3.0 Prospecting and Exploration

3.1 PROSPECTING, EXPLORATION AND GUIDELINES

Prospecting is an important tool and is defined as a branch of geological science which on its application is search for minerals/ores that can lead to the location of mineral deposit on surface or underneath the earth's crust. Prospecting is very often followed immediately by exploration.

Exploration can be defined as the science of prospecting in which modern and sophisticated instruments and equipment are used in search for, and qualitative assessment of mineral/ore in a prospect and known defined area. Prospecting and exploration form a prelude to estimation of a mineral/ore in a prospect. They are helpful in determining and establishing the geometry of mineral/orebodies and deciphering the workable and low grade sections of the deposits. The more the prospecting methods are systematic and organised, the greater the confidence in the reserve estimate of a mineral/ore in a prospect.

Prospecting and exploration methods of iron ores involve preliminaries to actual field exploration, such as geological mapping, aerial photography, geochemistry and bio-geo-chemistry, electrical surveying, drilling, geophysical surveying including aeromagnetic surveying and gravimetric surveying.

The choice of an exploration method for iron ore deposit depends upon the mineralogical and geological characteristics of the ore and also upon the size and kind of target for which the deposit is being sought. The target may be :-

(a) A new mineral district or area in which individual iron ore deposits occur under certain geological conditions, similar to each other but whose conditions are as yet unknown;

(b) An iron ore deposit in a mineral area in which iron ore is known to occur and in which the mineralogical and geological characteristics of the ore are known; or

(c) Another orebody of a known deposit or the extension of a known orebody. The possibilities of discovery, the costs and the methods that would apply to exploration differ greatly for different classes of these targets.

The chemical and physical characteristics of iron ore have a considerable bearing on deposit, ownership, exploitation and marketing. In most cases, feed for a specific blast furnace of a specific company should have certain chemical and physical characteristics determined empirically by the operation of the blast furnace under the operating conditions laid down by that company. To obtain the desired characteristics of feed, a blend of various ores from a number of deposits may have to be made.

3.1.1 Necessary Preliminaries to Actual Field Exploration

Many iron ore deposits worked today are the result of earlier discoveries. From these discoveries, attention was directed to the iron-bearing areas and after trenching, pitting and drilling along with applied geological correlation, major economic deposits have been developed. Unless the orebody is mined, mere visual prospecting is not likely to cover any new areas. This is particularly true in areas covered by drift or heavy vegetation. Where the area has been glaciated or otherwise denuded of drift or vegetation, visual prospecting may give results, especially under a programme of systematic and detailed visual search.

The preparation which precedes actual field work is an integral and highly important part of any exploration programme. Such preparation includes :

(a) A thorough review of all available geological literature of the area which is to be explored.

(b) Preparation of a base map for the area to be explored.

(c) Assembling of aerial photographs.

(d) Selection of the exploration method or methods to be used on the basis of a study of the geological literature, topographic maps and aerial photographs.

(e) Programme planning and arrangements for field parties, equipment, transportation supplies, communication and such other matters.

There are recent developments to a great extent, as a result of which renewed exploration in the areas of iron ores was launched and consequently investigation of old deposits in the light of present day economics and beneficiation techniques resulted in extension of known ore bodies.

3.1.2 General Guidelines[1]

Haematite and magnetite iron orebodies are generally either confined to the surface or very close to the surface under the cover of laterite/lateritic soil. Field guides which may help in the location of such orebodies are given in Table 3.1. The directly exposed orebodies are generally the hard massive ore outcrops. The orebodies under laterite/lateritic soil can be recognised by the presence of float ore or re-cemented ore boulders embodied with laterite or soil.

