CHAPTER IV. PRESENT PROCEDURES OF MINERAL PROSPECTING AND EXPLORATION IN INDIA

Despite the many entertaining anecdotes of accidental discoveries, it is safe to say that the majority of mines that are known to-day have been found by purposeful prospecting.

- H.E. McKinstry

1. Background

The beginnings of mineral prospecting and mining in India are lost in the mists of the past. The numerous old workings and slag heaps, which are found scattered in different parts of the country, however, bear convincing testimony to the existence of a flourishing mining industry in ancient times. Archaeologists have proved that minerals were used in India, both in pre-vedic and post-vedic times. According to the Rig Veda, the Indo-Aryan people knew the uses of copper, bronze, gold and silver. The earliest and the most authentic record of information relating to minerals is found in Arthashastra, composed between 321 and 296 B.C. This treatise describes the political, social, industrial, civil and military organisations of the 4th century B.C., and it also gives

a comprehensive account of the properties of ores, minerals and metals and methods of their production and treatment. The ores described are those of gold, silver, copper, lead, tin, iron and mercury. The qualifications of the officers responsible for the mines and processing plants have been described by Kautilya¹ in the following manner:—

"The superintendent of mine should possess knowledge of the science dealing with copper and other minerals; he should have experience in the art of distillation and condensation of mercury and of testing gems. Aided by experts in mineralogy and provided with mining labourers and necessary instruments he shall examine mines which, on account of their containing mineral excrements, crucibles, charcoal and ashes may appear to have been well exploited, or which may be newly discovered, on plains or mountain slopes possessing mineral ores, the richness of which can be ascertained by weight, depth of colour, piercing smell and taste."

It may be reasonably concluded that India had a flourishing mining and metallurgical industries in the past for many centuries when other countries of the world did not have any.

About² the middle of the 19th century, however, largely due to political vicissitudes and consequent inability to adjust to major international developments, all mining activity practically ceased, in India, reflecting the general decay that had set in in all branches of productive activities of the country. This

¹ Kautilya's Arthashastra, translated by R. Shamaasastry, Mysore, 1929.
state of affairs coincided with the dawn of the Industrial Era. The next 100 years period witnessed an enormous growth of mineral industry in the world as a whole in response to the ever increasing demands for mineral raw materials resulting from industrialisation. India slowly recovered from her long stupor and towards the close of the 19th century, a beginning was made in commencing mining in the sense in which it is understood today. Writing in 1881 Valentine Ball stated that mining for metallic ores by public companies had not been successful up to that time. Coal and salt mining and quarrying of building materials had been carried out, both by the Government and by private concerns, in many cases with very great profit. This author of the Indian Economic Geology published in 1881 adds "It would seem than regards the metals there is a new era about to commence and that the capabilities of India, not only as a gold producing country, but also in reference to other metals will in the course of the next few years be for the first time fairly tested." The prediction of Ball came true and a number of mineral deposits were discovered and exploited in the subsequent years. The greatest advantage that India had, was the early establishment of a Geological Survey in the country, as far back as 1851, and the history of the Survey is in fact the history of mineral prospecting in India. Although, primarily the Geological Survey was set up to survey the coal fields of India, gradually its scope and functions grew up in dimension and coverage so much so that at present the Survey is considered to be the third largest Geological Surveys of the World. It was under the leadership of Thomas Oldham, who joined the Survey in 1851 that the Survey was established as a regular Government department and its work was systematised. A large portion of the work during the first 25 years was directed to coal fields. In addition, iron ores, limestone, building stones, salt deposits of the Punjab and Burma and numerous minor occurrences of many other minerals were recorded and described in the publications of the Geological Survey of India.
The copper deposits of Singhbum, the gold bearing rocks of the Dharwar district and Wynaad may also be mentioned in this connection.¹

Next to coal, the most important problem of the time was the possibility of producing iron needed for the construction of Railways. Iron works were established in Kumaon from 1857-60, using local iron ore and wood as fuel.

