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Mineral Exploration Process and Technology

N. N. Singh

Director, Indogold Mines Pvt Ltd, IGMPL

ABSTRACT

The mineral exploration process is a dynamic system with a decision-making phase at each stage. The process of modern mineral discovery is characterised by a high element of risk, a lengthy time-span and sustained cash outflow, all of which may result in a zero return if an economic discovery is not made. Any successful exploration campaign must follow a route through genesis-oriented geological models and the application of appropriate exploration technology, which includes commercial and economic judgements at each stage of the process, so that chances of success may be optimized at an acceptable level of risk. The exploration process evolves from a generative stage and results in a) identification of appropriate geological models for mineralization b) identification of geologically conducive target areas c) testing and evaluation of target areas that culminates in discovery of mineral occurrences d) definition and delineation of the occurrence e) development of the deposit.

The application of exploration technology is an important aspect of any exploration program. The use of advanced exploration technology is necessary because we now often work in complex geological settings where discovery of subsurface mineral deposits is commonly based on subtle surface manifestations. Applying the advanced technology effectively may enable exploration of large target areas within restricted budgets. Advancements in exploration technology have progressed especially quickly in countries like Canada and Australia, where an evolved mineral exploration industry has already found the obvious deposits and more specialized techniques are required to detect the increasingly subtle indications of subsurface mineral deposits.

The advancements in Mineral exploration technology are mainly found in the following areas:

- Airborne geophysical surveys: Airborne electro-magnetic systems with advanced configurations both in frequency and time domains. The application of these advances has lead to a considerable increase in the bandwidth of both helicopter-borne FDEM and fixed wing TDEM systems, which has enabled to capture deep-seated EM anomalies.
- Ground geophysical surveys: Significant changes and improvements have occurred in ground electromagnetic (EM) techniques. Regarding the 10 to 100 Hz EM systems that are generally used for mineral prospecting and geologic mapping, improvements have yielded capabilities of detecting large conductive bodies to depths of 500m. Alternatively, smaller, less conductive tabular galena / sphalerite / pyrite bodies, such as the Licheen deposit in Ireland, are detectable to depths of 300m.
- Down-hole electromagnetic methods: DHEM has become a very important exploration tool for detecting conductive mineralization, particularly in areas where target definition by surface EM techniques is limited by either excessive depth or by interfering conductive bodies or overburden.
- Airborne spectral remote sensing: The technology for airborne spectral remote sensing based on spectral properties such as spectral reflectance, emittance, and microwave remote sensing is in use for mineral exploration.

- Geochemical surveys: Advancements in geochemical sampling and analysis, such as Selective or Partial Geochemical Extraction (SPGE) technology enzyme leach, Mobile Metal-Ion (MMI), Nanoscale metals in earth gases (NAMEG),mobile forms of metals in overburden (MOMEO) and measurement techniques of ionic conductivity of soil (ICS) and other such techniques have become important tools to locate concealed ore deposits through different types of overburden.
- The integration of geological data within a geographic information system (GIS) environment allows modern earth scientists to interpret and correlate diverse data sets as never before.

Introduction:
Mineral prospecting and exploration lead to minable deposit. To satisfy the requirement of mineral supply the subsequent exploration process converts the unknown geological resource in-to reserves and then to marketable commodity. The process of discovery is characterised by a high element of risk, large time-span and sustained cash outflow which is a total loss in case of failure to make an economic discovery. With the discovery of the surface or near-surface deposits, the mineral exploration agencies are required more and more to look for concealed deposits at ever increasing cost. For successful culmination of any exploration campaign in-to mining venture, it is necessary to follow an exploration route through genesis-oriented geological models with commercial and economic judgement at each stage of exploration so that success could be ensured at an acceptable level of risk.

EXPLORATION

Discovery Type

The discovery of a mineral occurrence or a deposit is characterized by a measurable quantity and grade, which indicate an estimated amount of minerals contained or metals. The discovery may be immediately useful and the exploitation profitable at that point of time, in which case it is classified as a reserve or more specifically ore reserves. On the other side, if the potential is known but not immediately extractable or profitable, it is classified as a 'Resource'. Explorationists must first find and then engineers convert theoretical resources into minable reserves. Often, the technology exists, but it toggles between one type and other with the changes in market price. An uneconomic discovery may become economic tomorrow and vice versa.

Reconnaissance

"Reconnaissance" is the "grassroots" exploration for identifying enhanced mineral potential or initial targets on a regional scale. The preparations at this stage include literature survey, acquisition of geophysical data, if any, synthesis of all available data and concepts, and obtaining permission (Reconnaissance-Permit RP) from the State/Provincial/Territorial Government. The activities encompass remote sensing, airborne and ground geophysical survey, regional geological overview, map checking/ mapping on 1:250,000, 1:50,000 scales, geochemical survey by chip/grab sampling of rocks and weathered profiles, broad geomorphology and drainage, pitting and trenching to expose mineralized zone at ideal locations, and limited scout/reverse circulation/diamond drilling to know the possible extent of mineralization. Petrographic and mineragraphic study will help to determine principal host and country rocks and mineral assemblages. The prime objective is to scan the entire area under leasehold within stipulated time frame and to identify probable mineralized area (targets) worth for further investigation. The targets are ranked on the basis of its geological evidence worth for further investigation toward deposit identification. The initial leasehold area is thus substantially reduced to smaller units at the end. Estimates are preliminary resource status. This enables to focus concentration of maximum exploration efforts to the target area in the next stage. The total area and duration permissible for RP vary between states and countries.