Wherever orebodies are not exposed and there are no obvious floats or other indications, it is necessary to rely on a combination of indirect criteria to locate the favourable targets. These

TABLE 3.1: GENERAL GUIDELINES FOR EXPLORATION WORK FOR IRON ORE [1]

Method	Capping-type deposit Regional	Capping-type deposit Intensive	Reef-type deposit with appreciable dip Regional	Reef-type deposit with appreciable dip Intensive	Remarks
1. Mapping Underground mapping for adits	1:2000 to 1:5000	1:1000 to 1:2000 1:200	1:2000 to 1:5000	1:1000 to 1:2000 1:100 to 1:200	To map lithology and boundaries, soil ore to waste contact, ore types and their contact, structural features, etc. Sludge collection is important wherever core loss occurs. Dry drilling useful in soft zones.
2. Drilling	100-500 m section intervals 1-2 boreholes in each section.	50-150 m section interval, 2-4 boreholes in each section to outline bottom of the ore.	100-300 m section interval along two levels	100-150 m. section interval down to 90 m depth	
3. Pitting	2-4 nos.	Deep pits down to 15 m. depth, 2-4 nos. on each section line to determine lump: fine ratio,etc.	up to 3 deep pits	1-2 nos. in alternate for every third section.	
4. Aditing	Not recommended	Cross-cutting adit intersecting orebody 2-3 nos. along representative sections with 30-50 m back	Not recommended	2-6 adits at different levels and at 300-500 m. lateral interval.	
5. Sampling	Core and sludge, bulk sample from pit	Cores, sludge, bulk from pits and adits for every 1-2 m. interval for grade and size classification.	Core and sludge, bulk sample for every 1-2 m. depth from pit for size and grade classification.	Core and sludge, bulk sample for every 2 m. depth from pits and adits for grade and size classification.	

(Based on Manual of Mineral Exploration, Geol. Survey of India, Misc. Pub.No.33) consist of :

1) the presence of BHQ/BHJ, etc.
2) topographic prominence
3) laterite with ore pieces, and
4) structural ridges on concealed outcrops, scout pitting and trenching may be done to confirm the presence of ore.

3.2 METHODOLOGY [2]

3.2.1 Geological Mapping[1]

All other exploration methods may be considered subsidiary to geological mapping. Geophysical prospecting based on the physical properties of minerals, prospecting by aerial photography based on the appearance of the structure and colour of the surface crust material, exploratory drilling techniques, as shown in Table 3.1, are necessary adjuncts to geological mapping but knowledge of the general geology of the area to be explored is essential. This knowledge can be derived from study of available geological literature. If the area has not been mapped, the reconnaissance geological traverses must be made. These traverses can be made before, during or after in association with geophysical traversing. If geophysical data are to be meaningful, the data must be interpreted in relation to the geology. Geological mapping is a prerequisite to other exploration techniques, in some cases, it is the only technique applicable to the type of iron ore for which the search is being conducted. The different examples are dealt in this Chapter under a separate heading 'Case Histories: Exploration' (Section 3.3).

The mineralisation of a region is merely an episode in the geological history and one of the tasks of applied geology is to ascertain the "contingent" relationship between mineralisation and general geology. Laboratory methods identified with mineralogy are being used increasingly as a supplement to the geological work. These methods are finding their ways into field application with the advent of co-ordinated programmes of mineral exploration and mineralogical research.

Mineralogical research is concerned with the development of suitable methods for studying the masses of weathered, oxidised and altered materials commonly found on or near mineral deposits. The significance of texture, colour and composition of gossan is another feature worthy of study. Mineralogical methods established new physical principles. Differential thermal analysis, which is now being employed in study of the altered material around orebodies in examination of limestones and other carbonate masses, in estimation of the nature and amount of clay material in weathered or altered rocks and in a number of other ways, is in fact the re-application of a method that has long been known. The same may be said for microscopic, petrographic,mineragraphic,X-Ray,spectrographic and other techniques. There has been a constant improvement in knowledge of how to apply these methods, in coordination with each other and in their application to the general problem of mineral exploration. Serious consideration of their applicability, individually or otherwise, should be given in every iron ore geological mapping or exploration programme.

3.2.2 Aerial Photography[1]

Aerial photography is more useful indirectly in the field of iron exploration. It permits rapid preparation of topographic maps essential to the planning of a systematic search for iron ore, preparation of geologic maps. and efficient exploitation of significant iron ore discoveries. Photogrammetry, the science of making measurements and extracting quantitative information from photography, offers the cheapest and fastest means for making topographic maps. Preparation of aerial photographic mosaics of interesting areas, as a basis of many types of annotations as transparent overlays bearing geological, geophysical and other field data may be of assistance in planning additional reconnaissance on detailed field work and may even offer "convergence of evidence" as to place and type of iron ore mineralisation.

