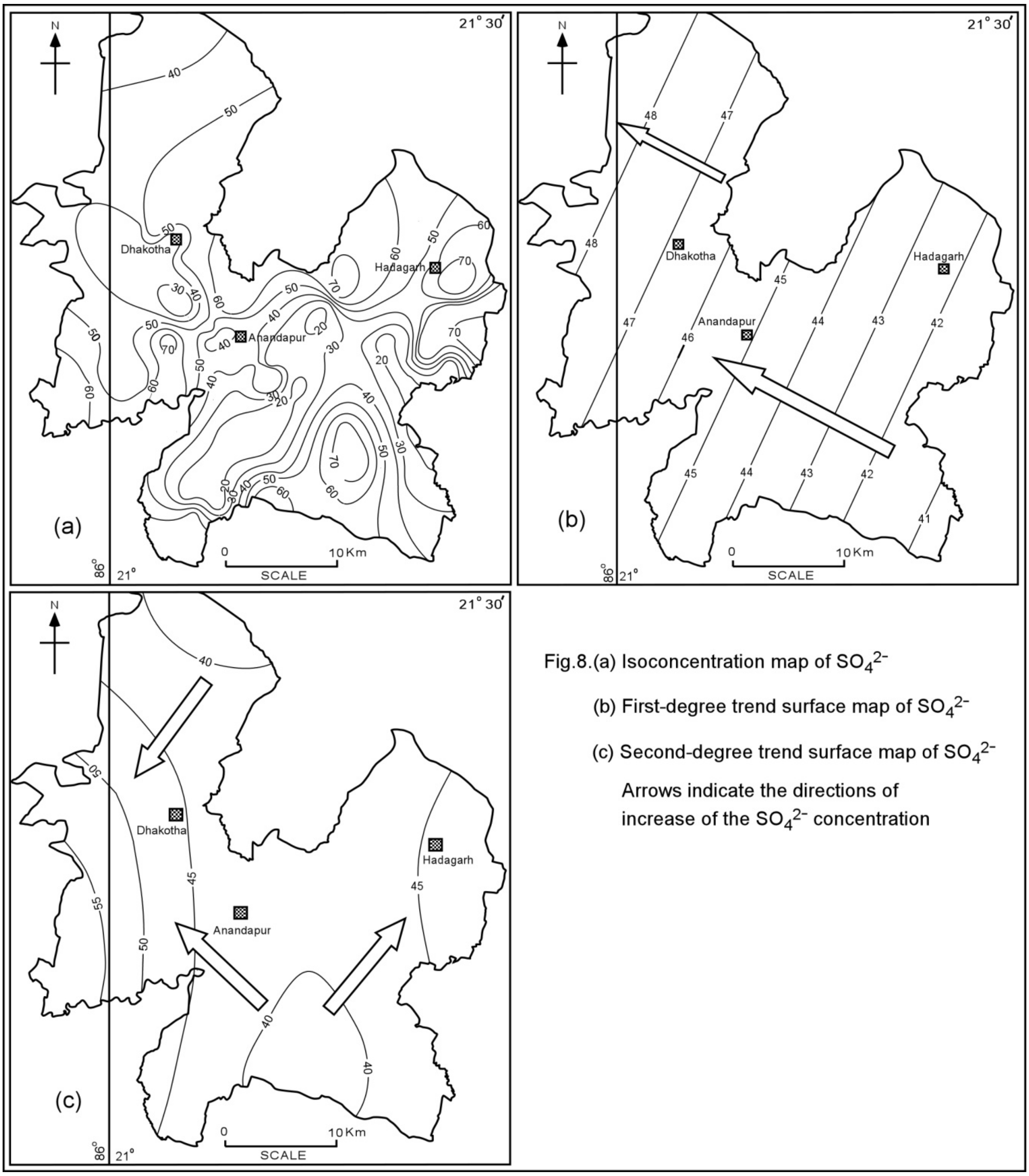

Fig.8.(a) Isoconcentration map of SO_4^{2-}

(b) First-degree trend surface map of SO_4^{2-}

(c) Second-degree trend surface map of SO_4^{2-}

Arrows indicate the directions of increase of the SO_4^{2-} concentration

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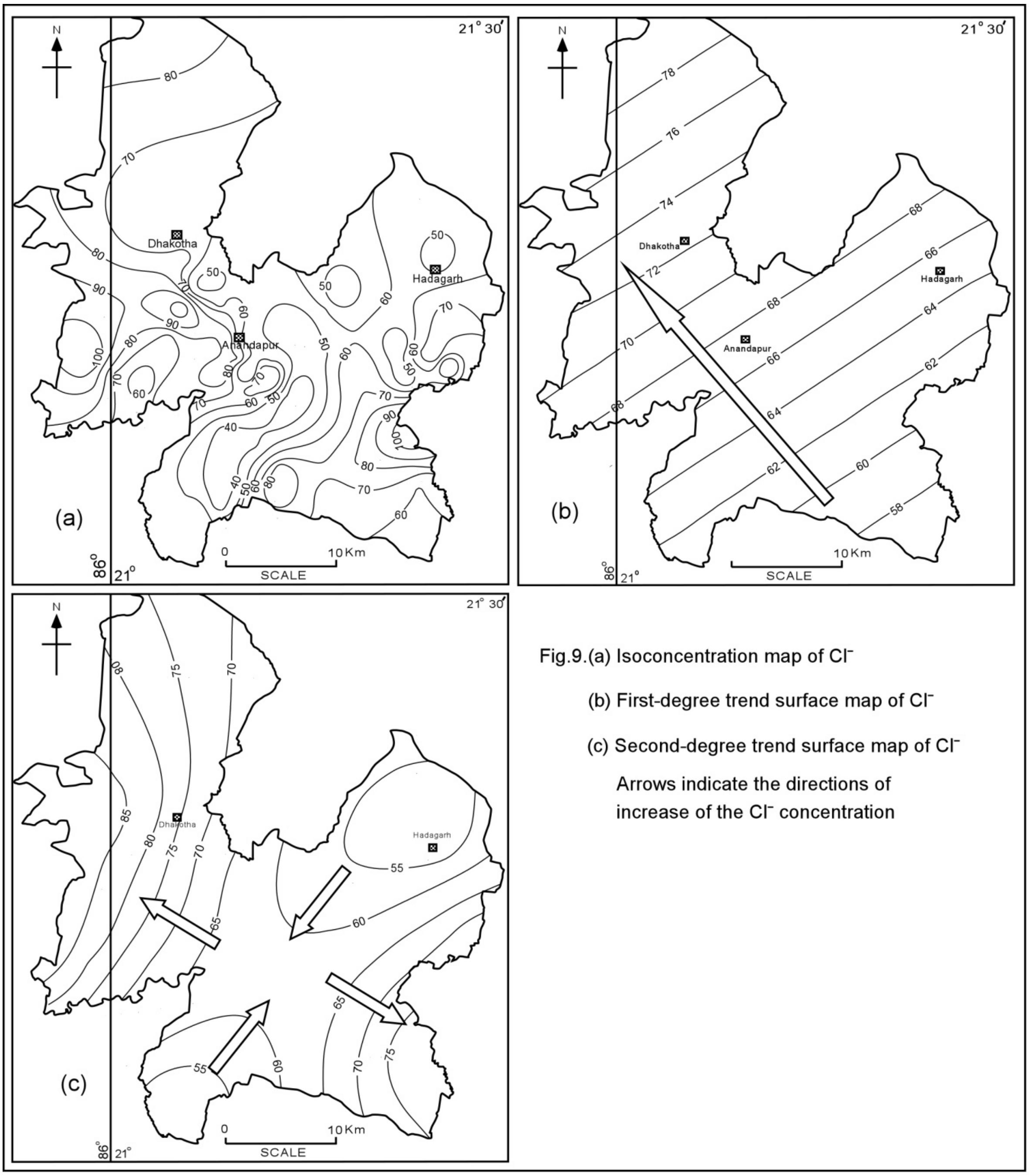