Large Area Prospecting "Large Area Prospecting", a blend of Reconnaissance and Prospecting License (PL), is initiated in some countries. It combines Reconnaissance and Prospecting activities including general and detailed exploration. It is systematic exploration of potential target anomalies after obtaining Large Area Prospecting License (LAPL) from the State/ Provincial/Territorial Government. The activities encompass detailed geological mapping, rock chip and soil samplings, close-spaced ground geophysics, Reverse Circulation (RC) and diamond core drilling on wide-spaced section lines, and resource estimation of Inferred or Possible category. Other information like rainfall, climate, availability of infrastruc- tures, and logistic facilities including health care and environmental implications are collected. The main objective is to identify a suitable deposit that will be the target for further definitive exploration. The permissible area and duration will be between Reconnaissance and Prospecting.

"Prospecting" is the systematic process of searching promising mineral targets identified during Reconnaissance. The objective is more definitive exploration for increasing geological confidence leading to further exploration. The program starts on obtaining PL from State/ Provincial/Territorial Government within the framework of area and duration. PL is granted to conduct prospecting, general exploration and detail exploration. PL shall be deemed to include "LAPL", unless the context otherwise requires. The activities include mapping on 1:50,000- 1:25,000 scale, linking maps with Universal Transversal Mercator (UTM), lithology, structure, surface signature, analysis of history of mining, if exists, ground geophysics, geochemical orientation survey, sampling of rock/soil/ debris of background and anomaly area, pitting/trenching, Reverse Circulation (RC) and diamond drilling at 100- 1000 m section at one level depending on mineral type, core sampling, petrographic and mineragraphic studies, bore- hole geophysical logging and baseline environment. Esti- mates of quantities are inferred, based on interpretation of geological, geophysical and geochemical results.

General Exploration

"General exploration" is the initial delineation of an iden- tified deposit. Methods include mapping on 1:25,000, 1:5000 or larger scale, for narrowing down the drill interval along strike (100-400 m) and depth (50-100 m), detail sampling and analysis for primary and secondary Commodities, value-added trace and deleterious penalty elements, ~10% check sampling and analysis for Quality Assurance/Quality Control (QA/QC), borehole geophysical survey, bulk sampling for laboratory and bench scale beneficiation tests and recoveries and collection of geo- environmental baseline parameters The objective is to establish the major geological features of a deposit, giving a reasonable indication of continuity and providing an estimate of size with high precision, shape, structure and grade. Estimates are in the Indicated and Inferred category. The activity ends with preparation of broad order of economic or "Pre-Feasibility" or "scoping" study.

Detail Exploration

"Detail exploration" is conducted before the start of mining phase or mine development. It involves three-dimensional (3D) delineation to outline firm contacts of the orebody, rock quality designation (RQD) for mine stability, planning and preparation of samples for pilot plant metallurgical test work. The works envisaged are mapping at 1:5000, 1:1000 scale, close space diamond drilling (100X50, 50X 50 m), borehole geophysics, trial pit in case of surface mining and sub-surface entry with mine development at one or more levels in case of underground mining. The sample data are sufficient for 3D geostatistical orebody modeling using in-house or commercial software for due diligence reports. The reserves are categorized as Developed, Measured, Indicated and Inferred with high degree of accuracy. Developed, Measured, and Indicated reserves make up 60% of total estimated resources used for investment decisions and preparing the Bankable Feasibility Study report.

The Mining Lease (ML) is obtained at this stage for the purpose of undertaking mining operations in accordance under the Act for major minerals. It shall also include quarrying concessions permitting the mining of minor minerals. ML is granted by competent authority, i.e. the State/Provincial/Territorial Government with the clearance from Federal Ministry of

Mines (MOM), Ministry of Forest and Environment (MOFE) and Bureau of Mines (BM). The permissible area under ML will be negligible and may be 1/100th of the Reconnaissance area. A total span of ~15-50 or more years, from beginning to closure of the mining, is conceived for project schedule. Conditions change in this time, and it is a combination of founding foresight, steady perseverance and agility in adaptation, which, along with a good measure of statistical providence provide for project success.

Ongoing Exploration

Diamond drilling is a continuous process throughout the entire life of the mine to supplement reserve for the depleted ore. Exploration continues during the mine development and production. This is primarily conducted by underground diamond drilling to enhance reserve down dip and in the strike direction. The aim of the mine geologist is to replace depleted ore of 1 tonne by 2 tonnes new reserve at the end of each year. This will increase the mine life and continue mining operation. It also upgrades the category of reserve from Inferred to Indicated, Measured and Developed. The drill information helps to precisely delineate ore boundary, weak rock formation and shear zones for mine planning. This also provides additional data on RQD. Geochemical sampling of soil, debris and ground water in wells, streams, and rivers within and around the mining license area is carried out at regular interval for monitoring environment hazards. The process continues beyond the closure of the mines.

Exploration Scheme

Diamond drilling acts as a prime exploration tool. It is expensive and is carried out in a planned logical sequence. The scheme can be divided into a number of phases depending upon the extension, size and complexity of the mineral deposit. The activity in each phase is defined in clear vision with respect to interval of drilling, number of drill holes, meters to drill, time and cost required to achieve the specified objectives (Table 1.2 and Fig. 1.5). At the close of each phase of activity the results are reviewed with economic benchmark. If necessary, the activities of next phase are modified or withdrawn from the project for the time being.