Direct use of aerial photography in mineral exploration is as follows :

i) To continue tests of colour photography.

ii) To extend, generalize and disseminate the principle of "photogeology"

iii) To precede every major mineral search with aerial photographic study.

iv) To compile photogeologic information as tables cross-indexed charts and annotated photographs for use as diagramatic "keys" to assist other photogeologists in deciphering analogous areas or other earth features under study.

v) To extend the use of the "convergence of evidence" principle by securing airborne magnetic or other instrumentation records.

Example in recent years of successful application of aerial photography to iron ore exploration was the discovery in Venezuela of the Cerro Bolivar iron ore deposit now being worked by a subsidiary of the United States Steel Corporation. Intensive study of photographs, combined with the knowledge already gained from the ground survey, indicated that a complete aerial mapping would be valuable for furnishing accurate maps of the region and for providing complete set of vertical aerial photographs for topographic and geological study with the aid of stereoscopic instruments. Geologists were able to study the aerial photographs carefully with the stereoscopic aid and were able to correlate the topography visible in the photographs with the geology of areas which had been studied in the field.

In this process, it was found that the ferruginous quartzite hills could usually be identified and differentiated from the areas underlain by igneous rock or the metamorphic complex series. Consequently, it was possible to guide the field parties on examination with a great saving in time and effort. The study of the aerial pictures had indicated that Ceroro Bolivar hill looked particularly interesting as a possible ore deposit.

3.2.3 Geochemistry & Bio-geochemistry

Geochemistry and bio-geochemical techniques would appear to have no general significance in the field of iron ore exploration. These techniques, as frequently applied, involve the systematic testing of a large number of samples in an effort to find and map patterns of dispersed elements related in some way to the commercial concentration of ore minerals. In case of iron, its occurrence in the earth's crust is so widespread and so general that it is highly improbable that any programme involving systematic geochemical and bio-geochemical analyses for iron would serve any useful purpose. Where there is some distinctive accessory mineral contained in a known iron orebody in minor quantities, systematic trace analyses for this distinctive mineral might be helpful in the location of additional orebodies in the same area. The bio-geochemistry of iron is more complex and not as likely to be used in the search for ore as that of copper and zinc. Nevertheless, iron and manganese do show anomalies which can be related to ore occurrences. In special circumstances, such as in the search for a particular type of ore, bio-geochemical studies of iron and manganese may have a practical application. In specific cases, the bio-geochemistry of iron may be of value in mapping the contacts of geological formations covered by overburden.

3.2.4 Geophysics

The value of geophysics as a tool in iron ore exploration is a result of the various physical phenomena which certain mineral deposits and geological structures exhibit. With suitable physical measurements, evidence may be observed of the existence of mineral bodies, containing iron, beneath the overlying rock or soil, or possible extensions to known orebodies. Contrasts in density, electrical conductivity, magnetism or other physical properties, singly or in combination of iron-bearing material with the surrounding rock may form the basis of an effective exploration technique. Exploration may be assisted by the geophysical determination of materials or structural configurations known to be associated with mineralisation.

The main limitations of geophysical methods applied to exploration arise from the following causes :.

(a) Lack of sufficient contrast in the physical properties on the part of the body or condition sought

(b) Decrease of anomaly with distance to the causative body

(c) Marked anomalies arising from surface features

(d) Uncertainty of interpretation as measured by the actual "Ore finding" or "Ore elimination" information provided.

All exploration techniques have their own inherent limitations and their usefulness in exploration depend not only on a thorough understanding of their capabilities, but also of their limitations. In iron ore exploration, the most widely used geophysical technique is magnetic surveying whereas the other techniques such as gravimetric, electrical, electromagnetic and other few physical techniques have been much less used. These are described below:

3.2.4.1 Magnetic Surveying[1]

The known techniques of ground magnetic surveying have acquired a distinct place in exploration for iron ores. Magnetic surveying and aeromagnetic surveys are based on the magnetic properties of the ore and surrounding material. Observations made during both types of survey are compiled into magnetic contour maps or series of magnetic profiles. The interpretation of these maps by profiles involves the same fundamental theories. Ground magnetic surveys usually measure variations in either the vertical or the horizontal components of the earth's magnetic field whereas aeromagnetic surveys measure variations of the total field. The accuracy of position of an aerial survey is affected by several factors chief of which is the accuracy of the map of the area flown. The accuracy of position in three dimensions of an aeromagnetic map is only in rare cases within 18 metres.