The study of the earthquakes in India was initiated during this period and a catalogue of Indian earthquakes was compiled. The first list of thermal springs numbering 301 was also prepared.

A broad general survey of a large portion of the country had been carried out during this period, and the compilation of the first geological map of India was undertaken and the map was published in 1877.

During 1876-87, when H.B.Medlicott held office as Superintendent of the Geological Survey of India, a great deal of attention was given to the manifold problems of Indian Geology. The new officers appointed during his time of office included P.N.Bose, the first Indian to join the Geological Survey of India on a graded post.

Dr. William King succeeded H.B.Medlicott as Director, Geological Survey of India, and he continued in the post till 1894.

From 1894-1903, C.L.Griesbach was the Director, Geological Survey of India. During the period of his Directorship, several

mining officers were appointed. Early in 1902 the mining side was separated from the Geological Survey and the mining specialists were transferred to the newly created department of the 'Bureau of Mines Inspection'. The name of this new department was later changed to the 'Department of Mines' in 1904.

During the tenure of Thomas Holland (1903-10), the Geological Survey was made responsible to Government for advice on policies relating to mineral concessions, including oil, in India and Burma. A comprehensive survey of the coalfields of India, the oilfields of India and Burma, the manganese-ore deposits of the then Central Provinces, the bauxite deposits in various parts of the country and the detailed investigation, by diamond drilling, of the Singhbhum copper deposits were initiated. The study of the Singhbhum copper belt as a modern industrial proposition dates back to this period. It was during this period also that P.N. Bose discovered the large iron ore deposits of Mayurbhanj, which led to the establishment of the Tata Iron and Steel Company.

H.H. Hayden became the Director, Geological Survey of India in 1910 and continued in the post till 1921. Hayden followed Holland's policy of systematic mapping for mineral development.

E.H. Pascoe was the Director, Geological Survey of India during the period 1921-32. The investigations carried out on the monazite deposits of Travancore and of samarskite deposits of Nellore resulted in valuable knowledge being gained of the radioactive minerals in India. Considerable work was also done in understanding the oil geology of Assam.

During the period 1932-35, L.L. Fermor was the Director, Geological Survey of India. In pursuance of the retrenchment
policy of the Government, the Survey was considerably reduced in strength. Though depleted in numbers, it carried on, to the best of its ability, the work which was started prior to retrenchment. The number of field parties had to be reduced from six to three.

Fermor was succeeded by A.M. Heron in 1935 as the Director, Geological Survey of India and continued till 1939. This was a period of comparative quiet and all the surveys initiated by his predecessor were continued.

C.S. Fox was appointed Director, Geological Survey of India in 1939 and continued to hold the post till 1943.

With the outbreak of war in 1939, immediate attempts were made for marshalling all the resources of the department to assist in the war effort. A series of memoranda was prepared by Fox between September, 1939 and June, 1940 dealing with the utilisation of the Geological Survey of India in time of war and with the more important problems relating to minerals, particularly with regard to their development, processing and utilisation in India. In this way he prepared the ground on which the department was to grow rapidly.

The period from 1943-47 witnessed a rapid change of Directors. E.L.G. Clegg was appointed Director in 1943, but died an untimely death at the age of 50 in September, 1944. During his period the work of the department continued to be chiefly connected with water supply and economic geology. The activities in the mica fields were continued vigorously. The most important development during this period was the setting up of a Technical Mission by the Government to advise them on the establishment of a large Fertiliser Industry in India, one of the chief raw materials of which is gypsum. The investigation undertaken in the
Salt range showed the existence of gypsum in sufficient quantities to ensure supply for many years, and on the basis of this investigation the Sindri Fertiliser Project came into existence.

From 1944-45, H. Crookshank was the officiating Director. During his tenure of office, engineering geology and ground water problems received more attention. The field circles continued as before and special investigations on bauxite in the Ranchi, Balaghat and Sambalpur districts were undertaken, and the gypsum investigation in the Salt range continued. Important dam site investigations were also undertaken.