Exploration process

An exploration process evolves from a generative stage that result in a) identification of geological conducive area b) identification of target areas through geological in-put c) testing and evaluation of targets culminating in-to discovery of mineral occurrences d) definition and delineation of the deposit e) development of the deposit. The process involves an inherent risk at each stage that requires testing of large number of ventures or mineral occurrences to discover and delineate an economic deposit. The risk is related to the factors of uncertainty associated with the occurrence of mineral with respect to its location , size, shape, quality, depth and the exploration technology employed. The risk therefore, could be minimised within the given limitations by evolving an exploration strategy which judiciously combines sound geological concept with economic and commercial judgement at each stage of exploration and an environment friendly mining plan to maximize the expected return. Exploration process is provided at Table:1

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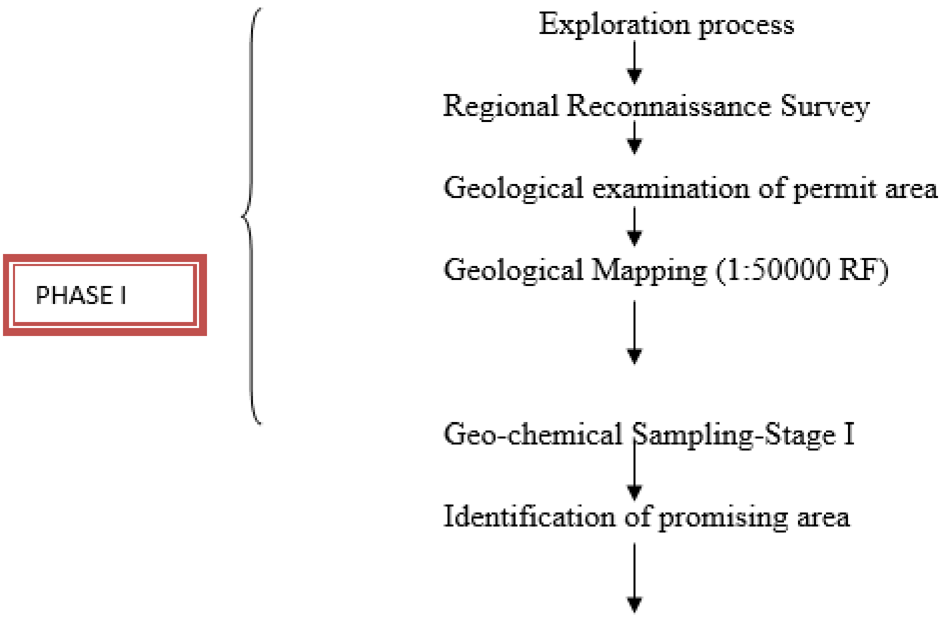
Exploration technology:

Exploration in India has two scenarios - ground that has already been explored but merits re-evaluation in the light of new techniques and/or data and ground that has been subjected to limited exploration. The ground requiring re-evaluation needs to be assessed on the basis of revised geological models supported by modern theories of basin-analysis, geo-dynamic-study and revalidation of the acquired exploration data while, the areas requiring first-hand exploration have to be selected on the basis of regional geological map and integration of available exploration data. In both the cases modern exploration techniques have to be deployed judiciously as the selection of technology is a function of geological setting and characteristics of exploration environment.

It can be seen that 77% of the deposits/prospects owe their discovery by ancient workings while only 15% are discovered by geological studies and 8% by geophysics. However, none has been discovered through geo-chemistry though, geological environment is conducive to host.

Table-1



PHASE II

Detailed Geological mapping (1:2000 RF)

↓

Detailed Geochemical Sampling-Stage II

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Geophysical survey

(Magnetic & EM)

↓

Test drilling(Non coring)

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Discovery of mineral prospect

↓

Delineation drilling(Diamond drilling)

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Possible economic discovery For Evaluation

