CHAPTER III. GEOLOGICAL OPPORTUNITIES FOR MINERAL EXPLORATION

Rather than exhausting his natural resources by profligate use, as is so often claimed, throughout history man has created resources as his knowledge has advanced and he is still doing so to-day.

- Thomas B. Nolan

The steeply rising demands of minerals and the present available inadequate knowledge of mineral resource base, call for concerted efforts to be put in deciphering the known deposits and locating new reserves. The dimension of the efforts will depend on available geological opportunities. It may, however, be borne in mind that the concept of geological opportunity has, in recent years, undergone a change. Advancements made in mining, beneficiation and metallurgical research have made it possible to convert minerals of almost any grade into a usable substance. To quote Nolan, "I believe it is fair to define mineral resources as naturally occurring materials - minerals and rocks - that can yield a product which may be used by man. I am sure no one would quarrel with this definition, but in practice many people concerned with the resource problem.

overlook the qualification that a resource is a usable substance. This oversight, in turn, leads to the misconception that resources are fixed in quantity, and hence are exhaustible according to a pre-determined schedule. It is true, of course, that the amount of a given material in the earth's crust is fixed. But which, and how much, of these materials are usable at any time and thus constitute a mineral resource, depends upon what man's knowledge makes it possible for him to use to his advantage at that particular time. For example, the material of critical value to a Stone Age man was flint, and if he had surveyed the mineral resources of the world, he would not even have thought of listing most of the several hundred rocks and minerals used in the U.S.A. to-day. Before he learned to control fire, he could not live in large parts of the world, and his resources of arable soils were but a fraction of the acreage so classed to-day. Resources, then, are literally created by man through research that develops new uses for raw materials, research that permits the recovery of ores of lower quality than were previously mineable and research that makes it possible to discover concealed deposits of usable raw materials. Rather than exhausting his natural resources by profligate use, as is so often claimed, throughout history man has created resources as his knowledge has advanced and he is still doing so to-day."

Boyd\(^1\) may also be quoted in the present context. He says, "throughout my career in and out of government, I have formed my decisions on two principles: (1) Fundamentally, all mineral raw materials exist within the earth's crust in quantities greatly exceeding man's needs. (2) Any problems of supply of these materials are primarily economic in nature.

With respect to my first assumption, analyses by geo-chemists enable them to estimate the quantities in which each of the known elements exists in the earth's crust. One of the most cautious and famous suggests that the average copper content of the lithosphere to a depth of ten miles is about 55 parts per million. If this is valid, then the lithosphere contains about 1.4 quadrillion \( (1.4 \times 10^{15}) \) tons of copper metal — an unimaginable quantity. This is 8,500,000 fold that which has been consumed by man in his existence. To illustrate further, consider that the deepest copper mine in history went to almost 9,000 feet below the surface; the present copper mines of the world now average less than 1,500 feet in depth. We can assume that in most continental land areas of the world, it is technically feasible to mine to a depth of at least one mile. The land area of the world to an average depth of one mile, then, contains 343 billion tons \( (343 \times 10^9) \) of copper metal, or 2,000 times that which has been extracted to-date.

"I do not believe man will ever expend his energies to extract copper from rocks which contain only a few parts per million, but he knows that each element appears in dissimilar rocks in different relative quantities. Those experienced in mineral technology search for useful minerals in those areas where accident of nature have concentrated them in sufficient quantities to make extraction economic.

"We really do not know where or how large are the deposits which are sub-marginal under present economic conditions. We frequently observe sizeable deposits in our exploration activities; hence, we are all aware that they exist, and many of us may even have given them enough consideration to appreciate their size and long term potential. Some of these are the lean 'red bed' coppers; the shales and limestones which contain small amounts of lead and zinc; or the sea waters that are known to
have gold and other materials. Harrison Brown has even
calculated that there is sufficient Uranium in some of the
granites to produce more energy than that necessary to extract
it, if we ever needed to do so."