Fig.9.(a) Isoconcentration map of Cl^-

(b) First-degree trend surface map of Cl^-

(c) Second-degree trend surface map of Cl^-

Arrows indicate the directions of increase of the Cl^- concentration

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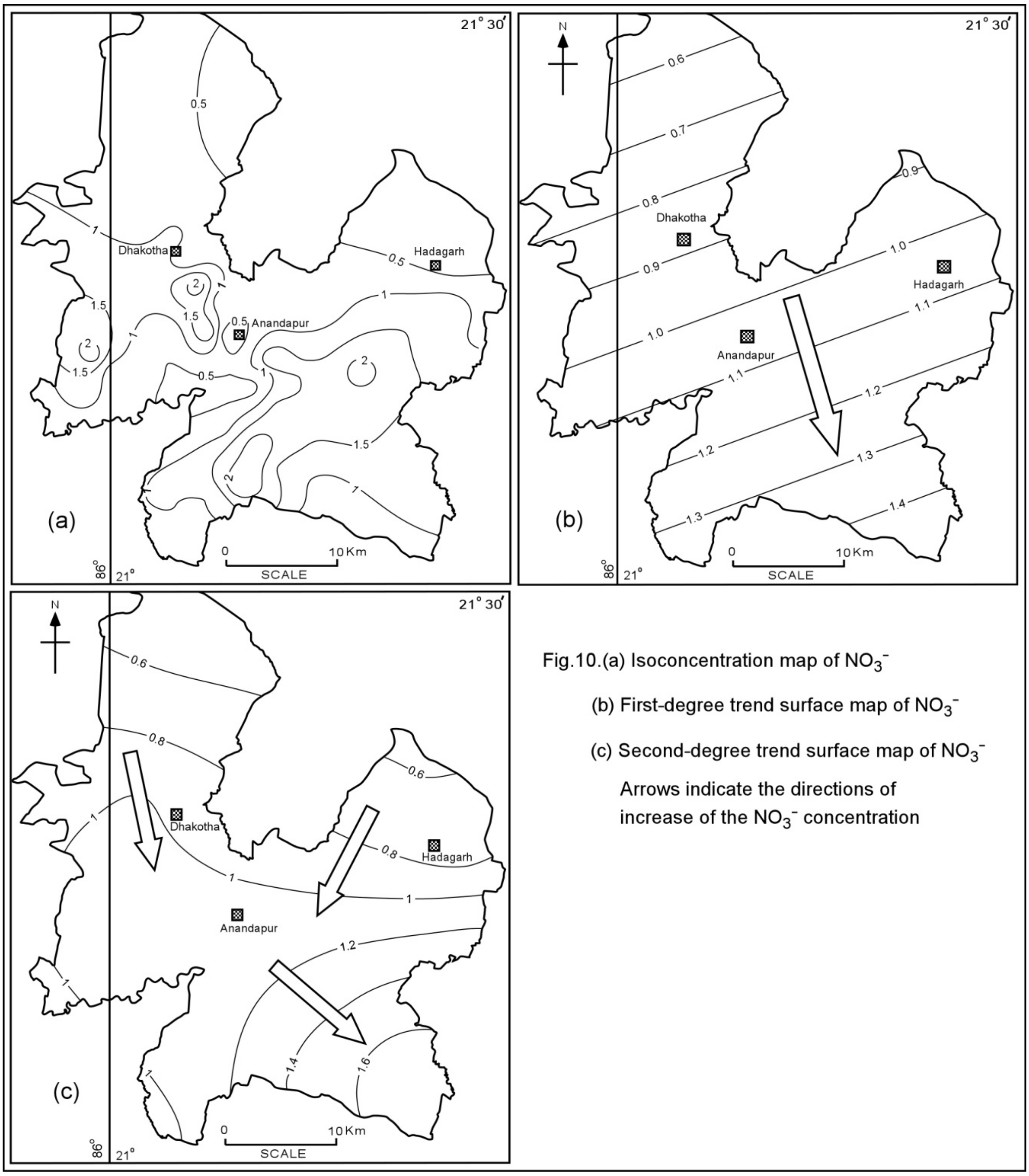

Fig.10.(a) Isoconcentration map of NO_3^-

(b) First-degree trend surface map of NO_3^-

(c) Second-degree trend surface map of NO_3^-

Arrows indicate the directions of increase of the NO_3^- concentration

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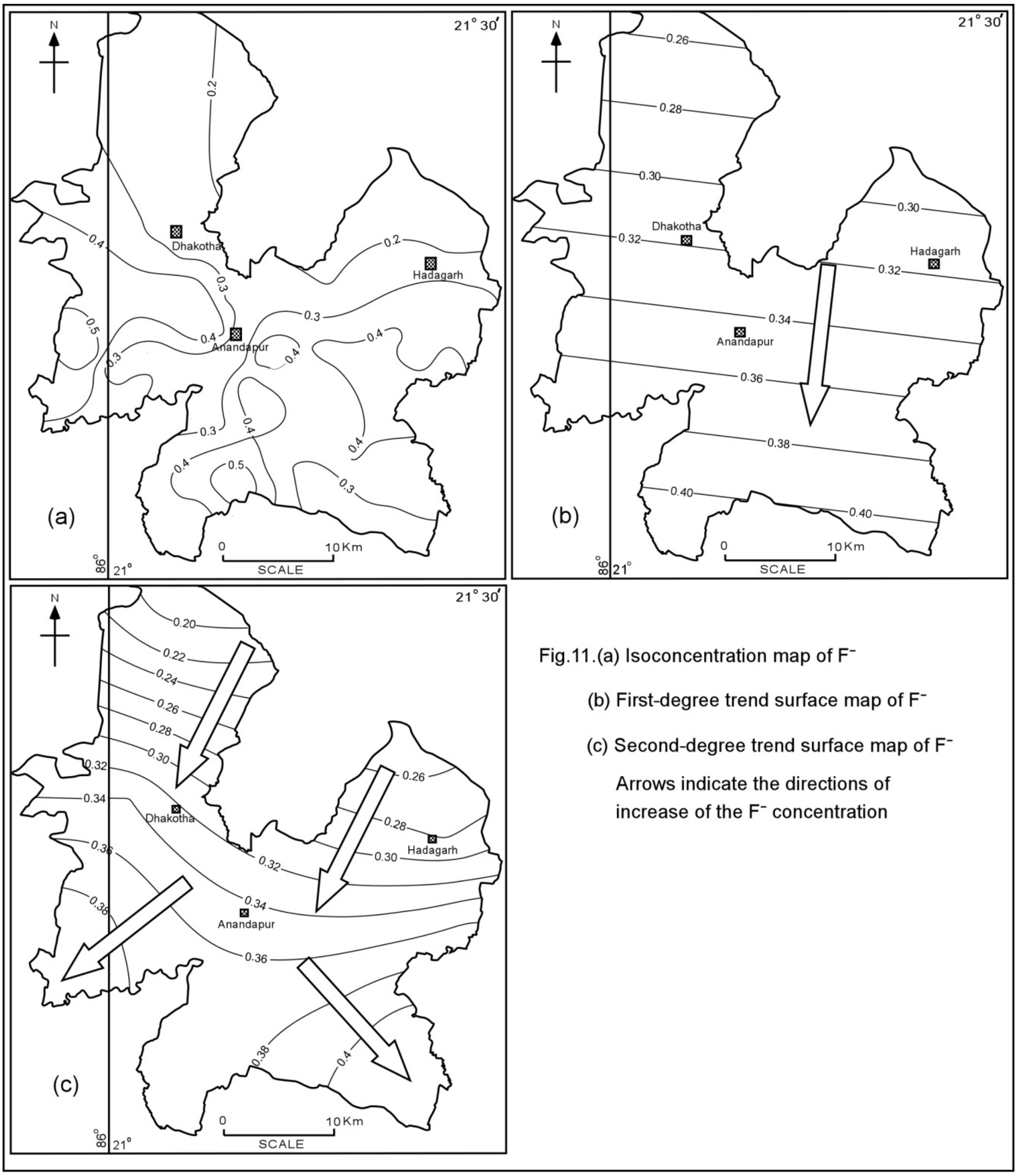

Fig.11.(a) Isoconcentration map of F^-

(b) First-degree trend surface map of F^-

(c) Second-degree trend surface map of F^-

Arrows indicate the directions of increase of the F^- concentration

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INTERNATIONALLY ACCEPTABLE RESOURCE CLASSIFICATION SCHEME AND RELEVANCE TO INDIA

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ABSTRACT

Mineral resource classification requires a team effort led by a Qualified Person (QP) who has required academic qualifications and industry experience. The QP decides and assigns his levels of confidence to quantify mineral resources which results in resource classification. This paper discusses the resource classification framework as suggested by the CRIRSCO. Discussions on best practices are also included.

INTRODUCTION

By mineral resource estimation generally it means 'quantification' of mineralized material, which forms an integral part of evaluation of a mineral deposit. The *estimated resources* need *classification* to categorize portions of the deposit in terms of 'confidence' on availability of the commodity of interest (such as iron, copper, coal, diamond, etc.) and potential for extraction of such commodity in foreseeable future. Such confidence is assigned by a Qualified Person (QP) such as RQP in India as recognized by IBM[1]. It should be noted that a qualified person is also known as Competent Person (CP) in Canada and some other countries. The importance of the role of CP/QP was discussed at length by Samal & Rao, 2015.

There are various parameters that can be used to assign confidence on availability of the material as discussed below.

i. Availability of sufficient number of drill holes (samples) at a reasonable spatial spacing. This parameter is useful for demonstrating continuity of mineralization and geology.
ii. Quality of information such as drill hole location, drill hole logs, sampling, assay data, density, topographical mapping etc.
iii. Robustness of resource estimation. The robustness of estimated resource is supported by substantial validation of estimation, which is a lengthy topic to be discussed elsewhere.

The confidence on extractability is based on various other parameters as listed below.

i. Sound economic viability analyses that support the criteria for eventual economic extraction of the mineral resources at a justifiable cutoff grade. This analysis should demonstrate a positive net present value (NPV). This analysis also includes an acceptable market analysis.
ii. Reasonable technical feasibility to extract the commodity. This criterion provides confidence on the technological feasibility. For an example, the mineral occurrences under a mountain range may not be technologically feasible to mine. In another case, due to technological advancements, the kimberlite pipes in northern Canada are now producing diamond.