Aero-magnetic readings over bands of iron formation running from 15 to 20 percent iron each show up to 20,000 gammas, while zones of information available, for many basic intrusives in the Michipicoten area carry from 5 to 10 percent magnetite and give aeromagnetic anomalies.

3.2.4.2 Gravimetric Surveying[1]

The application of gravimetric surveying for iron ore search is related to differences in specific gravity between the iron-bearing material and the surrounding rocks or overburden. Systematic local differences in gravity are directly related to differences in the density of the underlying rocks and to their physical shape. The differences may be the result of a variation in rock type or geological structure. The differences may even be augmented or compensated by porosity in one of the members due to leaching. Gravimetric survey results are of specific value to iron ore exploration in so far as they can be related to similar results over a known area. The variations of gravity encountered are extremely small and the instruments used for measurement have to be of great sensitivity. For exploration work, mechanical gravimeters are most widely used. These instruments use the elastic force of springs and the torsion of wires to measure gravity. The pendulum method and the torsion balance method consume considerable time and are not widely used for ordinary field mapping. The sensitivity of gravity instruments frequently results in complications in the interpretation of gravimetric readings. For instance, vibrations in the profile of a lake bottom, or even ice vibration, may make the interpretation of readings over a lake area difficult, if not impossible. Gravity surveys at steep rock have proved to be a useful exploration tool.

3.2.4.3 Electrical Surveying[1]

The application of electrical methods in exploration depends on the difference in electrical properties associated with certain minerals and rocks.

(i) Natural electric currents and the distribution of self potentials;

(ii) Properties of currents induced into the earth.

(a) Direct current; (b) Alternating current

(i) In respect of iron minerals, the self-potential method is applicable to the search for pyrite from which by-product iron may be obtained. It depends on the occurrence of a set of conditions which permit a sulphide body to form a natural battery. The orebody must be partly above the water table, thereby causing oxidation and forming a negative pole in the upper portion and a positive pole at the bottom. Electrochemical differences of potential, which may amount to more than half a volt, are measured by "exploring" electrodes connected with simple instruments. The practical application of measuring currents generated by chemical action is restricted almost entirely to the discovery of electrically conducting sulphides and oxides.[1]

(ii) If a current of electricity is introduced into the ground containing an orebody which is a good conductor compared with the surrounding rocks, the lives of current flow will become concentrated in the highly conducting orebody at the expense of the material enveloped therewith. Thus, the pattern of current flow will assume a forum different from what it would be with no orebody present. The resistivity of certain beds of rock may be determined by specific exploration techniques. The most usual method employed is to pass a direct current into the earth by electrodes inserted in shallow holes in the ground. 'Potential' electrodes connected to a galvanometer outline the pattern of current flow. If alternating current is used, electrodes may be dispensed with in favour of coils of wire both to provide the stimulus by electromagnetic induction and to decide the response by the same process.

In the middle arm area, measurements of the difference in electrical resistance of geometrically equal earth sections served to indicate the possible presence of haematite. It had previously been determined that dense haematite was more electrically resistant than the ash rocks and limestone which form the hangingwall and footwall, respectively. The electrical survey results at the northeast corner of the middle arm seemed to indicate extension of the haematite body downwards for at least several hundred metres. In the west arm, the electrical measurements substantiated the presence of a structural trough in one part of the arm and the magnetic measurements established rock contacts and types.

In the Michipicoten area of Ontario, most of the known siderite orebodies have a prominent pyrite zone along one wall and sometimes a much narrower pyrite zone along the other wall. Jones and Laughlin Steel Corporation, through its Canadian subsidiary, Jalore Mining Company Ltd. used an electromagnetic survey, carried out by Mcphar Geophysics Company to outline these pyrite zones and to provide an indication of the extent of the orebody. The electromagnetic results were later verified by drilling.

3.2.5 Drilling

There are two phases of exploratory drilling and these are :

(i) initial testing of a deposit to determine its ore possibilities ; and

(ii) detailed sampling and outlining of the deposit prior to development and mining.