It is in the light of the above optimistic concepts that
advanced countries have started to spend funds on studying even
the ordinary rock types which otherwise might not have attracted
any attention. The United States Geological Survey have started
a 'geo-chemical census' to acquire data on the distribution of
the elements in ordinary rocks which, it is hoped, will vastly
improve the knowledge not only of low grade deposits, but also
of the distribution and origin of the new elements.

The purpose of the above excursion was to take note of
the latest developments about the concept of mineral resource
base, before any discussion on Indian conditions is taken up.

Metallic ores such as iron ores, manganese ores, chromite,
copper-lead-zinc ores, bauxite and other scarce metals have been
critically examined with reference to opportunities for their
exploration, in the following paragraphs. It may be of interest
to mention in this context that the Dharwar and Cuddapah
formations are predominantly the ones which play host to metallic
deposits in India. Several occurrences of metalliferrous deposits
such as copper, lead-zinc, antimony have also been reported from
the Himalayan region in paleozoic sediments, but they have not
been fully explored.

It is significant to note that pre-cambrian formations
are widespread in India. They occupy two-thirds of Peninsular
India, from Cape Comorin to Madhya Pradesh and Bihar, and
continue apparently underneath the Ganges alluvium into the
Assam Plateau; the Mysore area is also presumably connected with
that of Gujarat and Rajasthan beneath the Deccan Traps.
In Extra-peninsular India pre-cambrian formations are presumed to occur throughout the length of the Himalayas. The regions which have been studied in some detail, however, are only a few, i.e. Kashmir-Hazara, Simla, Gharwal and Sikkim-Bhutan. The Extra-peninsular region may not offer any big metallic deposits due to its unstable conditions. This contention is borne out by the recent prospecting work done by the Indian Bureau of Mines in Bhotang, Dikchu and other neighbouring deposits in Sikkim. They, on the other hand, offer prospects of small but rich multi-metal deposits.

1. Iron Ores

It will be seen from the description given in chapter II regarding the occurrences and reserves of iron ores that nature has endowed India with bountiful resources of this commodity. Almost all the occurrences which crop out at the surface are known. They are so widespread and extensive that, at present, there is no need for prospecting the 'blind deposits'. The surface deposits, however, have to be explored in detail, before their exploitation is taken up. The engineering, mining and geological data have to be evaluated to design a mine. Extensive drilling, exploratory mining, sampling and analyses, etc., are already being done at Bailadila, Madhya Pradesh, Bellary-Hospet, Mysore and Bihar-Orissa region by government agencies and private parties to collect data pre-requisite to mining. Depending upon the scale of demand, both for internal use and exports, such activities may have to be intensified in future years. Government has already set up organisations such as the National Mineral Development Corporation, the Exploration Wing of the Geological Survey of India, which is engaged in detailed proving work and can take up further assignments of this nature.
Transportation costs of iron ore is one of the biggest factor which makes Indian ores incompetetive in the world market. Deposits nearer to coasts are, for this reason, receiving prior attention. Even the low grade deposits consisting of banded magnetite-quartzite can be examined if they work out economical. The Kudremukh magnetite deposit of Mysore is a case in point, where it is envisaged to produce pellets for exports. The project is likely to cost Rs.60 crores and the pellets will have a market in Japan. The National Mineral Development Corporation is already exploring the deposit.

2. **Manganese Ores**

Manganiferrous sediments are widespread in India and the history of production of manganese has all along been very impressive. But the resources position, as indicated in chapter II, has not yet been ascertained with certainty. Mining in most of the areas, owing to this reason, has not taken a scientific line.