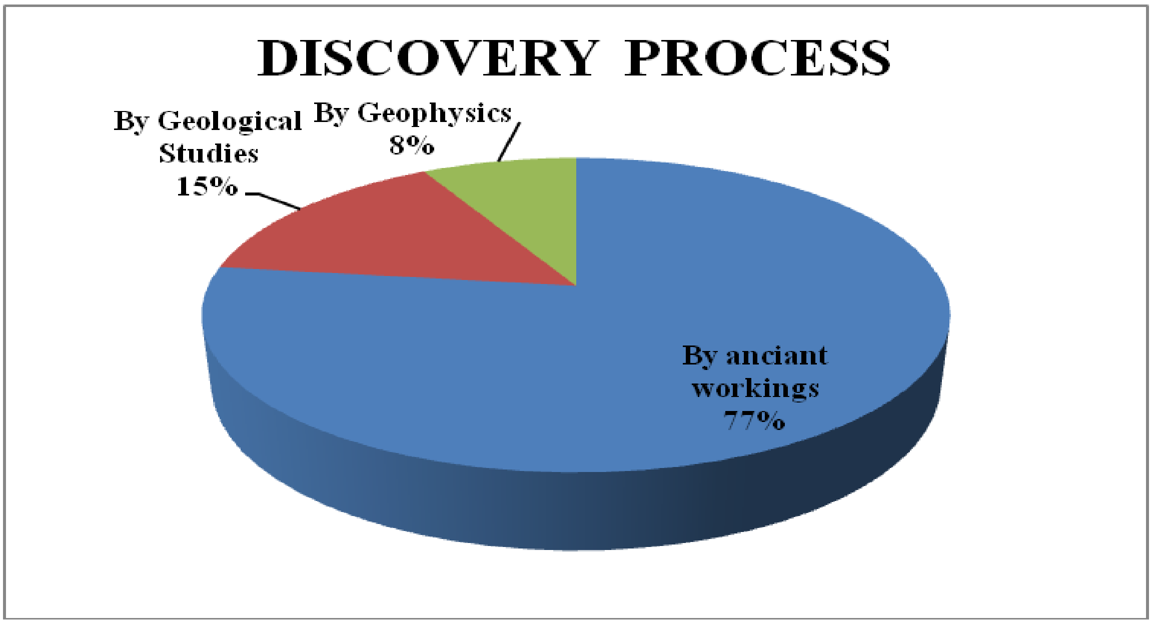

Fig 1: Discovery process

It is the application of exploration technology that can pay huge dividends through the efficient application of an exploration budget. Technical up-gradation in the exploration technology has kept pace

with time in countries like Canada and Australia where surface indications of the occurrence of a deposit are minimum if not negligible.
Major technological development in the field of exploration technology is as below:

Remote-sensing imagery:
Remote sensing techniques have proved of considerable importance as they are more effective in reducing the time and cost factors in the strategy of mineral exploration and management. The mineral exploration planning usually involves four stages namely – (1) prospecting, (2) regional exploration, (3) detailed exploration, and (4) mine exploration. Remote sensing satellite data analysis enables us in delineation of potential locations for mineral exploration even in the inaccessible regions. The demarcation of mineral deposits in dense vegetation terrains requires development of special techniques. The remote sensing represents an advance stage in the exploration technique and is the next step above aerial photography. This technique has proved its immense significance by providing synoptic overview, repetitive coverage, capability to look beyond visible region of the electro- magnetic spectrum, cost effectiveness, time savings, distinct advantage of obtaining information of inaccessible areas and responsibility of data to digital image processing which has proved to be advantageous over conventional methods in earth science investigations.
The occurrence of some deposits is confined to a particular rock which may constitute a valuable lithological guide. The deposit may be syngenetic (sedimentary deposits - banded iron formation, bauxites, coal, phosphorites; igneous deposits - chromite, mangnetite) or epigenetic (carbonates, volcanic flows, metapelites etc). The remote sensing data of adequate spatial and spectral resolution may be useful in location of the occurrence of lithological guides under favourable conditions, by virtue of synoptic overview and multi-spectral approach. Based on Landsat MSS data and supervised classification, likely extension of known strata-bound copper deposits in the Tertiary Totra sandstones of Bolivia, into adjoining territory of Peru has been located.

Geomorphological Guides
Geomorphological guides are significant in prospecting of mineral deposits resulted due to phenomena of sustained weathering and erosion. The geomorphological indicators such as hills, ridges, plateaus and valleys help in location of deposits formed by residual and supergene enrichment. All these deposits are confined to Quarternary terrain. The remote sensing data help in providing information pertaining to pattern of relief, drainage and slopes. The suitable sites of deposition and occurrence of placer deposits such as diamonds, gold, monazite etc. are better demarcated on the remote sensing data, e.g., in the case of fluvial placers, by identifying buried channels, abundant meander scars and scrolls.

Structural Guides
The structural guides in mineral exploration are of various dimensions and scales. The structure may control : (a) the distribution of metallogenic provinces within orogenic belts or platforms, (b) the distribution of ore-bearing regions and fields within the metallogenic provinces and (c) the localization of ore deposits in a particular ore field (Kreiter, 1968). The remote sensing data can provide useful information regarding the relationship of global, mega and minor structural features with ore deposits
The information regarding localization of mineral deposits by geological structural belts, shear zones, faults, fractures, contacts, folds, joints or intersections of specific structural features is of immense

importance in the planning of exploration. The identification of lineaments from satellite imagery has provided useful information for mineral exploration. However, some difficulties in integration of lineament maps with mineral exploration models have been observed which could be assigned to following reasons : (a) some of the features mapped as lineaments may not be structural-geologic nature, and (b) it may not be possible to distinguish between the post-mineralization and pre-mineralization structures. Aster image showing structural interpretation is shown in **Fig 2.**

Fig: 2 Satellite imagery showing structural interpretation

Remote sensing satellite data analysis has proved its immense significance in the mineral resource exploration and management. Most of the mineral deposits are detected with the help of various mineral guides as observed on satellite imagery. The LANDSAT - TM and RADAR images are used to map fracture pattern and distinctive spectral features that help in strategy of mineral exploration

Aerial photographs as well as imagery, obtained by remote sensing using aircraft or spacecraft as platforms, have applicability in various fields. By studying the qualitative as well as quantitative aspects of images recorded by various sensor systems, like aerial photographs (black-and-white, black-and white infrared, color and color infrared), multiband photographs, satellite data (both pictorial and digital) including thermal and radar imagery, an interpreter well experienced in his field can derive lot of information. Image interpretation is defined as the act of examining Image to identify objects and judge their significance. An interpreter studies remotely sensed data and attempts through logical process to detect, identify, measure and evaluate the significance of environmental and cultural objects, patterns and spatial relationships. It is an information extraction process.

Application of remote sensing data is useful because:

1. It represents a larger area of the earth from a perspective view and provides a format that facilitates the study of objects and their relationships.
2. Certain types of imagery and aerial photograph can provide a 3-D view.
3. It provides the observer with a permanent record/ representation of objects at any moment of time.