Crookshank submitted a scheme for the expansion and re-organisation of the Department, namely, increase in the strength of officers of the department from 75 to 111 and increase in the budget-grant from Rs.8 lakhs to Rs.16 lakhs. He wanted this expansion to take place by 1944. In 1945, J.A. Dunn became the officiating Director of the Geological Survey of India and relinquished office by the end of the year. The Utilisation Branch operations for lead and zinc at Kohi-Sultan and Zawar were closed in 1945, and the mica production Sections also started closing down gradually.

During the period December 1945 to January 1951, W.D.West was the Director of the Geological Survey of India. His five years expansion and re-organisation scheme was submitted to the Government in July, 1946. Between 1945 and 1947, the foundations were laid for the greatly expanded activities of the Geological Survey of India in the post-independence period.
By the end of 1947, almost the whole of the then Indian Empire had been traversed by geologists and a general geological map of the whole country was available on the scale of 1" = 8 miles or smaller, except for certain blanks in inaccessible regions in the Himalayas, in Orissa and along the India-Burma border. All the coal-fields had been mapped generally on scales of 1" = 4 miles and in exceptional cases (as in Jharia and Raniganj) on 4" = 1 mile scale. The iron ore deposits and the manganese ore deposits had been investigated in a general manner and the order of magnitude of the deposits was known. Detailed work had been done on certain areas in the Singhbhum copper belt which proved that the deposits were workable and led later to the establishment of the copper mining and smelting industry in Singhbhum. Most of the coal deposits had been investigated and their potentialities assessed. Many other mineral occurrences such as gold, bauxite, chromite, ilmenite, mica, barytes, magnesite, etc. were investigated in a general way. It was the work of an officer of this Department which established the presence of large resources of iron ore in Mayurbhanj that ultimately helped the establishment of the Tata Iron and Steel Company, and the Indian Iron and Steel Company.

In addition to the above, important advances in the more theoretical aspects of geology had been made in the country, particularly in understanding the geology of the Gondwana formations, in the study of glaciers, earthquakes and so on. It was the solid foundation of knowledge gathered over nearly a century by a small handful of officers of the Geological Survey of India which is now enabling us to plan for the future on an adequate scale without the handicaps suffered by several countries of Asia.
2. Present set-up of the Geological Survey of India

From the initial strength of 27 gazetted officers at the end of 1939, the Geological Survey of India has expanded considerably over the various Five Year Plans, and, at present, the total strength of officers in the Survey stands at about 1,000. For administrative functions, the Survey has been de-centralised into five regions, located at Calcutta, Lucknow, Jaipur, Nagpur and Hyderabad. The Headquarters of the Department remains at Calcutta.

With the expansion of the department, there has been significant changes in the purpose, scope, tempo and nature of mineral investigation and exploration. The Geologists of the Survey are engaged in mapping out the country from the southern tip to Kashmir valley. A geological reconnaissance of almost the entire country, excepting inaccessible areas of the vast Himalayas and elsewhere, has been completed. A number of well known mineralised belts have been investigated in detail and work on many others is in progress. For example, the copper belts of Bihar, Rajasthan and Andhra Pradesh, lead and zinc deposits of Rajasthan and Andhra Pradesh, iron ore deposits of Orissa, Bihar, Madhya Pradesh and Mysore, manganese-ore deposits of Madhya Pradesh, Maharashtra, Orissa, Andhra Pradesh, phosphates of Rajasthan and Uttar Pradesh and the coal bearing areas of Orissa, Bihar, Madhya Pradesh, etc. have been examined in greater detail and further work on many of the above deposits is in progress with great tempo. Studies on geochemistry and ground geophysics have also been taken up in some of the areas to a certain extent. Work connected with ground water surveys and engineering geology has increased considerably. In addition, fundamental studies on stratigraphy, petrology, ore-genesis and palaeontology are also in progress.
In the year 1965, the Government took a decision that the exploration wing of the Indian Bureau of Mines, consisting of prospecting, drilling and exploratory mining units, should be merged with the Geological Survey of India. This wing was for long functioning in the Indian Bureau of Mines, and it was responsible for exploring deposits declared 'promising' by the Geological Survey of India. It was realised by the Government that there was considerable over-lapping of functions between the exploration wing of Indian Bureau of Mines and the Geological Survey of India. Moreover, the expertise available with the Geological Survey of India in the initial prospecting of the deposit was not readily available to the Indian Bureau of Mines when it took up exploration of the deposit. Moreover, there was also a hiatus between one operation and the other, i.e. initial prospecting and detailed exploration. In view of this situation, the exploration wing was merged with the Geological Survey of India.