The important deposits both from the point of view of quality and dimension are those of Madhya Pradesh and Maharashtra which are associated with the Gondite series of rocks. The famous CPMO\(^1\) mines (now taken over by MOIL\(^2\)) are located in this belt, These mines, of course, are the best planned and are well mechanised. There is considerable scope for prospecting this belt in greater detail. Large scale mapping followed by drilling

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1 Central Provinces Manganese Ore Company, a British concern.
2. Manganese ore India Ltd., a Government of India undertaking, C.P.M.O. having a minor share.
might reveal interesting results. Attempts may be made to estimate reserves on the data available in the working mines of the region. The Indian Bureau of Mines has recently taken up work in this direction in this belt, as discussed in Chapter II. The estimation of quantities of low grade ores available in mine dumps should also be taken up with a view to upgrading them or selling them direct to the steel mills.

The manganese ores of Madhya Pradesh-Maharashtra region have, in general, relatively high phosphorous content. Beneficiation tests carried on them have failed to reduce phosphorous. The phosphorous, it is reported, is finely distributed and intermixed with manganese with the result that it is not liberated, and does not respond to any of the beneficiation methods. Sampling in the deeper section of the mines has shown that phosphorous content increases with depth but, fortunately, it responds to beneficiation and reduction in phosphorous has been noticed. Further work is in progress in the Indian Bureau of Mines. Although, generally, the ores of this region are high in phosphorous there are certain areas where the concentration of phosphorous is low. There is a need to understand the chemistry of the distribution of phosphorous both laterally and at depth in the Madhya Pradesh-Maharashtra belt.

The zig-zag mining is most prevalent in Orissa and Mysore States where the ores occur in pockets and lenses. Large scale mapping should be taken up in these areas to locate large concentrations of ores. Test drilling may be done, where necessary. Almost all the mine-owners in the region are persons of meagre financial resources. Finance generally comes from promoters. The mine-owners in this region may not be able to take up the type of work indicated above. The Government agencies should assist them in this work, and drilling machines may be provided to them on hire basis. The low grade dumps of
Orissa State are largely being consumed in the domestic steel mills. Besides, there is a good market of these ores in the Japanese market. The dumps of Mysore should be estimated along with low grade in situ deposits with a view to upgrading them by beneficiation methods.

The manganese ores of Mysore and Orissa regions are remarkably low in phosphorous but the iron content in them is high. The method of reduction roasting and magnetic separation has yielded product low in iron. The agglomeration of the final product should be attempted and economics worked out for final application. The proposition may not look attractive in view of the fact that there is good demand of ferruginous ores in domestic steel mills and in the Japanese market. But the use of agglomerated ore in domestic ferromanganese plants appears to merit consideration.

The ores of Andhra Pradesh and Gujarat are not important due to their high phosphorous content. Unless reduction of phosphorous is made possible these deposits would remain unimportant. For this reason, it is not desirable to devote any time in their prospecting or exploration. Similarly, Rajasthan ores owing to their remote location from ports as well as domestic ferro-manganese and steel plants, will remain unattractive from prospecting and exploration viewpoint.

3. Chromite

It has been concluded in Chapter II that to meet the rising demands of chromite, it is necessary to locate new reserves. The new reserves have to be located both in known occurrences and virgin areas. Since the occurrences of chromite
are almost entirely confined to ultra-basic rocks, prospecting for new deposits has to be planned in areas known to contain such rocks. The known occurrences will have to be examined in greater detail and, if necessary, fully explored by way of drilling, etc. The dimensions of reserves available even in producing districts are not completely known. Depending upon the opportunities available which will be revealed after a deposit is examined in detail, drilling may have to be done to decipher the extent and depth of chromite mineralisation.

The chromite deposits of India are not of 'stratiform' type like the South African 'Bush-veld' igneous complex. They are, on the other hand, of 'podiform' type resembling the deposits of Turkey and Pakistan. Due to this reason, prospecting or exploration of chromite in India becomes a difficult task. The new tools of minerals exploration, geophysical and geochemical are also not of much significance, as far as chromite is concerned. Murdock\(^1\) says, "Unfortunately in the search for chromite, new tools, such as geo-physics and geo-chemistry, which the geologist has found to be adjunct in exploring for other metals have proven to be of a rather limited value, due mainly to the inherent nature of chromite. Consequently, reliance must be placed on older established methods of basic aerial mapping, detailed mapping of ore bodies and enclosing rocks, petrographic and other studies. At the same time, there is need for a bold new concept for ore finding, something which can conceivably lead to a solution of some of the complex problems of finding new ore."