4. In addition, data is real-time, repetitive and, when in digital form, is computer compatible for quick analysis.

For many types of earth- resource analysis, the use of the convergence system by image interpretation of varying background is likely to produce a more accurate and thorough analysis than could be achieved by a single image interpreter working alone.

Hyperspectral Technology

Traditional remote sensing is based on the Landsat Thematic Mapper (TM). The coarse spectral resolution of the data serves only to detect mineral groups and prevents reliable discrimination of other features with similar spectral characteristics. The recent commercialization of airborne hyper spectral remote sensing-systems, with its ability to accurately map individual minerals, marks the beginning of a new era in geological mapping and mineral exploration. It has been well documented that reflectance and emission spectroscopy (the measurement of light as a function of wavelength) of minerals is sensitive to specific chemical bonds caused by electronic and vibration processes between elements

As a result, individual minerals may be fingerprinted by their spectral responses. Effective mineral exploration applications require a system that can acquire spectral information in the Short Wave Infrared (SWIR) . Fig 3.

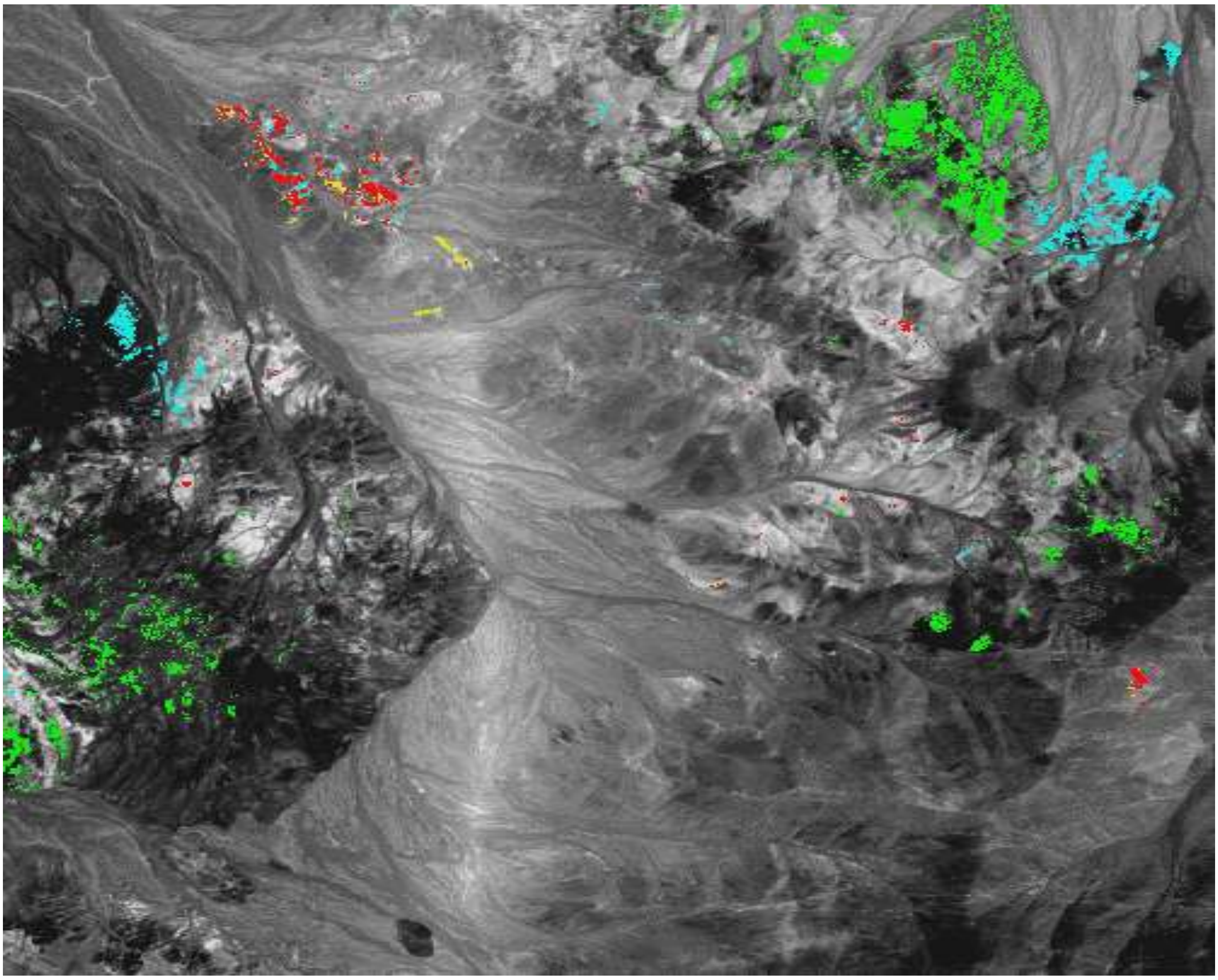

Fig 3: Hyperspectral Remote sensing Image

Airborne geophysics:

To see beyond the ground surface in to depth dimension is the objective of modern geophysical technique. Acquiring airborne geophysical data of a quality suitable for visualisation using image-processing technique is complex. The first and foremost development in data acquisition is for 'Positioning', which was originally, achieved with the help of maps and aerial photographs. The navigation aids were added by Global positioning system based on dedicated Satellite to provide precise position of data – capture location. At present, receivers used in Airborne surveys can achieve an accuracy of ± 15-50m in stand-alone mode and ± 5m in differential.