As discussed above, expertise from multiple disciplines (such as geology, mining,

[1] Recognised Qualified Persons (http://ibm.gov.in/index.php?c=pages&m=index&id=86; Accessed, September 13, 2015)

geotechnical, mineral processing, metallurgy, economists, assessors, legal experts, environmental scientists and social science experts) are required for assigning confidence on the estimated mineralized material. It is the responsibility of the QP or CP to ensure that experts from all disciplines are involved and his confidence is relying on his own and others' experience, expertise and knowledge of the deposit under consideration.

The resource classification represents the act of assigning various degrees of confidence to mineralized materials in various parts of the deposit.

RESOURCE CLASSIFICATION

The mineral resource classification is essentially a matter of skilled judgment of the QP and the contributing experts based on standard criteria. Such a set of criteria is published by CRIRSCO[2] in their 2013 template. It should be noted that the above scheme for resource classification is adopted by various other international standards and codes such as NI-43-101 Canada, JORC of Australasia, SAMREC of South Africa and SME of USA. In India an older version of UNFC Code is now enforced. After more than 10 years of its implementation, the UNFC code is still not completely adopted or, implemented for various reasons, which is outside the scope of this paper.

Opposed to the three dimensional UNFC[3] scheme for resource/ reserve classification, the CRIRSCO suggested scheme is modern, simple, easy to implement and internationally acceptable. This is one of the reasons why this scheme has been implemented effectively by many mineral rich economies in the world. The CRIRSCO scheme of classification suggests the following.

i. The mineral occurrence, mineralization and geological inventory are *not* mineral resources.
ii. The mineral resources meet the criteria for 'eventual economic extraction'. In this case 'eventual' implies in foreseeable future.
iii. The inferred mineral resource is the mineral resource with lowest degree of geological confidence and not suitable for application of modifying factors to convert into reserve.
    - With continued exploration, portion of the inferred material can be upgraded to indicated category resources.
iv. The indicated category resources are backed by sufficient geological confidence and supported by economic analyses. The measured category resources are of highest confidence category resources.
v. Portion of indicated and measured category resources can be converted into reserve.

The mineral resource is a concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade or quality and quantity that there ***are reasonable prospects for eventual economic extraction***. The location, quantity, grade or quality, continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from

[2]CRIRSCO (Committee for Mineral Reserves International Reporting Standards) is an international representative body whose members are National Reporting Organizations (NROs) that are responsible for developing and maintaining the market related mineral reporting codes, standards and guidelines for public reporting. These national and regional member organisations are: JORC (Australia), CIM Reserves Committee (Canada), Comisión Minera (Chile), PERC (western Europe), MPIGM (Mongolia), NAEN (Russia), SAMREC (Southern Africa) and SME Reserves Committee (USA). Additional information about CRIRSCO is available on CRIRSCO's website at: http://www.crirsco.com.

[3]International Framework Classification for Reserves and Resources – Solid Fuels and Mineral Commodities ('UNFC'), developed by the United Nations Economic Commission for Europe ('UN-ECE')

specific geological evidence and knowledge, including sampling.

The term "reasonable prospects for eventual economic extraction" implies a judgment (albeit preliminary) by the Competent Person with respect to the technical and economic factors likely to influence the prospect of economic extraction, including the approximate mining parameters, such as dilution, mining recovery, and minimum mining thickness. In other words, a Mineral Resource is not an inventory of all mineralization drilled or sampled, regardless of cut-off grade, likely mining dimensions, location, or continuity; rather it is a realistic estimate of mineralization which, under assumed and justifiable technical and economic conditions, might become economically extractable.

The term "reasonable prospects" implies that Measured, Indicated, and Inferred Mineral Resources are constrained within pit shells for surface mining methods (refer Figure 2) and constrained to coherent zones for underground extraction, both of which support mining, processing and future development cost estimates.

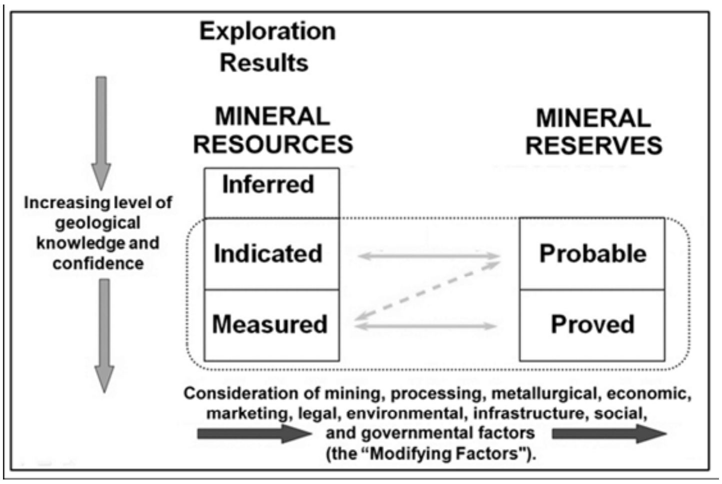

Fig. 1. General scheme of resource reserve classification (Source, CRIRSCO, 2013)

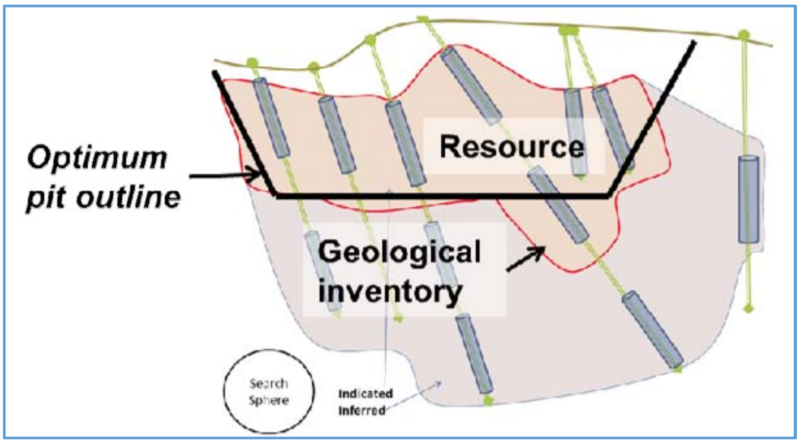

Fig.2. Explanation of reasonable prospect for economic extraction. In this figure, the mineralized material within the optimum pit-shell qualify for mineral resource; whereas the material below the pit-shell do not meet the criteria for eventual prospect for economic criteria, hence designated as 'inventory'. It should be noted that with continued drilling, potentially the geological inventory can upgrade into mineral resources.

RESOURCE CLASSIFICATION: BEST PRACTICES

As discussed earlier, the task of resource classification requires input from all contributing experts. The QP weighs in the information and makes qualified judgement based on outlined criteria (such as the criteria table-1 of the CRIRSCO template). As guidance, some of the best practices for mineral resource classification are listed below.

i. Use a life of mine that is projected to a foreseeable future: The life of mine can only be forecasted based on known economic criteria including price of the commodity. Because of the cyclical nature of the commodity price a mine plan that goes beyond approximately 20 years or so can be questionable.

ii. Use mathematical resource classification as mathematical resource classification can show spotty resource classification (left indicator contributing to the final resource classification). The left side diagram of Figure. 3, often known as ‘spotted dog effect’, should be cleaned.

iii. Avoid un-explainable and unclear mathematical techniques. Such an example is seen in the use of kriging variance[4]. In this case the inflection points on the cumulative frequency charts of the kriging variance used as indication of confidence. This is a vague criterion.

As shown in Fig. 4, the inflection point of the left side chart of Fig. 4 has no geological significance. The color coded image on the right side of Fig.4 shows that there is no continuity established by the use of such a technique.