The above decision of the Government has been criticised by an Expert Committee appointed by the Government of India\(^1\) for suggesting a scheme of re-organisation of the Indian Bureau of Mines so that it may serve effectively as an instrument of public service. The Committee has held the view that the responsibility for detailed exploration should rest with the Indian Bureau of Mines so that the Geological Survey of India is left to undertake basic studies in the Science of ore finding. If this important function is neglected, and it is likely to be so if the Geological Survey is overwhelmed with the task of detailed exploration, it will be ruinous to the country's interest. The science of ore finding, as is known, is becoming increasingly difficult and

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\(^1\) The author of the thesis was appointed Secretary of the Committee by the Ministry of Steel, Mines & Metals vide Government of India Resolution July 22, 1966.
complex. The surface 'elephant deposits' are gradually vanishing and it will be essential to locate ores at depth, concealed from visual examination. The search for such 'blind deposits' is not an easy task. Continuous efforts will have to be made in studying the behaviour and habitat of metals. Similarly, search for new elements coming into use in industry, such as selenium and tellurium, etc. will also have to be undertaken. The incidence of known metals will also have to be deciphered, in whatever quantity it is available, on the rocks exposed at the surface. And all this will require a geological survey full of eminent and devoted scientists, doing basic research in various fields. The question of detailed exploration, measuring the dimension of the deposit by drilling, exploratory mining and sampling, etc. should be left to another organisation like the Indian Bureau of Mines.

The Expert Committee had recommended the restoration of the exploration wing back to the Indian Bureau of Mines on the above premises; but unfortunately the Government have not accepted this vital recommendation of the Committee and the exploration wing continues to function under the Geological Survey of India, supervised by various regional offices of the Survey. Incidentally it may also be mentioned that the Geological Surveys of most of the advanced countries of the world, such as the United States of America, Canada, United Kingdom, etc. are charged only with the responsibilities of undertaking basic studies, and preparation of basic geological maps. Such maps then are used by private mining companies or Government departments for drawing up their exploration programmes. In India such well organised private mining companies do not exist, and the Government itself has taken on the task of mineral exploration. For this reason it was all the more necessary that the Indian Bureau of Mines should have continued to discharge the functions of detailed mineral exploration, leaving the Geological Survey of India for basic studies on mineral deposits.
3. **Present procedures of mineral exploration**

At present crash programmes of mineral exploration are in progress in various areas of the country, particularly for iron ores, non-ferrous metals, and phosphates. Generally the procedure followed is as follows:-

The information available on known occurrences is evaluated in the first instance and promising deposits are examined by a group of geologists for preliminary appraisal. If the indications are favourable, exploration by way of large scale mapping, drilling and exploratory mining is carried out. The procedures followed in respect of iron ores and non-ferrous metals are detailed below.

**Iron Ores**

The iron ore deposits, as can be seen from the descriptions given in other chapters of this thesis, are widespread and mostly confined to hill ranges in Bihar and Orissa, Madhya Pradesh and Mysore. Preliminary appraisal of such deposits which crop out at the surface and are visible to the naked eye, does not entail any complicated geological work. A general scheme of exploration is drawn up for obtaining requisite data for the assessment of the ore reserves, its quality, grade and recovery for further planning for exploitation of a known deposit. The details of the scheme run somewhat on the following lines.\(^1\)

1. Survey work which includes the following -
   1) Preparation of a large scale contour plan in the scale of 1:2500 (1 cm. = 25 m.) at 3 m. contour intervals.