Airborne electro-magnetic has also witnessed an advanced configuration system both in frequency and time domains. The application of the system has lead to considerable increase in the bandwidth of both helicopter-borne FDEM and fixed wing TDEM system. The frequency range of FDEM systems has extended higher by an order of magnitude so that shallow targets can be accurately mapped. Similarly, the frequency range of TDEM systems has also extended higher for exploration of highly conductive or deeply buried mineral targets with lower base frequency (e.g. 25 H_z) and longer pulse width (e.g. 4-6 ms). In India there has been the introduction of GEOTEM airborne geophysical technology for exploration of large prospecting license areas of HZL-BHPM JV in Southeast Rajasthan and HZL areas in Ajmer (Kala 2000) , **Fig 4**. These provide base for integrated ground surveys and drilling to locate possible mineralised zones.

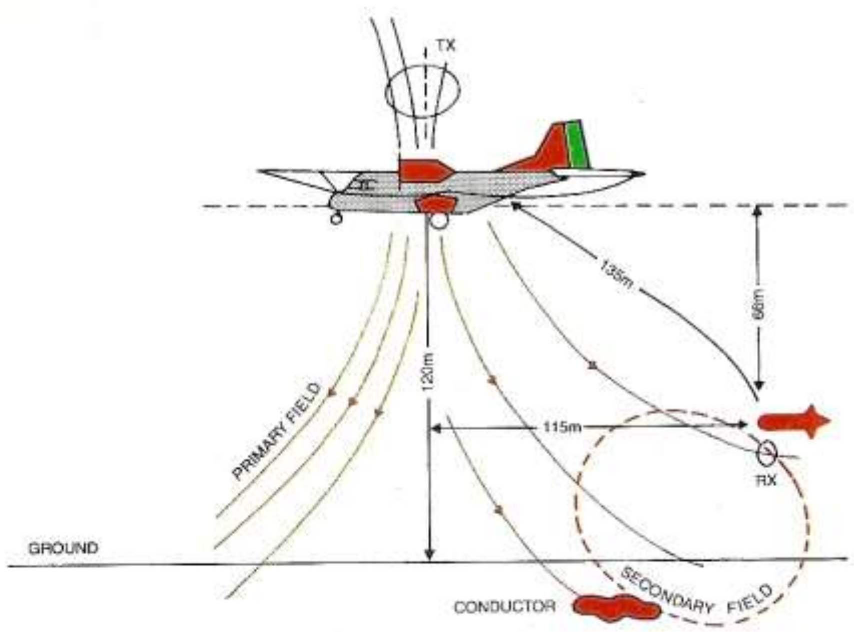

Fig 4: GEOTEM System Geometry

The EM data processing after synchronisation with navigation data and noise reduction etc generates products like vertical and horizontal synthetic sections from conductivity depth transformation algorithms for each flight line, channel amplitude maps, amplitude weight decay index maps, multi-parameter profile plots, stationary current image etc. Similarly, the magnetic data processing and interpretation, after synchronisation, diurnal levelling, generates magnetic profiles and contours and images **(Fig 5)**.