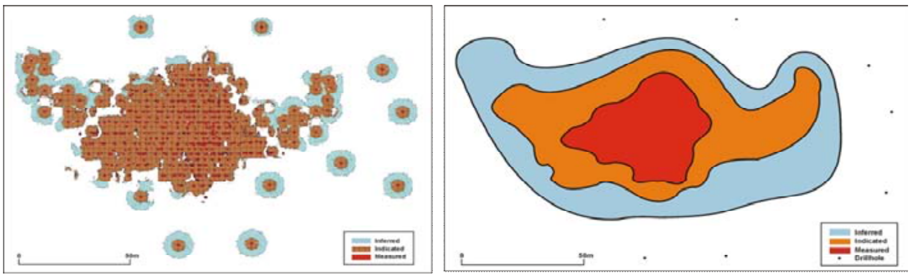

Fig.3. Left: Spotted dog effect. Right: final resource classification (Source: Parker, 2013, personal communication)

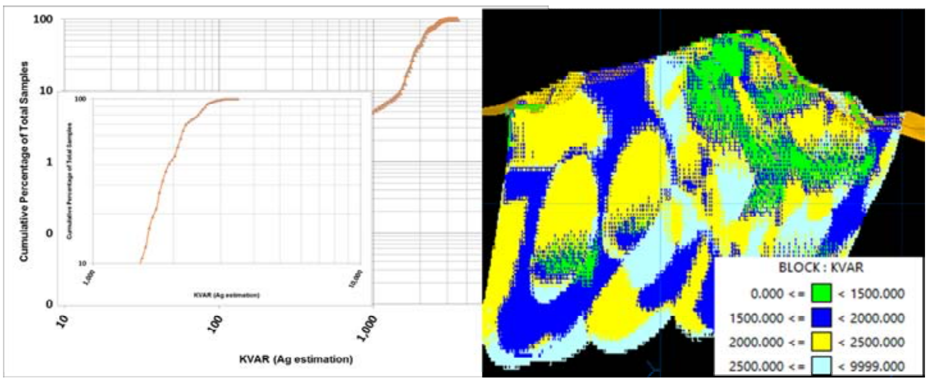

Fig. 4. Use of cumulative frequency chart of kriging variance for resource estimation

[4] Kriging variance is a measure of error and uncertainty in estimation of grade using variants of kriging interpolation technique

The authors suggest using the mathematical / numerical classifications in interim and clean the classifications to create reasonable classification, which shows continuity of measured and indicated resources in areas of high density of drill holes.

iv. Drill enough holes and improve the estimation quality so as to lower the variability of estimated grades.

FINAL THOUGHTS: IMPORTANCE FOR INDIA

In order to influence growth in mineral resource development, use of an internationally recognized standard classification scheme is important. This process increases transparency, reduces ambiguity and enhances reliability of quantified mineral resources in any part of the world and facilitates investment opportunity at international level.

In India adoption of UNFC code is still an ongoing process. Therefore, the resource classification process is not yet robust. According to these authors, one of the reasons of this near failure situation is the ambiguous UNFC code, which seems difficult to implement. The latest version of UNFC (2009) is not directly mappable with UNFC (1997) version and hence making the authorities scary of adopting the new version of UNFC in India. This makes the resource classification based on UNFC standard vastly unreliable. It is time for India to adopt the international standards of mineral resource classification and be part of the international group.

Adoption of an international standard for resource classification would enhance the reliability of mineral resource inventory of the nation. It may be advisable to have a look at the Australian system of maintaining national inventory and learn from their experience on how to implement similar system in India. This would also enhance the prospects of increased foreign investment opportunity in the country.

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FLUID INCLUSION STUDIES OF AURIFEROUS QUARTZ VEINS FROM SONAKHAN GREENSTONE BELT, CENTRAL INDIA

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ABSTRACT

The fluid inclusions of the auriferous quartz veins emplaced in the metavolcanics are biphase in nature. Heating and freezing studies reveal that the temperature of homogenization of these inclusions ranges from 130^0C to 170^0C and a narrow range of temperature of melting (-1 °C to –2 °C). The density of fluids was found to be 0.9 to 0.95 gms/cm^3.The low temperature and low salinity of the fluids from the above study revealed the telethermal conditions of the mineralization in the present area.

Key words: *Fluid inclusion studies, Sonakhan, Greenstone belt, Gold mineralization.*

INTRODUCTION

The Sonakhan Greenstone Belt (SGB) is a late Archaean Greenstone Belt covering an area of about 1200 Sq. km. along the Northeastern part of Raipur district of Chhattisgarh state (Fig.1). It comprises metavolcanic and metasedimentary sequences which have undergone greenschist to amphibolite facies of metamorphism (Saha et al., 1994; Ray and Rai, 2004). Structurally, it is a broad synformal basin with moderate plunge to the North- Northwest and closure to the South near Baya.

The area yields primary gold mineralization in the form of primary auriferous quartz veins in the older metavolcanics emplaced post-tectonically on one hand and secondary gold rich alluvial placer deposits on the other besides a number of base metal sulphides.

The name Sonakhan (meaning gold mine in Hindi) is attributed to the ancient gold mine developed during the regime of Emperor Chhatrapati Shivaji (1400 A.D.). Presence of a few old workings in the form of pits and reporting of gold particles as alluvial placer in the streams joining Jonk river invited the attention of Geologists to study the area to explore the economic potential of gold mineralization in the area.

The Sonakhan Greenstone Belt (SGB) was first studied by King (1899) and he attempted to correlate Sonakhan beds with the Precambrians of Central India, namely Chilpighat and Sakoli series. Pascoe (1950) correlated the belt with Dharwars of South India.

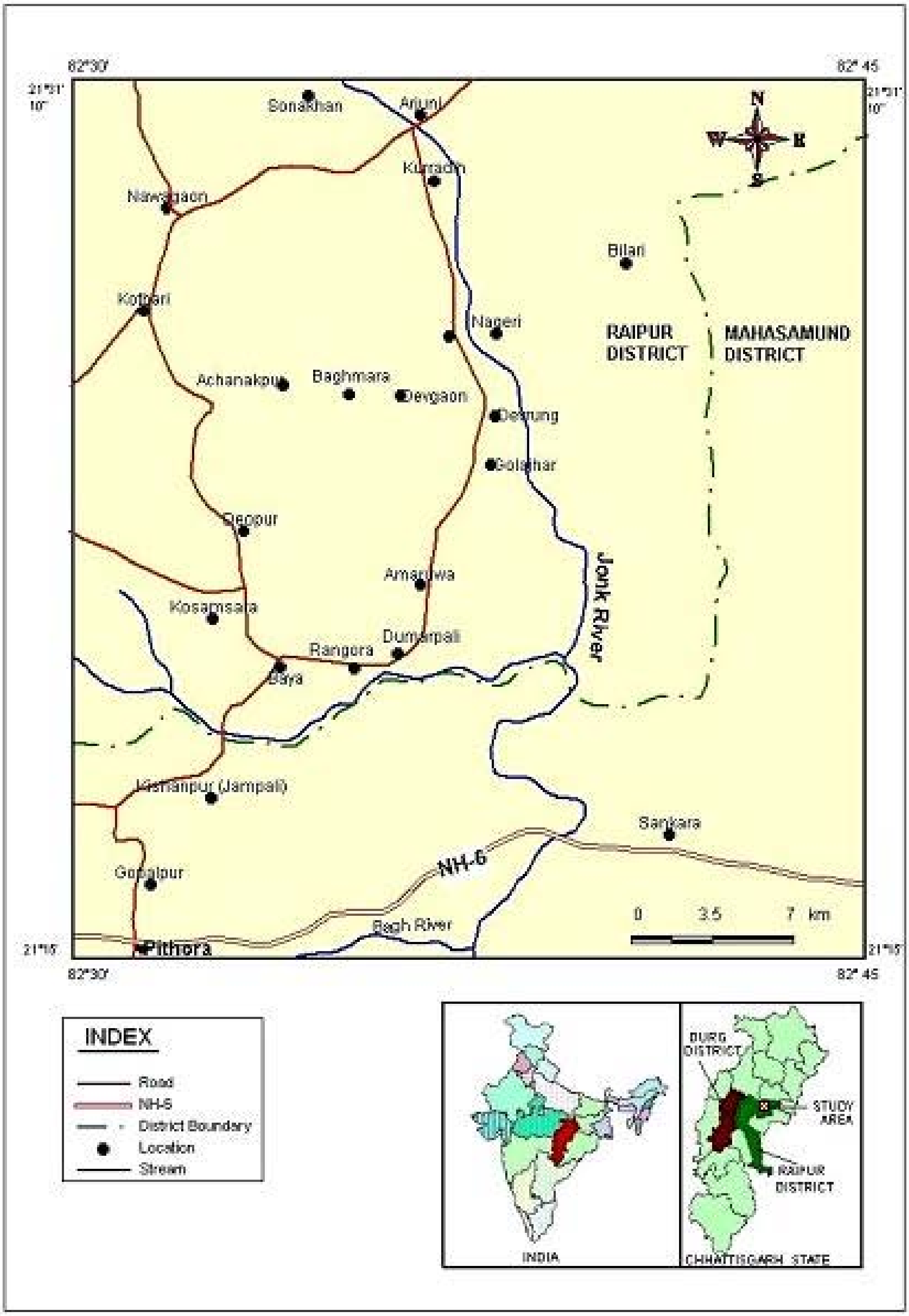


Fig.1. Location map of the study area.

Das et al (1990) described the lithostratigraphy of the SGB and further emphasized the need for identification of gold targets in the quartz veins and ferruginous sulphidic chert and the study of tectonic significance of Sonakhan Greenstone Belt in the evolution of Bastar craton. Saha et al (1994) studied the structural relationships of the various constituents of Sonakhan Group with the Baya Gneissic Complex. The geochemistry of the rocks in the area was studied by Rai (2000), Venkatesh (2001) and Ray and Rai (2004).

GEOLOGICAL SETUP

The SGB rests unconfomably over the Baya Gneissic Complex and is overlain by the rocks of Chhattisgarh Supergroup. Das et al (1990) classified SGB into Sonakhan Group (older) and Bilari Group (younger).The Sonakhan Group was further classified by them into two formations. The older one is Baghmara Formation, which consists of mafic to felsic volcanics, chert and B.I.F. and the younger one is Arjuni Formation which consists of greywacke-argillite suite, B.I.F. and younger metavolcanics. The two formations of Sonakhan Group are separated by a prominent polymictic conglomerate called Jonk conglomerate.