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\(^1\) The given scheme was followed for the exploration of deposit Nos. 5 and 11, Bailadila, Madhya Pradesh by the Indian Bureau of Mines.
ii) Fixing of a Central Axial Line (C.A.L.) on the crest of the deposit along the strike direction roughly dividing the deposit into two equal portions.

iii) Laying of cross-section at regular intervals of 100 metres and further extensions of the cross-sectional lines right up to the float zone beyond the main-ore-body boundary.

2. Geological work, which comprises the preparation of a large scale geological plan on the same scale of 1:2500 (1 cm. = 25 m.) by means of plane table and telescopic alidade, recording thereon the nature of different types of ores, country rocks, float ore zones as revealed by bore holes and pits sunk, and the detailed structural features exhibited by the deposit.

3. Drilling of bore-holes on alternate cross-sections on the crest of the deposit as well as at lower levels, especially where the ore is heavily concentrated, for assessing the depth persistence of the ore and ascertaining the type of ore, its nature grade, etc. Bore-holes are spaced roughly in a grid pattern and on important cross-sections forming the controlling sections for accurate ore reserve estimation.

4. Mining work, consisting of -

   a) driving of adits in case of huge cliffs so as to ascertain the thickness of the ore-body, quality of the ore, percentage of fines produced during blasting.

   b) sinking of deep-pits (10 metres) and medium pits (4 m.) along the cross-sections mostly on the flanks to delineate the ore-boundaries and also in the float ore, for knowing the nature and persistence of float in depth.

5. Conducting screening tests using the 1/2 inch wire mesh screens and determination of the recovery percentage of +1/2" fractions of the different types of ores.
6. Determination of tonnage factors for different types of ores for estimation of ore-reserve of the entire deposit.

7. Collection, preparation and analysis of different ore samples from surface outcrops, bore hole cores, blast and channel samples of selected pits for determining average grade of different types of ores and an overall average grade for the entire deposit.

8. Estimation of reserves of different types of ores available in the deposit, their grade and recovery based on the data collected during exploration. Ore reserve is estimated by two methods, namely (i) Cross Section Method and (ii) Bench Plan method.

(i) Cross Section Method:

Cross Sections are drawn on a millimeter tracing graph paper in the scale of 1 : 2500 (1 cm. = 25 m.) taking the exact profile from the contour plan along different cross sections. The surface boundaries of different types of ores and country rocks are plotted in the cross-sections with a uniform dip as shown by the ore-body. The lower limits of the ore-body are fixed on the data obtained from the adit and the bore-holes especially as indicated by the control sections. The area of these cross-sections is read by planimeter setting it to 1 : 1 scale, i.e. reading actually in sq.cm. The mean area of the ore-horizon is calculated for two adjacent X-Sections and this is taken as the area representing width X depth factor in between two cross sections. Effective volume of the ore body in between two cross sections is determined by multiplying area by the length factor. Reserves are calculated with the help of the tonnage factor assigned to the ore-type. The total gross reserves of the deposit are obtained by adding up the cross-sectional reserves.
Where the ore-body at the ends is not covered by cross-sections, separate cross-sections are prepared and the volume is calculated by taking into consideration the distance of influence from the first or last cross-section, whichever may be the case, instead of multiplying by the length factor.

(ii) Bench Plan Method:

The bench plan is prepared with the help of the cross-sections in the scale of 1 cm = 25 m. as reduced from the enlarged cross-sections of 1 cm = 12.5 m., and the area of each bench is read off by planimeter reading the actual sq.cm., setting the instrument to 1 : 1 scale. Thus the area occupied by each bench from the first to the last is determined block-wise. Not all the blocks would have all benches, as the number of benches in a particular block will depend mostly on the topography of the ore-body at the top as well as its depth persistence and fall in the lower ore boundary, etc.