\(^1\) Murdock, T.G. - Chrome ore in World Affairs, Symposium on chrome ore held in Ankara, Turkey, September, 1960 under the auspices of Central Treaty Organisation (CENTO).
Zengin\(^1\) has concluded that prospecting, detailed studies and core drilling of the important occurrences exploited in the past or currently being exploited must be preferred to the prospecting of new deposits.

In his excellent paper entitled 'Applications of geology in chromite exploration and mining' Thayer\(^2\) says, "The chromite deposits in Turkey, Iran and Pakistan are of the podiform type that occurs in alpine-type peridotite-gabbro complexes. Dominance of clastic textures in ores and lineation and foliation in ore bodies and country rocks indicate extensive deformation by flowage during emplacement. The chromite deposits are believed to have been carried up as solid inclusion in semi-solid crystal mushes that formed by partial melting and remobilization of rocks differentiated at depth by fractional crystallization. If the chromite deposits are regarded as xenoliths and schlieren, their structural relations to the country-rock peridotites are seen to be fundamentally consistent.

"All podiform chromite deposits are associated with dunite or troctolite, either as host rock or gangue. Chromite deposits appear to be scattered at random in many peridotite masses, but where gabbroic rocks are present, most deposits occur in dunitic zones within 1 or 2 m. of the peridotite-gabbro contact. Most extensive tabular or elongate fusiform ore bodies, regardless of grade, lie parallel to layering in the surrounding peridotite, with their longest axes parallel to the lineation. In the few irregular tabular ore bodies that lie across layering in the

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country rock, layering and lineation in the ore parallel foliation or layering and lineation in the country rock. Although well-developed layering, foliation, and lineation control the attitudes of ore bodies in many districts, their applicability as guides for exploration in any particular district must be determined by geologic mapping. Chromite deposits in peridotite that shows little internal structure are likely to be irregular in form and grade, and random in occurrence.

"Geophysical prospecting for concealed deposits has succeeded in only a few places under especially favourable conditions. The non-magnetic nature of most chromite and irregular distribution of secondary magnetite in nearly all serpentine and peridotite severely limit the value of magnetic methods. Gravimetric surveys have succeeded only in finding large or shallow ore bodies in areas of low relief and require extreme precision. Drilling has shown that most gravimetric anomalies are caused by feldspathic rocks or variations in density of partly serpentinized peridotite. Seismic, electrical, and geochemical methods of prospecting for chromite are not promising."

It may be concluded from the above that prior attention should be paid to the known promising chromite deposits for the purpose of estimating their reserves. The less important occurrences as well as examination of ultra-basic rocks of other areas should find second place in priority of prospecting and exploration work.

A brief resume on various occurrences in India follows in the following paragraphs.
Orissa State

Orissa is the most important chromite producing State in India. Chromite deposits are confined to Keonjhar, Cuttock and Dhenkanal districts, where the exposures of ultra-basic rocks are extensive. The Geological Survey of India has been prospecting these belts from time to time. During the year 1966 investigation by pitting, trenching and geo-chemical sampling for chromium-nickel ore was carried out near Kumarkoh in the Sukinda area in the Cuttock district by the Geological Survey of India. Geophysical investigation was also carried out for chromite in the Cuttock and Dhenkanal districts. The results of these investigations are not readily available. It should be borne in mind that Orissa contributes about ninety per cent of all India production of chrome ore. It may also be seen from Chapter II that according to the present knowledge Orissa contains the largest resources. In view of this position it seems desirable that the Geological Survey of India or other agencies should devote more time in this belt and the investigation that may be taken up should end with conclusive results. A large chunk of the known mineralised areas is held under lease by private parties such as Tata Iron & Steel Company. There is need to assess the resources position in such areas also.