The basic metavolcanics of Baghmara Formation are pillowed metabasalts. They also exhibit vesicular and amygdular structure at places. The felsic volcanics are rhyolites and tuff. They are pinkish to greenish gray in colour and exhibit variolitic texture.

The metavolcanics have suffered hydrothermal alteration represented by intense silicification, carbonation, sericitization, chloritization, sausseritization and sulphidation akin to Hutti-Maski belt [Venkatesh (2001)]. Numerous quartz veins of variable width ranging from few centimetres to up to 3 metres are frequently seen intruded in the metavolcanics. These veins follow major shear trend (NNW-SSE) and exhibit massive to sheared and brecciated nature [Mishra (1996)].

Milky quartz veins and smoky quartz veins as mirrored by silicification represent the hydrothermal activity. These veins form favorable locales for sulphides (arsenopyrite and galena) and gold mineralization in the area

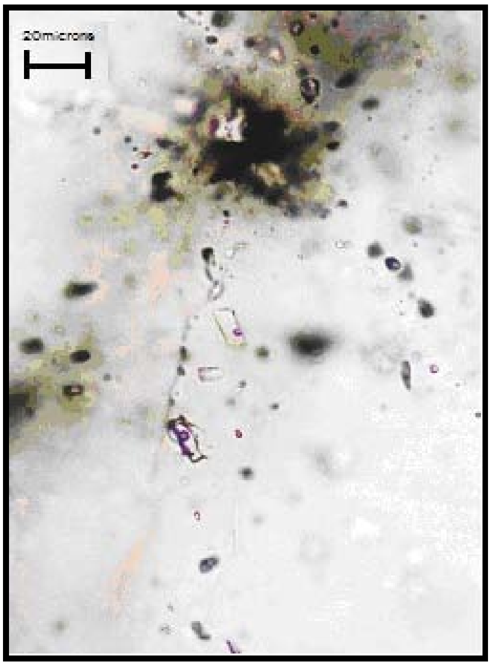
Here we report results from a fluid inclusion study of the gold-bearing quartz veins.

FLUID INCLUSION STUDIES

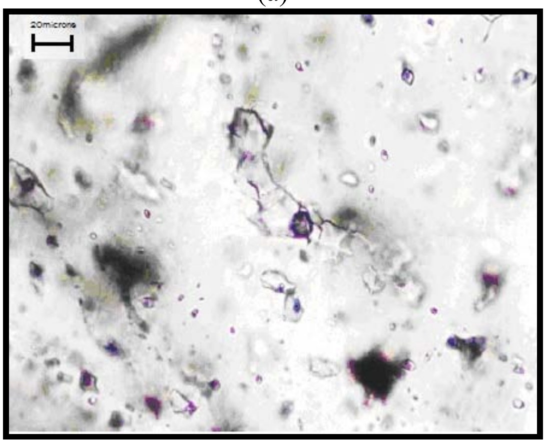
Doubly polished plates of milky and smoky quartz were prepared and fluid inclusion optical studies were carried with the help of petrological microscope. Heating-freezing experiments were done using a LINKAM-600 micro thermometric apparatus calibrated with a precision of ±0.2 degrees.

The quartz samples examined in this study contain numerous fluid inclusions which show primarily two types of distribution pattern. Type-I inclusions occur scattered and generally are azonal. They range in size from 10 to 20 microns (Fig-2 a, b and c). Depending upon their nature of distribution, they can be classified as primary or syngenetic, corresponding to entrapment coinciding with the early growth regime of the minerals (Roedder, 1984). The second category, type-II is usually found along arrays that start at the grain boundary and ends in the middle, without reaching completely across it. These inclusions may be categorized as sub syngenetic or pseudo-secondary (Roedder, 1984) and have cavities smaller in size than the type-I inclusions. They appear to have been trapped later to type-I inclusions, during some stage after the partial growth of the minerals.

(a)



(b)



(c)

Fig. 2 (a), (b) and (c) Photographs exhibiting biphase fluid inclusions in quartz. (bar scale indicates 20 micron length)

The inclusions show different cavity shapes including rectangular, ovoid and irregular. Both type-I and type-II inclusions in quartz are bi phase in nature. At room temperature they show predominantly liquid plus a gas bubble.

Heating and Freezing Studies

Heating and freezing studies were confined to Type -I inclusions only. Due to their small size leading to the difficulty in the observation of the actual homogenization temperature, the study of type-II inclusions could not be carried out .The type-I inclusions show slow disappearance of gas bubble on heating and homogenize into liquid phase. They show a temperature range from 131° C to 169° C with a peak value of 150° C to 155° C (Fig-3). Upon freezing and slow warming, the melting temperatures of the inclusions observed were between –1° C to –2° C.

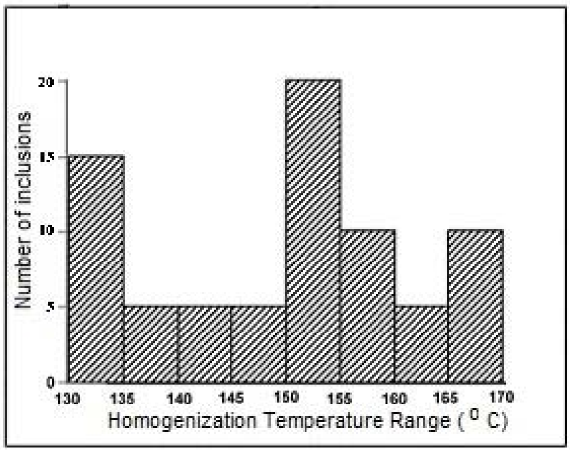


Fig. 3. Histogram showing final homogenization temperature of the inclusions in quartz.

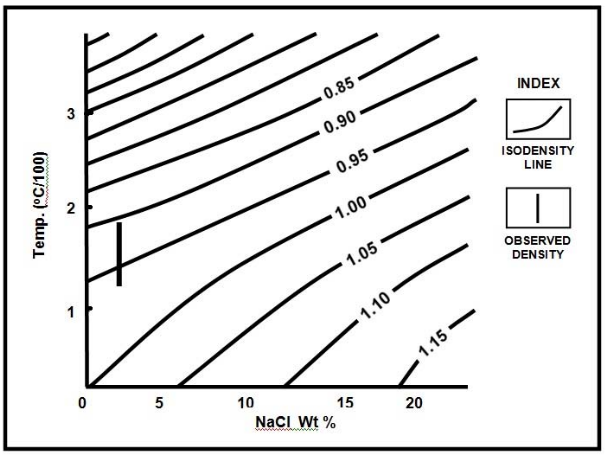


Fig 4. Salinity versus homogenization temperature diagram.

DISCUSSION AND CONCLUSION

The genesis of gold mineralization as suggested by Sibson et al (1988) highlights the possible role of fluids in the formation of gold deposits. They suggested that gold bearing quartz veins form in lithologically heterogeneous, deep transcrustal fault zones that develop in response to terrain collision and these faults act as conduits for CO_2 – H_2O rich (5-30 mol% CO_2) low salinity (< 3 wt.% NaCl) aqueous fluids with high Au, Ag, As and low Cu, Pb, Zn metal contents. Low salinity aqueous biphase inclusions and monophase carbonic inclusions associated with gold mineralization in Hutti Greenstone Belt have been reported by Pal and Mishra (2000). They suggested that low salinity H_2O-CO_2 rich fluids were responsible for the gold mineralization in Hutti. However, in the Sonakhan area only biphase inclusions were noticeable and carbonic inclusions are notably absent. The narrow range of temperature of melting (-1^{o}C to –2^{o}C) indicated that the salinity of the fluids is very low (~ 3wt. % NaCl). When the homogenization data from the primary inclusions were plotted in salinity versus homogenization temperature diagram with the isochores after Ahmed and Ross (1980), the density of fluids was found to be 0.9 to0 .95 gms./cm^3 (Fig-4). The low temperature (130° to 170° C) and low salinity of the fluids from the above study revealed the telethermal conditions of the mineralization in the present area.

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VISION FOR DEVELOPING MINERAL RESOURCES AND INDUSTRIALISATION OF ODISHA

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INTRODUCTION

Endowed with plentiful reserves of valuable ores and minerals, it was expected that Odisha would emerge as the leading industrialised state of the country. This has not happened. The reasons are many, which are discussed later in this paper.

The mineral resources of the State can be considered under four categories namely,

1) Those which are currently being mined like iron ore, manganese ore, chromite, bauxite, coal, limestone, dolomite, mineral (beach) sand.
2) Those which were mined in the recent past but currently suspended such as china clay, fireclay, graphite, gemstones, kyanite, soapstone, asbestos.
3) Those which have potential for development like nickel ore, PGM, gold, tin ore, vanadium bearing magnetite, base metals, diamond, atomic minerals, oil and gas.
4) Host of minor minerals like granite, quartz, serpentinite, feldspar.