Churn drilling and diamond drilling are both used in the initial phase of exploration drilling. Churn drilling is less expensive and is particularly adopted to iron-bearing deposits where relatively soft to medium hard formations occur and where possibilities of core recovery are low. It has a hole of relatively large diameter and thereby it yields large and representative sample. Sludge samples for analysis are usually taken at 1.5 m interval. Diamond drilling is suited to the testing of deposits in which the ore and waste are hard and which will yield cores for visual examination. Magnetic deposits are usually tested by diamond drill splitting of the core which provides material for megascopic & microscopic examination as well as analysis and beneficiation tests, etc.

Once it has been determined by initial testing, pitting and exploratory drilling that the area offers ore potentiality, planning a detailed drilling programme is necessary to determine the ore reserves so that the economics of development and mining may be evaluated. The exact attitude of the deposit such as open-pit or underground mine, the amount of Bessemer, non-Bessemer ore in the deposit and the precise physical and chemical characteristics of the deposit for future ore blending purposes could be ascertained. Detailed drilling is generally carried out on a grid pattern with a 150 m spacing. Depending upon the depth of the deposit, all holes may be or may not be drilled to the bottom of the deposit. They are frequently put down to a uniform depth.

3.3 CASE HISTORIES: EXPLORATION

The case histories of important deposits of Bihar, Karnataka, Madhya Pradesh and Orissa are dealt hereunder.

3.3.1 Bihar

Iron ore deposits of Bihar belong to the pre-Cambrian iron ore series and ore is within the banded iron ore formation(BIF) occurring largely as hard massive along with blue dust and weathered ore. These deposits occur in the shape of a horse-shoe synclinorium and depending on the prevailing meteoric and chemical conditions, the deposits vary considerably in their physical nature and chemical composition both as regards iron content and gangue materials like Al_2O_3/SiO_2 of iron ore fines. Haematite ores of Bihar and Orissa show a more or less reversed Al_2O_3/SiO_2 ratio.

3.3.1.1 Meghahatuburu Iron Ore Mines

Meghahatuburu deposit[3,4], Singhbhum district was geologically mapped in 1932. The Meghahatuburu mining lease area was thoroughly explored by SAIL. The exploration data initially revealed that the deposit contains 121.8 Mt of ore, with an average grade of Fe 63.29 percent, SiO_2 2.4 percent, Al_2O_3 2.65 percent, to a depth of 120 m. This includes 10.8 Mt of laterite/limonitic ore having an average grade of Fe 58.02 percent, SiO_2 3.29 percent and Al_2O_3 6.22 percent.

The exploration of ore had been planned taking into consideration the availability of indigenously manufactured equipment and present operating practices in the country. The mine has been planned for excavation of 5 Mt of r.o.m. with additional 1 Mt of waste excavated annually. The ore is available to a depth of 120 m and as such it has been planned to exploit the ore in slices having height of 12 m each and to maintain uniform quality as well as smooth operations in the 1st stage, 5 benches have been developed initially. Subsequent exploratory drilling of 60 m interval proved the increase in bulk of orebody to 132 Mt. As on 1.4.1994, an amount of 7,396 m borehole drilling was done. Based on the above exploratory work, reserves are estimated 32 Mt under proved category up to VI bench (846 mRL) and probable ore of about 100 Mt up to XI bench (796 mRL) containing 62% Fe.

3.3.1.2 Chiria Iron Ore Deposit

Haematite iron ore capping of the Chiria hill[5,6] in Singhbhum district, Bihar near Manoharpur railway station of the S.E. Rly, India, is one of the first occurrences discovered in the country. The details of exploration phasing inputs are given as under. MECL has geologically classified the Chiria iron ore deposit into the following two types for detailed mapping excercise:

1) Lumpy ore zone : Wet drilled :	Laterite ore, Hard & massive ore shale massive ore, Thick laminated ore (>1 cm)
2) Powdery ore zone: Dry drilled:	Thinly laminated ore (<1cm) Red powdery ore & Red ochre, yellow ochreous ore ,Blue dust.

The major tool of exploration for detailed appraisal was core drilling. As general hardness and tensibility of the ore were much inferior, dry drilling technique had to be deployed for over 90% of the metreage in order to effect reliable and high core recovery, over the depth ranges of ore going beyond 150 m. Square grid patterns at an interval of 400 m in the Ist Phase over the entire deposit end-to-end and at an interval of 200 m in selected block in 2nd Phase were worked out. Core sampling was at interval of 1m in the primary first analysis for Fe and the composites were at 1 m interval. Depending on geological and physiographic heterogeneities, the deposit was divided into North, West-Central, East-Central and South blocks. The 2nd Phase of intensive exploration was confined to stay in the North and the West-Central blocks.