Bihar State

Bihar has been one of the important producers of chromite in the past. During the year 1966, however, no production was reported as a result of uneconomical mining (as reported by mine-owners to Indian Bureau of Mines).
The ultrabasic rocks are widespread in the Singhbhum district. The chromite occurrences near Jojohatu are famous. Occurrences of relatively less importance are also reported from Ranchi and Bhagalpur districts. Krishnan\(^1\) recommends that 'these and other occurrences of ultrabasic rocks in Eastern Singhbhum should be examined in detail for finding out where workable deposits exist.'

**Mysore State**

Mysore has also been one of the important producers of chromite in the past. During the year 1966, however, no production was reported as a result of accumulation of stocks and un-economical mining (as reported by mine-owners to Indian Bureau of Mines).

Important deposits of chromite occur in the Hasan and Mysore districts. Sporadic occurrences are reported from the Chitaldrug and Shimoga districts. Next to Orissa, Mysore State appears to be a potential area for chromite concentration. Efforts should be directed to establish reserves in this area by large scale mapping, petrographic studies and drilling.

**Maharashtra, Andhra Pradesh and Madras States**

The deposits of Maharashtra, Andhra Pradesh and Madras are of comparatively less importance. The Pauni and Belgatha areas are important in Bhandara district of Maharashtra. Deposits of economic importance are known only in Warangal and

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1 Krishnan, M.S. - Chromite, Bulletin No.7, Geological Survey of India.
Krishna districts of Andhra Pradesh. Detailed mapping and geochemical investigation of the chromite deposits in an 80 km. long band from Kondepalli to Kothagundem has been taken up by the Directorate of Mines and Geology, Andhra Pradesh. Some encouraging results appear to have been obtained. In Madras, important deposits occur near the Sithampudi area in Namakkal taluk of the Salem district. The Geology Branch of the State Directorate of Industries and Commerce is reported to have taken up investigation in this area.

4. Non-ferrous Metals

Finding out additional reserves of non-ferrous metallic ores except bauxite is really a serious problem. The geological setting of deposits is difficult to decipher, and the costs of prospecting and exploration are quite high. However, when the matter is looked upon from the Indian point of view, certain encouraging features are noticeable. By virtue of the fact that the country has had a Geological Survey for over 100 years, the entire country, apart from the large tracts in the Himalayan terrain, has been covered by broad regional mapping adequate for purposes of preparation of a geological map of the country on a scale of 1" = 32 miles. Around a quarter of the country has been covered by 1" = 1 mile scale geological mapping. In addition, during the last decade, a number of deposits such as Madhan-Kudhan, Khetri, Rajasthan; Bhotang, Dikchu, Sikkim; Dariba and Kolihan, Rajasthan; Rakha and Roam Sideshar, Bihar, have been explored in detail. The success achieved in their proving operations, apart from its direct impact on production programmes, has an important bearing on the scale and tempo of future exploratory programmes that can legitimately be undertaken. These operations have established the persistence of ore to a
depth of 2,500 ft. in areas marked by old workings and where the old workings have gone to a depth of 300 feet only. "In relation to our exploratory programmes for copper, lead and zinc, we must look upon the results of ancient mining activity, consisting of old mine workings, dumps of mine, wastes and slag heaps, as a great legacy to be taken maximum advantage of in the context of intensifying the development of the country's reserves in non-ferrous metals. Such evidence is seen in the most impressive scale in Rajasthan. In a part of the Khetri copper belt, extending from Singhana to Babai it has been estimated that around 6 million tons of ore must have been mined in the past. These old workings are, as it were, 'foot prints on the sands of time' which point the way to where ore is likely to be found. Properly interpreted, such evidence greatly facilitates the choice of prospects and guiding of the exploratory and proving operation."