LOOKING BACK

- The industries set up during the early years of the last century, 1950s and 1960s were a few and dispersed. These include

- Aluminium smelter at Hirakud
- Refractory plant at Belpahar,
- Ferromanganese plants at Rayagada and Joda, Low shaft pig iron plant near Barbil
- Graphite crucible plant at Titlagarh
- FeCr plant at Jajpur Road
- Cement and refractory plants at Rajgangpur
- Refractory plant at Latikata
- Fertilizer plants near Rourkela and Paradeep
- FeSi plant at Theruvali
- The first integrated iron and steel plant in the public sector at Rourkela
- Coal based thermal power plants in Talcher and Ib river coal field areas and Choudwar

Later years witnessed commissioning of

- Charge chrome plants near Bhadrak, at Brahmanipal, Choudwar, Theruvali & Meramunduli.
- Cement plant near Bargarh
- Mineral separation plant of IREL at Matikhal
- Host of mini cement plants (since closed)
- Host of sponge iron plants (most of which are not in operation)
- Alumina refinery at Damanjodi and smelter at Angul of Nalco
- Alumina refinery of Utkal Alumina at Doraguda
- Alumina refinery at Lanjigarh and smelter at Jharsuguda of Vedanta
- Iron and steel plant of NINL near Duburi
- Iron and steel plant of MESCO near Jajpur Road
- Stainless steel unit of Jindals in Kalinganagar
- Iron and steel complex of Bhushan Steel in Jharuguda

Recent development in the industrial sector in the State include

- Commissioning of 3 million tonne integrated iron and steel plant of Tata Steel in Kalinganagar in the first phase as a part of ultimate 6 million tonnes capacity.
- Oil refinery at Paradeep

- Expansion of Rourkela Steel Plant of SAIL (4.5 million tonnes of hot metal, 4.2 million tonnes of crude steel and 3.9 million tonnes of saleable steel). The capacity of Rourkela Steel plant is planned to rise to 10.8 mtpa by 2025, though appears ambitious.
- Expansion of Nalco (mines, refinery and smelter)
- Iron and steel complex of Jindals in Angul area. FeCr plant of Tata Steel near Berhampur.

(The list is not exhaustive and somr might have been missed).

INFRASTRUCTURE

In the infrastructure front, the following projects are of significance for growth of mineral based industries in the State.

1. Hydel projects at Machhkund, Balimela, Rengali, Kolab and Indravati
2. Commissioning of Paradeep and Dhamra Ports
3. Rail links
   a. Banspani-Jakhpura
   b. Bailadila-Kottavalsa
   c. Sambalpur-Talcher
   d. Barsua-Rourkela
   e. Kiriburu-Bimlagarh-Bondamunda
   f. Bolani-Barbil
   g. Banspani-Padapahar
   h. Bhadrak-Dhamra
   i. Rayagada-Bhawanipatna
   j. Rayagada-Jeypore-Jagdalpur
4. Road Links
   i. Daitari-Paradeep Expressway.
   ii. Keonjhargarh-Naranpur-Bamanipal
   iii. Panikoili-Bhadrasahi-Koira-Lahunipada-Rourkela (Development of this vital NH is continuing at snail's pace. Needs urgent attention of both the Central and State Governments)
   iv. Joda-Bamebari-Palaspanga
   v. Talcher/Angul-Kaniha-Pallahara

This in brief, is the infrastructure set up relating to growth of mineral-based industries in the State. Though relevant, healthcare and education facilities have not been discussed. Suffice to say, these areas call for considerable improvement.

Some of the failures and priority areas that require urgent attention of both State and Central Governments need to be highlighted.

Topping the list is failure of both the State and Central Governments in materializing the 12 mtpa mega steel project of POSCO. Delay in decision making and particularly delay in granting a lease for iron ore has been the main reason for stalling the project. No foreign steel company will like to have access to an iron ore property through auction.

Next in the list of failures is inability of the State Government to provide required facilities for Mittal's proposed iron and steel complex in Keonjhar district.

The third failure, a major one, is not providing a lease for bauxite to Vedanta Aluminium in spite of assurance. On the basis of assurance given by the State Government, Vedanta set up a 1 million tpa refinery at Lanjigarh at an investment of nearly Rs. 4000 crores. Political class and NGOs combined to stall the possibility of supply of bauxite from Niyamgiri although there is absolutely no technological basis for the same. The unfortunate part is that the State Government took a passive role. The least that can be done to save the project from closure is to make available required quantity of bauxite either directly by grant of a lease or through OMC.

Some of the priority infrastructure projects that call for early completion include the following:

Railway Links

- Haridaspur-Paradeep
- Talcher-Bimlagarh
- Angul-Duburi-Sukinda
- Badampahar-Keonjhar
- Jeypore-Malkanagiri
- Bolani-Roxy
- Doubling of
  - Banspani-Daitari-Jakhpura line
  - Sambalpur-Titilagarh
  - Sambalpur-Talcher

Sambalpur-Jharsuguda

Urgent need for completion of **Bhadrasahi-Koira-Lahunipada-Rourkela road link** has already been mentioned**.**

With regard to development of **major ports**, Gopalpur assumes strategic importance.

Water reservoirs can be constructed on Brahmani and Baitarani rivers at favourable locations to meet the requirement of water for the industries in a planned manner. Construction of Kanupur dam on river Baitarani should be expedited.

In the mineral sector, priority should be given to revive the mines where operations have been discontinued and to accelerate the process of exploration inducting expertise and technology from abroad.

Mineral based industries which can come up in the State and those which need revival include

(a) Ferro vanadium and ferro titanium
(b) Nickel and cobalt ,
(c) Aluminium lithium alloys,
(d) Aluminium silicon alloys
(e) Manufacture of value added products in medium and small scale sector – confined to special alloys and automobile components.
(f) Revival of sponge iron manufacturing units
(g) Control of NINL should be vested with either SAIL or RINL to facilitate its growth.

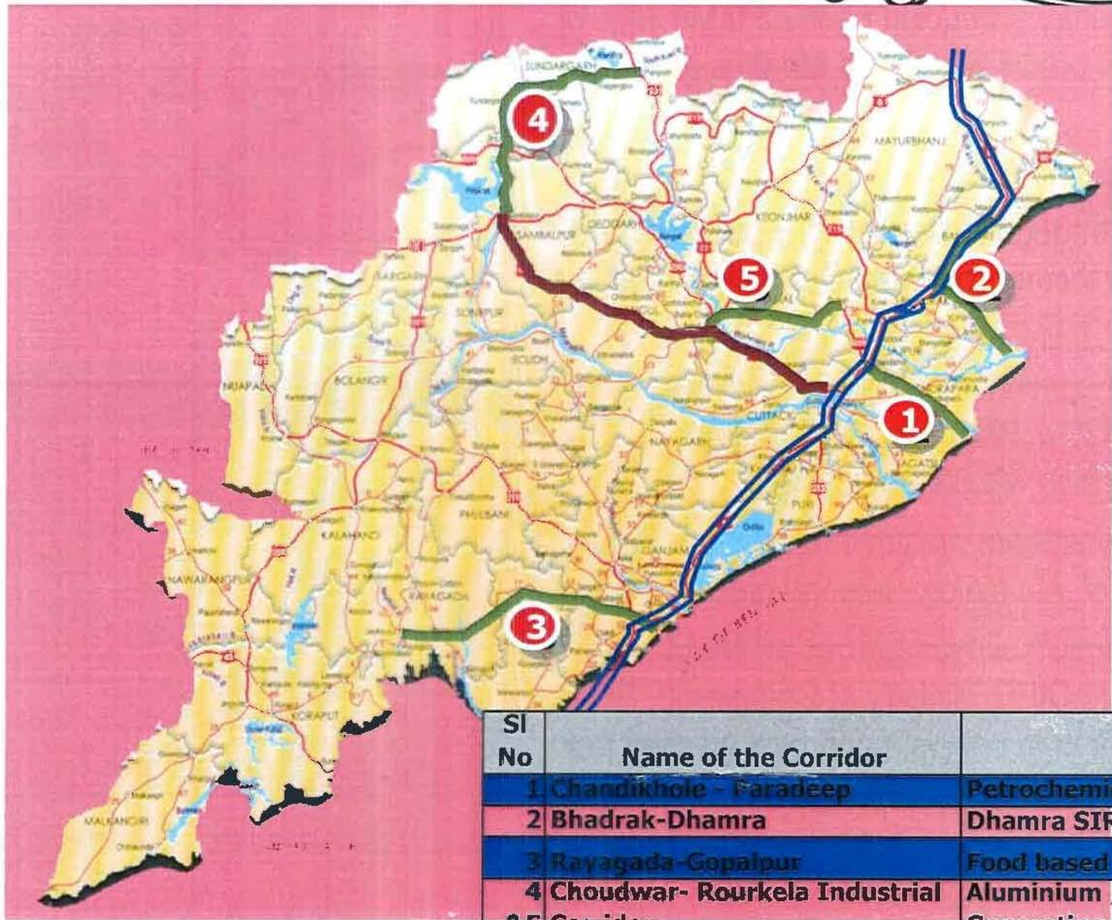
Former President, Dr. Kalam always mentioned that for a country to grow people must learn how to dream in a big way. In our journey for establishing mineral based industries, innovation is the keyword to be competitive in national and international sector. To sustain the process of industrialization, professionalism at every stage of our operation is extremely important. But I am sorry to tell that we are yet to insulate industries from political interference.