(a) The salient inferences from the Ist Phase of the exploration work are summarised as under :

Block (Area:m²)	Reserves (Mt)	Accuracy (%)	Av.Fe (%)	Accuracy of Average
North Block (2.11)	521	72	62.26	99.5
West-Central(4.07)	682	76	61.53	99.5
East-Central (2.89)	409	59	62.65	99.5
South Block (1.93)	353	66	62.59	98.6
Overall (11.00)	1,965		62.15	

(b) The salient inferences from the 2nd stage of the work are given below:

Method deployed	Reserves (Mt)	Chemical Constituent % Fe	Al_2O_3	SiO_2	P
West Central Block					
Cross sectional	450	62.04	2.54	2.83	0.06
Slice plan based	439	61.75	2.66	2.48	0.06
Bench based	376	61.90	2.66	2.50	0.06
Borehole influence	545	61.88	2.58	2.74	0.06
North Block					
Cross sectional	364	62.60	2.52	2.57	0.06
Slice plan based	353	62.20	2.66	2.23	0.06
Bench based	260	62.24	2.66	2.26	0.06
Borehole influence	350	62.49	2.61	2.49	0.06

(c) Comparision of phases :

In the West-Central and North blocks, both the phases were overlain and have thus provided an ideal case for comparing the relative status of conclusions on the same points reached through wider spaced and closer spaced exploration systems. The results are given at the bottom of the page.

3.3.1.3 Kalta Iron Ore Mine

Exploration in Kalta Sector, Singhbhum district[7] was completed in 1972-75. Regarding mine development during 1989-95 of Block 'A' Kalta Sector, south faces were to advance towards N&E. Faces have not advanced as planned instead, advance has been mainly from E & S to W & N; North faces were to advance from W to E. Benches have been worked as planned but the rate of advance has not been as per plan due to lower level of production. Block 'B' Kalta Sector benches were to advance from centre towards both E & W. Benches have advanced from E,W. Thus mining was more practicable.

The exploration and assessment of ore reserves in all three blocks (A, B & C) of Kalta Sector had been completed during 1972-75. The entire estimated reserves were classified under proved category on the basis of detailed exploration carried out in this area.

Mineable reserves were estimated by taking into consideration the ultimate pit limits and other geo-mining constraints as revealed by the plans prepared for different working levels.

Exploration in Blocks D & B of Taldih Sector which forms a part of the Kalta mine was taken up during 1989-95 after completing the Kalta Sector exploration. All reserves of this sector are also classified under 'Proved' category. In Kalta area, a lease is spread over into two blocks on the northern end. While Block B is contiguous to another lease, Block A is separated from it. Prospecting and exploration in this area were completed during 1968-70. No drilling has been done in this area subsequently. Only geological mapping, trenching and pitting were done. The proved geological reserves in this lease have, therefore, been calculated for a thickness of 5 m only. The depth of trial pits and the workings of Kalta Mine were further extended during the seventies. Since then, benches have been developed up to 808 mRL. Reserves in Block 'B' have been categorised as 'Proved' up to this depth only.

Block	Grid Interval (m²)	Mean thickness (m)	Reserves (in millio tonnes)	Predictive accuracy(%)	Grade factors in Chem % Fe	Al_2O_3	SiO_2	P	Accuracy (%)
(i) West	400	89.66	425	82	62.17	2.29	2.90	0.06	98.00
Central	200	89.83	450	89	62.04	2.54	2.03	0.06	98.00
(ii) North	400	78.25	358	68	62.94	2.07	2.22	0.06	98.00
	200	87.12	364	85	62.56	2.57	2.57	0.06	99.14