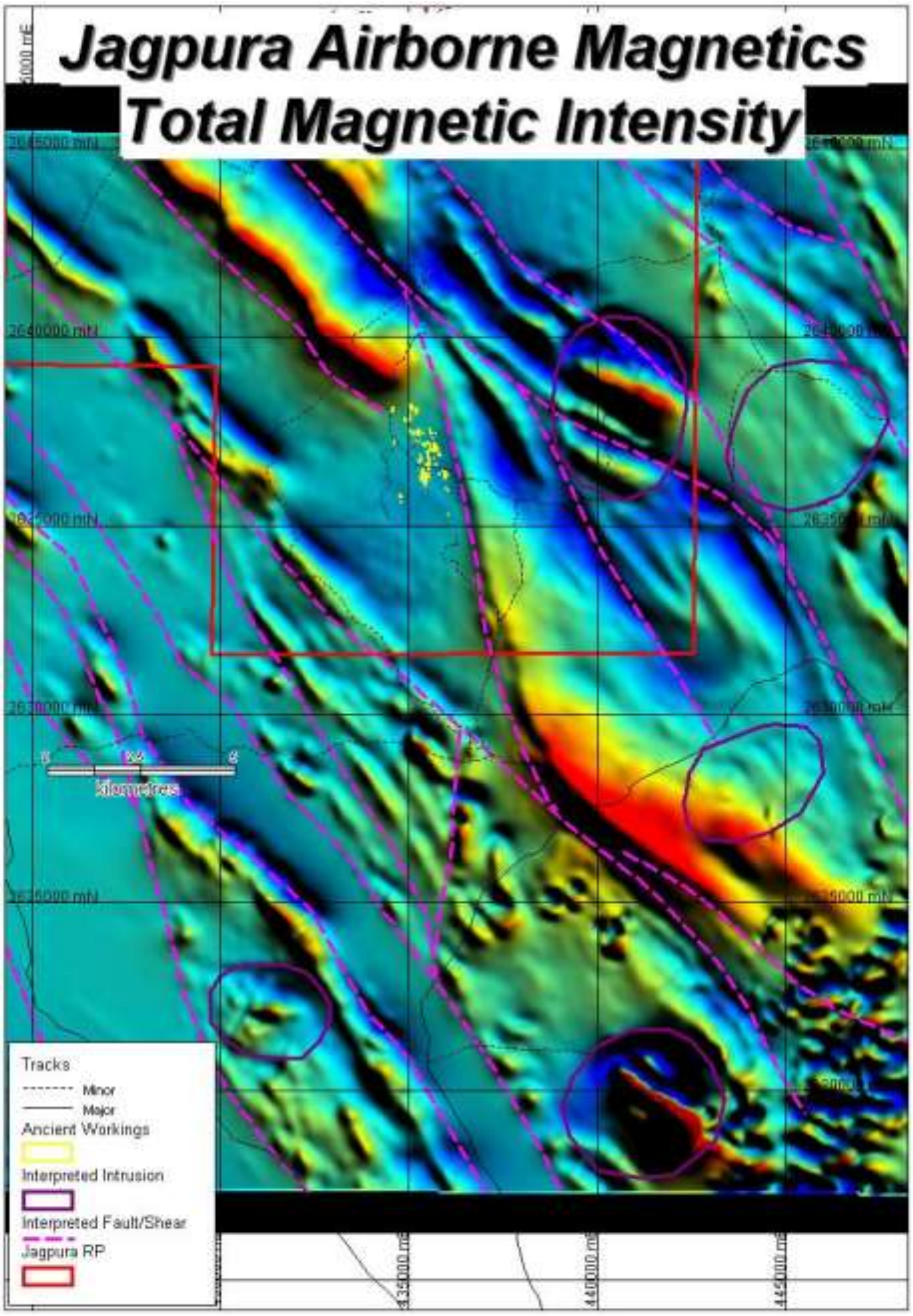

Fig 5: Airborne magnetics

The technology for airborne spectral remote sensing based on spectral properties has been developed. Spectral reflectance, emittance, and microwave remote sensing is in use for mineral exploration. This data is used in the primary or target generation stage of exploration to assess on a small-scale regional level. The reflectance spectra for most common rock-forming silicate, oxide, carbonate and sulphate minerals as well as a suite of hydrothermally altered rocks representing potassic, argillic alterations have been determined visible to SWIR (Short Wave Infrared). The information received through Spectral Remote sensing technique is integrated with all other available data such as geological, geophysical and geo-chemical and, interpreted within the context of a geologic model within a geographic information (GIS) environment.

Ground Geophysical survey:

Significant changes and improvements have occurred in Ground Electro Magnetic techniques. With regard to the effective EM systems that operate in the range of 10 to 100 Hz and which are generally used for mineral prospecting and geologic mapping, improvement has yielded EM instrumentation presently capable of detecting large conductive bodies to a depth of 500m or smaller, less conductive tabular galena / sphalerite / pyrite bodies such as Licheen deposit in Ireland to a depth of 300m.

Seismic reflection technique developed for Petroleum exploration has now been extended to the domain of hard rock application including mineral exploration. Recently Seismic reflection surveys have been attempted in hard rock mining environments in Canada such as Ni/Cu deposits at depth in Sudbury intrusive complex and volcanogenic polymetallic massive sulphide deposits in Matagami and Kidd Creek in Canada.

The application of borehole geophysical techniques to mineral exploration has become more wide spread in last decade. There have been a number of significant technological developments in hardware (probes, sensors, cables and winches), and software (modelling, interpretation and data display). The use of borehole EM techniques in base metal exploration has become routine. Several new three-component borehole EM systems have emerged and new advances have taken place in the area of orientation of the three-component probes and in borehole directional surveying. New generation three component magnetometer probes with orientation are available. Improved interpretation has led to increased requirements for physical property logs, especially magnetic susceptibility and resistivity/conductivity measurements. Logging for other physical rock properties is also receiving more attention in mining and mineral exploration. A multi-parameter approach to borehole geophysics provides the best data required for interpretation and for imposing constraints on models. Great strides have been made with respect to inverse modelling of surface data, and extensions of these inverse methods to the borehole environment are currently being developed.

GIS provides a computing environment of handling images, maps and data tables, with tools for data transformation, visualisation, analysis, modelling and spatial decision support (Bonham-Carter 97). Methods of integrating exploration data sets for mineral potential mapping are facilitated by GIS, and can be either knowledge-driven or expert-system – driven, depending on the level of prior exploration.

Down hole Electromagnetic methods:

During the past decade, downhole electromagnetic (DHEM) has become a very important exploration method for conductive mineralization, particularly in areas where the ability of surface EM to define the target is limited either by large depths or by interfering conductive bodies such as overburden, surface sulphides and peripheral mineralised horizon. The power of DHEM is that the receiver is placed in the exploration drillhole, generally locating it closer to the target than to most of the interfering bodies **(Fig 6)**. From this position it can detect conductive bodies at distances greater than 100m from drillhole (depending on the size of target), at depths well over 1000m. However, to date the main problem with the application of DHEM has been inaccurate interpretation.