The individual areas of all the benches in all the blocks are computed separately excluding the unproductive barren areas occupied by banded hematite quartzite, ferruginous shale and other country rocks. The total area is read to the second decimal place in sq.cm. and is tabulated bench-wise in each block. The average area for each bench is arrived at by adding up the top and bottom of each bench and averaging. The total average area for each bench is multiplied by the height of the bench to arrive at the average volume of the ore in each bench.

Reserve is calculated with the help of tonnage factor assigned to respective blocks. The total of the bench-wise reserves up to the last bench in each block are cumulated to give the reserves up to the lowest bench. The gross reserves of each
block are obtained by cumulating the total of all the benches present in that block. Ultimately the gross reserves of the blocks are added up to give the insitu gross reserve for the entire deposit. The method is advantageous in the sense that it covers almost the entire deposit, whereas in the cross-section method flanks, bulges etc. may have to be left out.

**Calculation of effective reserves, average grade and average recovery:**

1) The average grade and recoveries bench-wise are determined as an arithmetical mean of all the intersections in the bench. The average recoveries for different types of ores are obtained from actual fields tests and assigned to different benches. Similarly, average grade for each bench is computed by taking an arithmetic mean of the weighted averages of the intersections of the bore-holes, pits, adits, etc., in that bench. The total effective reserves per bench are calculated by multiplying the recovery factor with the reserves obtained from the bench.

The total effective reserves for all the benches or the entire deposit is obtained by adding up all the bench-wise reserves.

The recovery factor for the entire deposit is determined as a percentage by dividing the total reserves by the total effective reserves.

The average grade of the total reserves is computed by determining the means of the average grade for the different benches, weighted for the reserves.
Non-Ferrous Metals:

Unlike iron ores, exploration for non-ferrous metals poses a serious problem, as the ore bodies are concealed in the ground and the behaviour of lodes is generally unpredictable on surface evidences. At present, in India, all efforts are concentrated in those areas where old workings of these metals exist. The normal procedure followed for exploration is given below.\(^1\)

1) Detailed near surface investigations, including preparation of large scale contour geological plans and examination of old workings.

2) The major programme of diamond core drilling.

3) Test exploratory mining programme.

4) Sampling and survey connected with the exploratory programme.

5) Estimation of reserves.

Examination of old workings:

The data obtained through the examination of old workings provide extremely valuable evidence regarding the size, shape, width persistence, frequency of occurrence and attitude of various ore bodies. The inferences made on the basis of total extent of workings, mines spoil, slag heaps, coupled with the information relating to the history of mining in a region help in arriving at broad generalisations and judging the relative importance of different sections of a mineral belt, and a proper appreciation regarding their potentialities.

\(^1\) The given scheme was followed for the exploration of Mudhan/Kudhan, copper deposit, Khetri, Rajasthan, where development of a copper mine is in progress to feed a copper smelter of the capacity of 21,000 tons per annum.
Surface Geology:

Surface geology forms the basis for the initial recognition of the potentialities of a deposit and in drawing up the detailed programme of exploration. This plays a major role in guiding the more expensive and time consuming programmes such as drilling and exploratory mining. Surface geological evidences provide a comprehensive and reliable basis for the delineation, correlation and interpretation of major geological units. It provides a wealth of data with respect to extent of mineralised zones, their trends, persistence along the strike and in depth to a certain extent, variations in the intensity of the mineralised zones, the attitude of lodes, veins and stringers, etc.

The geological plans are generally prepared on a scale of 1" = 100 feet and contour interval of 20 feet.