An area of concern is poor law and order situation and negative approach of the NGOs. The State Government should do well to take note of this and remedy the negativism. Finally, I feel, we will have to consciously make effort to develop technology entrepreneurship who are well equipped professionally. Our promoting organizations like IPICOL, IDCOL and OMC should be staffed with professionals of repute. They must learn to project the enormous potential of the State for industrialization and interact with organizations in India and abroad to bring in the best technologies for adoption in our State. In IPICOL, we should have venture capital fund to assist entrepreneurs who have acquired technological expertise but lack funds back up. Both the State and Central Governments must involve technical and professional scientists and engineers in decision making process. Then only the State's industrialisation process

Development of Industrial Corridors in the State

Odisha

Department of Steel & Mines

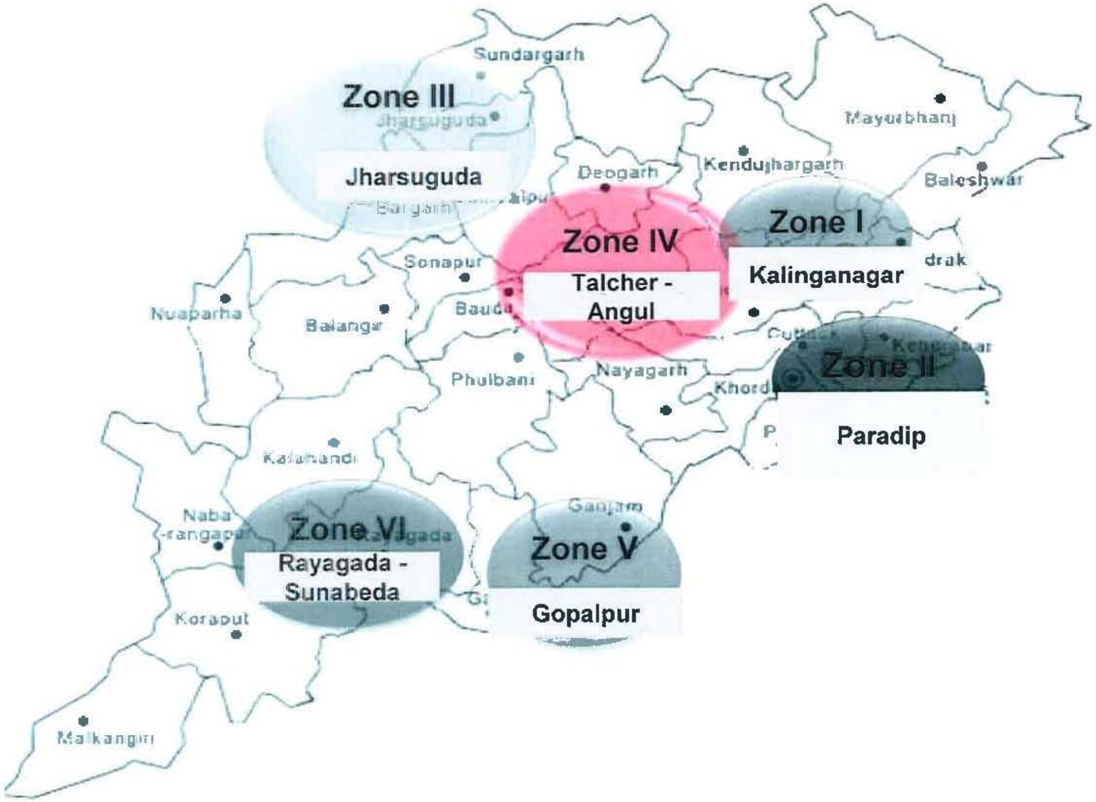


Sl No	Name of the Corridor	Proposal
1	Chandikhole - Paradeep	Petrochemical Investment Region
2	Bhadrak-Dhamra	Dhamra SIR
3	Rayagada-Gopalpur	Food based industries, Rare earths,
4 &5	Choudwar- Rourkela Industrial Corridor	Aluminium / Steel / Power Generating Industries

Excellent industrial infrastructure

Odisha | Department of Steel & Mines

86 industrial estates & 6 Industrial Zones



➢ **SGAT NEWS**

- **51st State Geological Programming Board Meeting:** The 51st State Geological Programming Board Meeting on 9th June, 2015 was attended by Dr R.C. Mohanty and Shri R N Patra in which the suggestions of SGAT regarding the State's programme for exploration were submitted.

- **Workshop on DGPS Survey and its Applications:** Workshop on "DGPS Survey and its Applications" was organized by SGAT on 22nd August, 2015 in the Conference Hall of SGAT, Bhubaneswar. The workshop was co-sponsored by Elcome Technologies, AIMIL and Tata sponge Iron Ltd. A total number of 73 delegates representing SGAT, Elcome Technologies, AIMIL, PANINDIA Group, Directorate of Geology, Odisha, Directorate of Mines, Odisha, Geological Survey of India, Odisha Space Applications Centre, Bhubaneswar, Odisha Mining Corporation Ltd., M/s AMTC Ltd., GEMCO, Geomin, Geo Consultants Pvt. Ltd., GEMS, Gemtech Consultants Pvt. Ltd., Global Marine Infratech, SAIL, JSPL etc. participated in the event.

  Dr Sandeep Tripathy, IFS, Chief Executive, ORSAC was the Chief Guest of the Inaugural Session and Sri Siddhanth Das, IFS, Addl. PCCF (Nodal), Govt, of Odisha graced the valedictory session.

  Eight papers covering basics of DGPS Survey, Instrumentation, Application for Cadastral Georeferencing, Lease Boundary Survey and Demarcation of Forest Plots for forest diversion proposals and compensatory afforestation were presented in two Technical Sessions.

- **Mineral Development Awareness Quiz Programme 2015:** Mineral Development Awareness Quiz (MDAQ) Programme, 2015 was organized by SGAT at Officer's Club, Noamundi, West Singhbhum district, Jharkhand from 28th to 30th August, 2015 in association with Tata Steel, Essel Mining Industries Ltd., Rungta Mines, Tata Sponge Iron Ltd., M/s MGM Group & M/s S N Mohanty. Students from 18 institutions, namely, Calcutta University, Ravenshaw University, Utkal University, Sambalpur University, Khallikote Autonomous College, Berhampur; DD Autonomous College, Keonjhar; IIT, Kharagpur; IIT, Bhubaneswar; Indian School of Mines, Dhanbad; NIT, Raipur; Govt. College of Engineering, Keonjhar (Geology); AKS University, Satna; University College of Engineering, Kothagudem; NIT, Rourkela; IIEST, Shivpur; Govt. Engineering College, Keonjhar (Mining); IGIT, Sarang and Govt. College of Engineering, Keonjhar (Metallurgy) participated in the quiz programme.

  The programme consisted of identification of rock and mineral/ore samples and interpretation of satellite imagery by geology students; identification of mineral/ore samples and photographs of mining equipment by mining students and identification of mineral/ore samples, metallurgical products and photographs of metallurgical processes by metallurgy students. The programme also included visit to the Siljora-Kalimati Manganese and Iron ore Mine of Rugta; Tata Sponge Iron Plant, Bileipada; Noamundi Iron ore Mine and Rain Water Harvesting Structure of Tata Steel, Noamundi. In the final oral quiz programme subject specific questions on geology, mining & metallurgy and questions on general knowledge were answered by the participants.

Ms. Urmi Ghosh & Mr. Soubhagya Ranjan Behera of School of Earth, Ocean & Climate Sciences of IIT, Bhubaneswar emerged the overall winner of MDAQ, 2015. Amongst others, Officers of Directorate of Geology, Odisha and Directorate of Mines, Odisha assisted and attended the programme.

- **Regional Environment-cum-Mineral Awareness Programme:** Regional EMAP in twelve mining and industrial zones; namely, Badampahar, Keonjhar, Bhubaneswar, Sukinda, Jilling, Koira, Gomardihi, Lanjigarh, Doraguda, Talchet, Matikhal and Bangur have been conducted between 4th October, 2015 to 4th December, 2015. The final State Level EMAP will be held at Bhubaneswar on 8th and 9th January, 2016.

- **11th CGPB Sub-Committee Meeting of ferrous minerals:** SGAT was represented by Shri G.C. Das in the meeting held on 24th August 2015. SGAT's views on exploration of ferrous minerals were presented in the meeting.

- **Workshop on Odisha Mineral Exploration Policy:** The meeting convened by Steel & Mines Department on 29th September 2015 was attended by Shri B. K. Mohanty, Shri S. K. Mohanty and Shri G.C. Das and the shortcomings of the policy and SGAT's view on the matter were presented. During presentation SGAT was critical about the Policy as Govt. did not consult all the stakeholders prior to finalization of Odisha Mineral Exploration Policy. Advising the Govt, SGAT stressed on changing the existing exploration execution approach and ensuring institutional strengthening in order to realize the objective of the Policy.