Copper:

An interesting study has been made by the Exploration Wing of the Geological Survey of India regarding the potentialities of copper occurrences in India. 602 occurrences of copper have been listed in various states, out of which 490 occurrences are those where no work in respect of preliminary appraisal, geological mapping, geo-chemical and geophysical investigation appears to have been done. 49 occurrences are those where one or two of the above operations have been carried out but no drilling or exploratory mining has been done. Preliminary drilling appears to have been conducted or in progress in respect of another 47 occurrences. Prospects in which intensive proving operations have been carried out or are in progress

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1 A Draft Scheme for intensifying Non-Ferrous Metal development by the officers of Geological Survey of India, August, 1966 (Unpublished).
number 12, while those under exploitation are four.

Based on the above studies further work required to be carried out has also been assessed. Table No.XIV gives details of these studies. It will be seen from the table that efforts both in the matter of prospecting and exploration have to be concentrated in Bihar, Rajasthan and Andhra Pradesh mineralised belts. These belts are situated in the plains and rightly deserve more attention than those in the Himalayan terrain. The occurrences in the Himalayan terrain, i.e. those of Sikkim, Jammu and Kashmir and Kulu Valley, should be considered from a long range point of view. The work carried out in some of these areas, as for example, Sikkim, indicates that a large number of small but rich multi-metal deposits can be expected to be located in the regions. Because of the nature of the terrain and geological setting, a long and expensive exploration programme will have to be drawn up. Exploration of the Himalayan region should be appropriately taken in hand, so that by the time difficulties are experienced with respect to finding additional resources on the plains, the Himalayan prospects are ready for exploitation.

**Lead and Zinc:**

The occurrences of lead and zinc have also been listed in table No.XIV. Of the 345 known occurrences, Zawar mine, Rajasthan is the only one under exploitation.

As is known, lead and zinc occur together. In the majority of cases they have small lateral and depth persistence. It appears reasonable to recommend that concerted efforts should be put to explore the Zawar belt in the first instance. Exploration on a limited scale is in progress in this area by Hindustan Zinc Ltd. The other areas such as Agnigundala, Andhra Pradesh, Dariba Rajpura deposit, Rajasthan where the
Geological Survey of India is already doing exploration work, will come only next to Zawar in importance. Regarding the Himalayan region, the same comments hold good as those given for copper.

**Aluminium:**

The bauxite deposits generally form cappings on trap rock types and the resources, as can be seen in Chapter II, are widespread in the country. It will be necessary, however, to prove the reserves by shallow drilling, pitting and trenching on various deposits in relation to the requirements of a particular aluminium plant keeping various economic factors in view. Such work is already in hand by private and public sector agencies, responsible for the production of aluminium metal.

**Scarce metals:**

The occurrences of nickel, cobalt, tungsten, tin, molybdenum, vanadium and antimony have been discussed in Chapter II in some detail. It appears difficult to expect that any sizeable deposit which can be worked alone for any of the above metals can be found. Most of them such as nickel, cobalt and molybdenum may be produced as by-products during the smelting of sulphide ores. The envisaged production of nickel sulphate and selenium by the India Copper Corporation is a case in point. However, it may be worthwhile to examine in detail the reported nickeliferrous laterites of Assam and Orissa. The known deposits of tungsten in Rajasthan and West Bengal have been examined in detail by the Government agencies and private parties, and the results obtained indicate sporadic mineralisation with limited reserves. The tin occurrences so far known have been of uneconomic dimensions. The vanadium bearing titaniferous
magnetites of Bihar and Orissa are large enough and could be a source of vanadium. Antimony deposits are located in rather inaccessible regions.

It may be worthwhile for the Geological Survey of India to have a special team of geologists and geo-chemists and embark on a long drawn programme to study the habit of mineralisation of these and other scarce metals. Potential rock as well as ordinary rock types should be studied in detail. A so called 'geo-chemical census' of rock types should be taken up.

5. Conclusions

1. The demands for metals are rising rapidly. Knowledge of mineral resources in the country with special reference to their measured reserves is rather hazy. All concerted efforts will have to be put in deciphering the known deposits and locating new reserves.