Drilling:

The estimation of reserves and grade can be carried out mainly on the basis of bore-hole data interpreted and checked with the help of surface investigations and exploratory mining. Bore-hole results are points of intersection and indicate directly the width and grade of the ore body intersected for purposes of ore reserve estimation. The data obtained from bore holes at a number of points in respect of width and grade have to be correlated, interpreted and given appropriate areas of influence. The detailed bore hole evidence has to be examined critically for internal mutual corroboration as well as data obtained at the surface and from underground workings.
Exploratory Mining:

Bore holes give width and grade as pointed out above, but they are point intersections and a continuous behaviour of the ore bodies along the strike cannot be determined through them. Exploratory mining permits continuous exploration along drives. In cases where the widths of the ore bodies are very large, it may not be possible to expose the full width in drives. It is, however, possible to obtain a large number of intersections of full width by means of cross-cuts and bore holes off the drives. In other words, detailed and conclusive evidence can be obtained regarding the behaviour of the ore bodies at the level of the underground workings. Further, the variations in width and breaks can be demarcated in detail. The effects of faults, dykes, etc. can be known and taken into account.

Estimation of Reserves:

Estimation of reserves for non-ferrous metals is based on the data obtained by surface geology, drilling, exploratory mining, accurate sampling and analysis. Large scale surface and underground geological maps and sections, assay plans of underground workings, detailed bore hole logs, bore hole assay histograms, bore hole sections, ore reserve plans and sections, etc. are prepared on the basis of explorations carried out in a particular area. Depending on the nature of occurrence and the shape of various shoots, lenses, etc. the deposit is divided into various blocks, sub-blocks and sections. The reserves of each block, sub-block or section is determined by applying the following formula:
Volume = 1 x d x w
Reserves = \( \frac{1 x d x w}{t} \)

where

l = length in the strike direction
d = depth extension in dip direction
w = average width (true width)
t = tonnage factor

Geophysical Surveys:

Ground geophysical methods have been applied by the Geological Survey of India in the past for locating various metallic deposits and for ground water and engineering geology projects. At present such surveys are in progress for locating chromite, copper, lead, zinc, iron ore, and tungsten, etc. in various States. In addition, geophysical surveys are also being undertaken for ground water and dam site investigations. The scope of these surveys has for long been very limited, till recently when the long planned U.S.A.I.D. - sponsored 'Operation Hard Rock' air borne geophysical survey programme was launched on February 4, 1967 by the officials of the Government of India and the Ralph Parsons Co. of Los Angeles, California. Under this programme, the search for base metals with emphasis on copper, lead and zinc is being intensified. Air borne geophysical surveys of six areas are being carried out, i.e. Ranchi plateau, Bihar; Mica belt, Bihar; Eastern Cuddapah basin, Andhra Pradesh; Bharatpur zone, Rajasthan; Ajmer-Banswara zone, Rajasthan and Bhadasar zone, Rajasthan. The Ralph Parsons Company is being assisted by Aero surveys, Inc., a division of Litton Industries, as sub-contractor, and a selected team of Indian specialists assigned to the project from the Geological Survey of India. The
entire project is scheduled for completion within a thirty month period, and will involve costs of United States dollar 3.5 million in foreign exchange and Rs.5.0 million in local currency. The survey is already in progress.

4. Role of other agencies in mineral exploration

In addition to the Geological Survey of India, almost all the State Governments have organised their own geological and mining departments. These departments are carrying out prospecting and exploration work of important minerals in their respective States in addition to mineral leasing and other work. Their activities cover a wide range, from initial prospecting and mapping to exploration by drilling. In order that there is no over-lapping of functions, State Minerals Programming Boards, have been formed in nine important mineral producing States, Andhra Pradesh, Assam, Bihar, Kerala, Madhya Pradesh, Maharashtra, Madras, Mysore and West Bengal following a directive from the Ministry of Steel, Mines and Metals to co-ordinate exploration and to make maximum use of all available man-power and equipment and of other related resources. A Central Geological Programming Board has been constituted to coordinate all programmes of the State Minerals Programming Boards with the Geological Survey of India and other interested agencies of the Government of India.