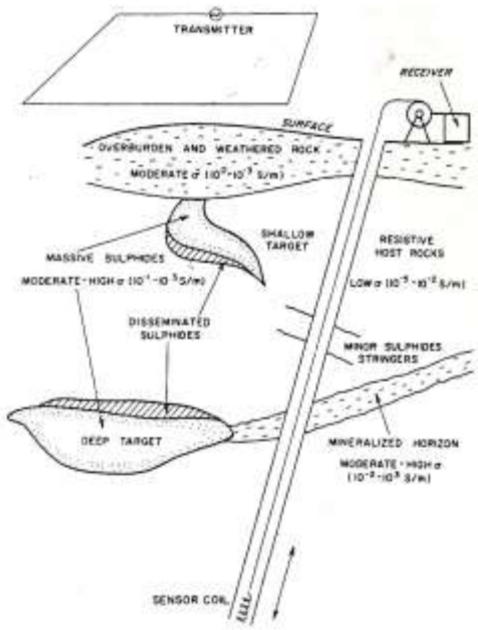

Fig: 6 The advantage of DHEM is that the sensor coil is located in the hole, closer to the target

Geo-chemistry

Geochemistry is an essential component in most modern integrated mineral exploration programs. It constitutes 10 to 25% of exploration budgets. Advances in the field include progressive improvements in mineral deposit models, conceptual models, ICP-ES and ICP-MS instrumentation and capabilities, partial extraction analysis, and computer-based data analysis and visualization techniques **(Fig 7)**.

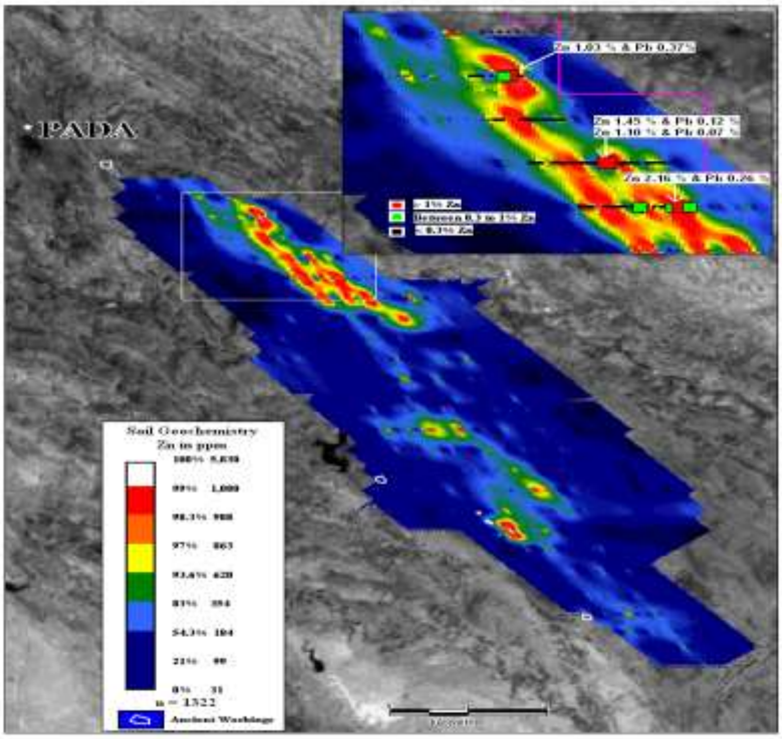

Fig: 7 Imagery of soil geo-chem plot

New and rediscovered developments include formulation of preliminary geoenvironmental mineral deposit models, and renewed interest in field-based, in situ geochemical analysis via soil gas, x-ray fluorescence and near-infrared spectrometric instruments. Geochemistry has the potential to make additional contributions to the mineral supply process through initial baseline and subsequent monitoring studies for environmental purposes and to the ore reserve estimation process. With the increasing use of geochemistry in all aspects of mineral resource development, there is concern that insufficient numbers of qualified people will be available to meet these needs.

Conclusions

It can be observed that in India there is still a vast scope to study the problems of the Precambrian, since large tracts of the Indian shield are occupied by them having a good frequency of outcrops. In India a large number of the base metal, precious and non-ferrous metal deposits / prospects are discovered on the basis of surface shows of mineralization and extensive old working because of a long history of ancient mining. A stage has been reached where mineral discoveries based on surface indications have come to an end, since large areas have already been covered based on such evidence. To make a breakthrough in mineral finds, the problem has to be visualised in light of mineral genesis and their localisation in space and time. It is necessary to make systematic detailed analyses of the favourable litho and tectonic settings and their relation to the geodynamical process, which together is responsible for the emplacement and localization of different metallic phases. The analyses and approach to the problems of the Indian Precambrian mineral deposits require an assessment not only through detailed geological-geochemical studies of the known metal environments and basin studies laying stress on the nature of magmatic and hydrothermal activities in different types of basins along with their time connotations but, also through in-put of state-of-the art exploration techniques in the Precambrian like:

- *Airborne electro-magnetic with advanced configuration system both in frequency and time domains.* The application of the system has lead to considerable increase in the bandwidth of both helicopter-borne FDEM and fixed wing TDEM system.
- *The technology for airborne spectral remote sensing based on spectral properties.* Spectral reflectance, emittance, and microwave remote sensing is in use for mineral exploration. The information received through Spectral Remote sensing technique is integrated with all other available data such as geological, geophysical and geo-chemical and, interpreted within the context of a geologic model within a geographic information (GIS) environment.
- *Selective or Partial Geochemical Extraction (SPGE) technology enzyme leach, Mobile Metal-Ion (MMI), Nanoscale metals in earth gases (NAMEG) and mobile forms of metals in overburden (MOMEO) (Xueqiu Wang et.al 1999) and measurement techniques of ionic conductivity of soil (ICS) (Luo Xianrong et.al 1999) etc also will be of immense use to locate concealed ore deposits with different types of overburden.*

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