2. While drawing up prospecting and exploration programmes, the new concept of geological opportunity must be kept in view. Advancements made in mining, beneficiation and metallurgical research have made it possible to convert minerals of almost any grade into a usable substance.

3. The rock types of the Archaean system are predominantly the one which play host to metallic formations. It is significant to note that these formations are widespread in India. The formations occurring in the plains are important both from the point of view of reserves and mineability.
4. In the case of iron ores, the surface deposits are widespread. These deposits, however, will have to be explored in detail, before exploitation begins. The engineering, mining and geological data have to be collected for evaluation to design a mine. Such work is already being conducted by Government and private agencies. Even low grade deposits nearer to coasts are under investigation with a view to exporting them after beneficia-
tion and pelletisation.

5. Manganiferrous sediments are extensive in India, and the history of production of manganese-ore has all along been very impressive. But the resources position has not yet been ascertained with certainty. The important deposits both from the point of view of quality and dimension are those of Madhya Pradesh and Maharashtra which are associated with the Gondite series of rocks. There is considerable scope for prospecting this belt in greater detail. Large scale mapping followed by drilling might reveal interesting results. Attempts may also be made to estimate reserves on the data available in the working mines of the region. The estimation of reserve of low grade ore available in mine dumps should also be taken up with a view to upgrading them or selling them direct to steel mills.

There is urgent need to understand the chemistry of the distribution of phosphorous both laterally and at depth in Madhya Pradesh-Maharashtra belt with a view to locating low phosphorous zones, and also to collect data for the reduction of phosphorous in these ores.

The zig-zag mining is most prevalent in Orissa and Mysore States where the ores occur in pockets and lenses. Large scale mapping should be taken up in the areas to locate large concentrations of ores. Test drilling may be done, where
necessary. The Government agencies should assist the mine-owners in this work and drilling machines may be provided to them on hire basis.

Time and finance should not be spent on Andhra Pradesh and Gujarat ores unless reduction of phosphorous in these ores is made possible. Rajasthan ores are unimportant at present due to their remote location from the ports as well as domestic steel and ferro-manganese plants.

6. The chromite deposits of India are not of 'stratiform' type like the South African 'Bush-veld' igneous complex. They are, on the other hand, of 'podiform' type resembling the deposits of Turkey and Pakistan. Due to this reason, prospecting of chromite in India becomes a difficult task. The tools available to prospectors, geophysical and geochemical, are of little avail.

Evaluation of geological data elsewhere in the world shows that prior attention should be paid to the known promising deposits and producing districts for the purpose of proving their potentialities. The less important occurrences as well as examination of ultrabasic rocks of other areas should find second place in priority of prospecting and exploration work.

Orissa contributes about ninety per cent of all India production of chromite. According to the present knowledge Orissa also contains the largest resources of this mineral. In view of this position it seems desirable that the Geological Survey of India or other agencies should devote more time in this belt and the investigation that may be taken up should end with conclusive results.
The ultrabasic rocks are widespread in the Singhbhum district of Bihar. The chromite occurrences near Jojhuhatu are famous. Occurrences of relatively less importance are also reported from Ranchi and Bhagalpur districts. Krishnan recommends that these and other occurrences in ultrabasic rocks in Eastern Singhbhum should be examined in detail for finding out where workable deposits exist.

Efforts should be directed to establish reserves in Hasan and Mysore districts, Mysore State by large scale mapping, petrographic studies and drilling.

7. Prospecting and exploration of non-ferrous metallic ores except bauxite is a serious problem. The geological setting is difficult to decipher and the expenditure on prospecting and exploration tends to be quite high. However, the redeeming feature in India is that most of the country has been geologically mapped. The old workings are extensive. The persistence of ore in some of these areas has been established to a depth of 2,500 feet, although the old workings extend to a depth of 300 feet only. The data available in the old workings can be taken maximum advantage of in drawing up exploration programmes. These old workings are, as it were, 'foot-prints on the sands of time' which point the way to where ore is likely to be found.