The role of public sector corporations and private agencies is no less important. In mineral exploration activities, the Government owned National Mineral Development Corporation, the country's most progressive minerals development organisation, has launched aggressive copper exploration and development programmes at Rakhla, Bihar, Agnigundala, Andhra Pradesh and Dariba, Rajasthan
in an attempt to fully evaluate the economic possibilities of each of these areas and, if found to be suitable, prepare it for an early exploitation. The role of private companies, specially for the exploration of non-ferrous metals is insignificant, and almost all the burden has been taken over by the Government itself. Certain well organised firms such as Tata Iron and Steel Co., Indian Iron and Steel Co., Hindustan Aluminium Corporation, Indian Aluminium Co., have put-forth efforts to explore iron ore, manganese ore and bauxite, etc.

5. Conclusions

1. The beginnings of mineral prospecting and exploration in India are lost in the limbo of antiquity. Numerous old workings, slag heaps, which are found scattered in different parts of the country, however, bear convincing testimony to the existence of a flourishing mining industry in ancient times. These workings are so to say 'foot prints on the sands of time' and form useful guides for locating metallic deposits. Maximum use is being made of these indicators in various investigations for copper, lead and zinc metals.

2. The existence of the old Geological Survey in the country, set up as far back as 1851, has been a boon in evaluating the Geology and Mineral resources of the country, although, in the initial stages, most of the work of the survey was concentrated on coal geology.

3. Most of the country, barring a few inaccessible regions, has been geologically mapped on a scale of 1" = 8 miles. The present expanded Geological Survey is engaged in many other fields,
in addition to basic studies in the science of ore-finding which should be its prime function. From 1965, the work of detailed exploration of promising deposits has also been given to this organisation, which is a step/retrograde as the crowding of functions might result in neglecting the basic research. The work of detailed exploration should appropriately be given back to the Indian Bureau of Mines.

4. A crash programme of exploration is in progress in various fields for iron ores and non-ferrous metals, etc. The information available on known deposits is evaluated in the first instance and promising deposits are examined by a group of geologists for preliminary appraisals. If the indications are favourable, explorations by way of large scale mapping, drilling and exploratory mining is carried out. The procedures followed have been detailed in the thesis.

One important comment that might be made in this connection is that the time taken on various projects has been unduly long, without conclusive results except for certain bright exceptions. Work has been in progress on certain deposits for more than 10 years, e.g. the Sikkim multi-metal deposit. Normally a deposit (non-ferrous) should be evaluated in detail in a maximum period of 3-4 years. The work of the survey should be organised accordingly.

5. An airborne geophysical survey with the assistance of U.S.A.I.D. has been launched recently and the work, according to schedule, is likely to be completed within 30 months time. The results of this survey should be watched with interest and expectations. The application of photogeology and geophysics has now been extended from oil explorations to mineral investigations with good results in other countries. It is a worthwhile attempt to apply the new techniques for the location of hidden deposits.
6. In India there is a tendency to set up new organisations to deal with almost the same type of work. For example, almost all the State Governments, have also organised their geological surveys, drilling units, etc. and are engaged in mapping, drilling, etc. for various minerals in their own States in addition to mineral disposition and royalty collection work. The efforts are good but undue expansion should be checked and rigorous co-ordination should be maintained to avoid overlapping and duplication.

7. The achievements of various organisations in the field of mineral discovery have not so far been of any great consequence. The monumental work done by the Geological Survey in India in the past still remains its only trump card. During the last 20 years considerable money has been spent, but not even a single new mine of copper, lead, zinc, etc. has been opened up. Similarly, other organisations both at Central and State levels are tending to expand every year unmindful of the negligible contribution that they make to the national economy. Such tendencies must be curbed.
WORLD EXPLORATION ACTIVITY BY METHOD UTILISED
(EXCLUDING COMMUNIST COUNTRIES)
MAN MONTHS BASIS

COMBINED RESISTIVITY
1,334

SEISMIC
1,036

GRAVITY
836

ELECTROMAGNETIC
777

GROUND MAGNETIC
771

AEROMAGNETIC
664

RADIO-ACTIVITY SELF POTENTIAL
565

GEO-CHEMISTRY
416