- **Observation of Indian Mining Day:** The Indian Mining Day was organized by Bhubaneswar-Sukinda chapter of Mining Engineers Association of India in association with SGAT in the Auditorium of Tata Steel at Sukinda on 1st November 2015. Amongst others the meet was addressed by Mr Sanjay Patnaik, ED, Tata Sponge, Mr R. Subramaniam, Director of Mines Safety of Bhubaneswar region and Dr. S. K. Sarangi, President, SGAT. Mr B K Mohanty, Advisor, SGAT and Mohammad Fasihuddin, former General Manager of Tata Steel were felicitated on the occasion.

- **Meeting on CRIRSCO Code:** On behalf of SGAT Mr Sunit Patel attended the core committee meeting for CRIRSCO Code at Hyderabad on 19th November, 2015 where he discussed various issues of this code.

- **Visit of Geology Students of Jammu University:** The final year post graduate students of Department of Geology of Jammu University, accompanied by Prof. G. M. Bhat and Dr Yudhbir Singh, visited SGAT on 3rd December, 2015. A detailed and lucid presentation on "Geology of Odisha" was made by J. K. Nanda while an overview of the mineral sector of Odisha was presented by T. Mohanta to the visiting students and professors.

Dr Sandeep Tripathy, IFS being presented a memento by B K Mohanty during the Workshop on DGPS Survey and its Applications

Participants of the Workshop on DGPS Survey and its Applications

Shri Siddhartha Das, IFS as Guest of Honour in the valedictory session of the Workshop on DGPS Survey and its Applications

Written test during the Regional EMAP in SGAT building at Bhubaneswar on 10.10.2015

Quiz programme during the Regional EMAP in SGAT building at Bhubaneswar

Prize distribution during the Regional EMAP in SGAT building at Bhubaneswar

Guests on the dais during the Regional EMAP at Badampahar on 04.10.2015

Students watching the quiz programme of the Regional EMAP at Badampahar

Guests on dais during Regional EMAP at Doraguda on 17.11.2015

Audience and participating students during Regional EMAP at Doraguda

Guests addressing participating students during Regional EMAP at Doraguda

Winner of Written Test sharing her thoughts during Regional EMAP at Doraguda

Identification of rock and mineral samples by students during Regeional EMAP at Keonjhar

Written Test during Regional EMAP at Lanjigarh on 16.11.2015

Sample identification during Regional EMAP at Lanjigarh

Participating students being presented with mementos during Regional EMAP at Lanjigarh

Participating students being presented with mementos during Regional EMAP at Lanjigarh

Participating students being presented with mementos during Regional EMAP at Lanjigarh

Participants of MDAQ Programme 2015 at Noamundia during 28-30.08.2015

Interpretation of satellite image by students during MDAQ Programme 2015 at Noamundi

Identification of rock and mineral samples during MDAQ Programme 2015 at Noamundi

Identification of rock, mineral and metallurgical samples during MDAQ Programme 2015 at Noamundi

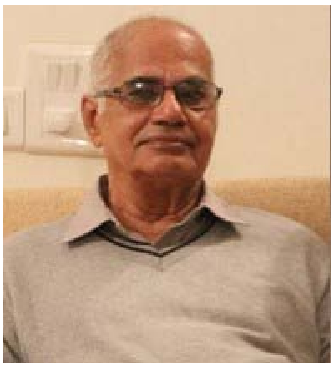
Guests on dais during valedictory session of MDAQ Programme 2015 at Noamundi

Group photograph of participants and organizers after the MDAQ Programme 2015 at Noamundi

- **NEWS ABOUT MEMBERS**

- Prof. Bhabesh C. Sarkar, Professor, Department of Applied Geology, Indian School of Mines was awarded with "Dr J Coggin Brown Gold Medal" for outstanding contributions in Geological Sciences in 2014-15 in the field of Mineral Exploration by the Mining, Geological and Metallurgical Institute of India at its 109th Annual General Meeting held on 26 September 2015 at Novotel, Kolkata.
- Dr. Desh B. Sikka was awarded the Lifetime Achievement Award of 2015 - 2016 by SAAEG.
- Mr. Duryodhan Behera has been awarded Ph. D. degree in Geology by Sambalpur University on 15th September 2015. Dr. Behera was working on the topic "Study of the Geology, Mineral Resources and Assessment of Environmental Impact due to Mining in the Joda-Barbil region of Keonjhar District, Odisha" under the supervision of Prof. Ashutosh Naik.
- Subhajyoti Das, Director (Retired), CGWB has been conferred "Life Time Achievement Award for outstanding contributions in hydrogeology and ground water management", by Centre for Ground Water Studies (CGWS) at Kolkata. The occasion was International Seminar on Ground Water Management: Vision 2050, organised by CGWS in collaboration with CGWB, GSI, World Bank, UNICEF, DST, MOES, PHED-WB etc during 13-14 November 2015.

OBITUARY



DWIJENDRA NATH RATH
(08.10.1935 to 23.10.2015)

Society of Geoscientists and Allied Technologists deeply mourns the sad demise of Er. Dwijendra Nath Rath, former Joint Director, Directorate of Mining & Geology, Govt. of Odisha and one of its esteemed members who left for heavenly abode on 23rd October 2015. Born on 8th October 1935, D. N. Rath did his M. Sc. degree in Geology from Banaras Hindu University in 1957; M. Sc. degree in Technology from Andra University in 1961; M. Sc. degree in Engineering from London University in1972 and Diploma from Imperial College, London in 1972. He started his service career as a Lecturer in Geology of Utkal University in 1958 and subsequently moved to the National Metallurgical Laboratory, where he served as a Junior Science Officer from 1961-1962. He served in the Directorate of Mines, Orissa from 1962-1969 in the capacity of Mineral Technologist, as supervisor of research laboratory from 1970-1982. Subsequently he worked as a Deputy mineral dressing engineer of Panna Diamond Project of NMDC from 1969-1970. Finally, he retired as a Joint Director from the Directorate of Mining and Geology, Govt. of Orissa in 1993. Discovery of platinum in laterites of Bhuban in Dhenkanal district of Orissa was one of his landmark achievements. He was a Fellow of Institution Engineers and Member of Indian Institute Mineral Engineers and New York Academy of Sciences. He was actively involved in setting up medical camps for the under privileged in Odisha. He was a member of Rotary Club and Buddha Society. He was instrumental in setting up Hobby Club at Bhubaneswar.

We pray God to rest his soul in peace and convey our deepest sorrows and condolences to his bereaved family and pray The Almighty to bestow enough courage to his family members to withstand this irreparable loss.

MEMBERS OF SGAT

- **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 a soft copy of the entire material prepared in Microsoft Word. The figures, if any, may be submitted in JPEG/ TIFF/ BMP format. Both the text files and figures may be written on a CD/DVD and should be submitted with the manuscript. 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
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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 is to be included in the beginning. Not more than 5 key words are to be listed at the end of the abstract. Text of research papers and review articles should not exceed 4000 words. The short communication is for quick publication and should not exceed 1200 words.
Headings: Different headings should be in the following format.
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(b) Author(s): Centrally aligned, short name, bold, first letter of all words capital followed by communication address (Not Bold, Italic)
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(h) Acknowledgements: Left aligned, bold, first letter capital
(i) References: Left aligned, bold, first letter capital
(j) Figure Caption: Centrally aligned, first letter of first word capital, below the figure
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Illustrations: All illustrations should be numbered consecutively and referred to in the text. They should confirm to A-4 size and carry short captions. Lettering inside figure should be large enough to accommodate up to 50% reduction. One set of hard copy of all figures (either tracing in ink or laser prints) should be provided in a separate envelope marked "Original Figures". Photographs should be of good quality with excellent contrast, printed on glossy paper. Colour photos are acceptable, provided the author(s) bear the cost of reproduction. Figure captions should be provided on separate sheet.

Tables: Each table must be provided with a brief caption and must be numbered in the order in which they appear in the text. Table should be organised within A-4 size and should be neatly typed for direct reproduction. Tables will not be typeset by the printer, so their clarity and appearance in print should be taken into account while the author(s) prepare(s) them. Use of 10 points Times New Roman/Arial Font for table is recommended.
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(b) Reference list at the end of the manuscript should be in alphabetical order, in the following format: Sehgal, R.K. and Nanda, A.C. (2002) Paleoenvironment and paleoecology of the lower and middle Siwalik sub-groups of a part of North-western Himalayas. Jr. Geol. Soc. Ind, vol. 59, pp. 517-529

(c) Articles from the books should follow the format given below:

Windley, B.F. and Razakamanana, T. (1996) The Madagascar – India connection in a Gondwana framework. (In Santosh, M. and Yoshida, M. Eds.)

The Archaean and Proterozoic terrains of South India within East Gondwana. Gond. Res. Group Mem. No.3, Field Sci. Publ., OSAKA, pp. 25-37

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

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