(a) Copper:- In respect of copper, the prospects situated on the plains deserve prior attention compared to those in the Himalayan terrain. The deposits in Bihar, Rajasthan and Andhra Pradesh should receive immediate attention. The occurrences of the Himalayan region i.e. those of Sikkim, Jammu and Kashmir and Kulu valley should be considered from long range point of view, and their exploration should be planned in such a way that these
deposits are ready for exploitation as soon as the deposits in
the plains get depleted.

(b) **Lead-Zinc**:- As is known, lead and zinc occur together. In
the majority of cases, they have limited lateral and depth
persistance. It appears reasonable to recommend that concerted
efforts should be put to explore the Zawar belt, Rajasthan, in
the first instance. Other areas such as Agnigundala, Andhra
Pradesh, Dariba-Rajpura, Rajasthan where the Geological Survey of
India is already doing some work, will come next to Zawar.
Regarding the Himalayan region the same comments hold good as
those given for copper.

(c) **Aluminium**:- The bauxite deposits generally form cappings on
trap rock types which are widespread in the country. It will be
necessary, however, to prove the reserves by shallow drilling,
pitting and trenching on various deposits in relation to a
particular project keeping various economic factors in view.

(d) **Scarce metals**:- The occurrences of nickel, cobalt, tungsten,
tin, molybdenum, vanadium and antimony have been discussed in
Chapter II in some detail. It appears difficult to expect that
any sizeable deposits which can be worked alone for any of the
above metals can be found. Most of them such as nickel, cobalt
and molybdenum may be produced as by-products during the smelting
of sulphide ores. The envisaged production of nickel sulphate
and selenium by the Indian Copper Corporation is a case in point.
However, it may be worthwhile to examine in detail the reported
nickeliferrous laterites of Assam and Orissa. The known deposits
of tungsten in Rajasthan and West Bengal have been examined in
detail by the government agencies and private parties and the
results obtained indicate sporadic mineralisation with limited
reserves. The tin occurrences so far known have been of
uneconomic dimensions. The vanadium bearing titaniferrous magnetites of Bihar and Orissa are large enough and could be a source of Vanadium. Antimony deposits are located in rather inaccessible regions.

It may be worthwhile for the Geological Survey of India to have a special team of geologists and geochemists and embark on a long drawn programme to study the habit of mineralisation of these and other scarce metals. Potential rock as well as ordinary rock types should be studied in detail. A so called 'geo-chemical census' of rock types should be taken up.
### Table XIV. Occurrences of copper, lead and zinc ores in India indicating the nature of prospecting/exploration work done, and further action needed.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of States</th>
<th>Copper</th>
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|             | A | B | C | D | E | b | c | d | e | A | B | C | D | E | b | c | d | e |
|-------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| TOTAL:      | 490 | 49 | 47 | 12 | 4 | 493 | 80 | 13 | 5 | 271 | 44 | 26 | 3 | 1 | 273 | 70 | 4 | 1 | 348 |

**INDEX**

A - Recorded occurrences only - preliminary appraisal, geological mapping, geo-physical and geo-chemical investigations not done.

B - Occurrences/prospects in which one or more of the following i.e. preliminary appraisal, large scale mapping, geo-physical and geo-chemical investigations - are either in progress or have been completed but no drilling, exploratory mining, etc. have been carried out or commenced.

contd...
C - Occurrences/prospects in which initial drilling programme with or without exploratory mining have been carried out or are in progress. No detailed or intensive proving operations have been commenced in these prospects.

D - Prospects in which intensive proving operations have been completed or are in progress.

E - Prospects under exploitation.

b - One or more of the following - i.e. preliminary appraisal, large scale mapping, geo-physical and geo-chemical investigations etc. needed.

c - Initial drilling programme and limited exploratory mining needed.

d - Intensive proving operations involving substantial drilling and exploratory mining called for.

e - Commencement of exploitation.

   A, B, C, D, E - Status of information.

   b, c, d, e - Further action called for.