3.3.1.4 Duarguiburu Leasehold of Gua Iron Ore Mine

The Duarguiburu leasehold in Singhbhum district is the largest in the group of leaseholds of Gua Iron Ore Mines. This area in its totality falls within Ghat Kuri Reserve Forest in Singhbhum district, Bihar. Geologically, the deposit occupies the north-eastern tip of the western limit of Bonai synclinorium. The major litho types are shales, BHQ/BHJ, laterites and iron ore of various types. At few places, dolerites are encountered. The dominant strike of the foliation is NNE-SSW and the inclination ranges from sub-horizontal to sub-vertical with both the easterly and westerly dips. The mineralisation is controlled primarily by leaching process aided by weathering. The iron ore deposits of different leaseholds of IISCO in Gua iron ore mines are parts of Singhbhum - Keonjhar group of iron ore deposits. It falls in Noamundi sub-division of Singhbhum district, Bihar. The exploration of iron ore in this leasehold has been continuing since 1925. The details of exploration during 1953-54 by IISCO reveal that 42 boreholes were drilled up to a depth of 66 m on sectional alignments which have been 300 m apart and a few trial pits were excavated. The exploration results showed iron ore reserves up to 75 m depth. In 1967, the ore reserves were re-estimated at 234 Mt. up to a depth of 50 m. When the exploration activities were undertaken by NMDC and RSP, the leasehold of Duarguiburu was sub-divided into four blocks A,B,C and D on the basis of grid lines.

The Prospecting Division OMQ., Dept. RSP during 1982-91 conducted core drilling operations totalling 6,299 m out of which 95 boreholes involving 4,176 m drilled in 'A' block were taken into account for geological evaluation. The boreholes drilled by RSP are numbered from 501 to 611. A total of 13 cross-sections at an interval of 100 m for Block A were drawn by RSP.

NMDC carried out detailed exploration of Gua Iron Ore Mines, which included contouring and geological mapping on 1:2000 scale, drilling through core drill and DTH drills in 296 holes with total 16,660 m. The grid has been laid at an interval of 100 m. Based on the data generated from the exploration works of both RSP and NMDC, the following geological drawings were prepared by NMDC. The detailed geological maps on 1:2000 scale & 1:5000 scale; geological cross-section - 59 Nos; geological longitudinal sections 5 Nos; and geological bench plans 34 Nos. were drawn in 1991.

3.3.1.5 Ajitaburu Leasehold (Budhaburu Block) Manoharpur Iron Ore Mines

The Ajitaburu leasehold[10] of iron of M/s IISCO comprising 323.747 ha falls in the Chakradharpur sub-division of Singhbhum district, Chiria taluka, near village Anqua (Budhaburu Block of Saranda R.F., Compartment No. 3) Bihar. The exploitation of iron ore in this leasehold has been continuing since 1925. Geological mapping aided with pitting, drilling and sampling, etc was conducted Departmentally in 1964-65. In 1975, MECL conducted exploratory work in the total Chiria block and portions of this leasehold. The results of such studies indicated the presence of prolific resources of very good grade ore in the total Chiria block. Tectonically, the structural configuration of the iron ore group has been interpreted as a synclinorium plunging toward NNE. The host rocks of iron ores being BHQ, the total characteristics of the mineralisation have been dependent upon the disposition of the host rocks. This leasehold forms a part of the so called Chiria block where Budhaburu (Ajita) leasehold forms a part of west-central block. Lithologically, it comprises conglomerate, ferrugenous shale, sandstone, quartzite, banded formations. Broadly, three types of formations are identifiable within the leasehold. These are laterite, iron ore and BHQ with associated quartzite.

Position of this leasehold (the eastern zones) was subjected to exploratory activity in the first phase exploration of Chiria block (more than 16 sq. km. of aerial extent in the total of Mac Hellan, Agita and Dhobil leaseholds). The following works were completed by MECL:

1) Large-scale geological mapping of the entire block was completed on 1:2000 scale for

the entire area of 16.09 sq. km.

2) Core drilling in 90 boreholes, having a total meterage of 6,989 m, core logging, core sampling, analysis of the core samples, etc. were done. In total, 8,716 samples were analysed, out of which 39 were subjected to complete analysis, 669 pertained to check analysis, and 6 bulk density determinations were made.

Out of the above quantum of exploratory works, the work relating to present leasehold Ajita block is given below :

(i) Topographic survey of the area and preparation of the topographic map of the leasehold on 1:2000 scale with 5 m contour interval; geological mapping of the area and preparation of the geological map of the leasehold on 1:2000 scale. (ii) core drilling in 12 boreholes with the depths varying from 45 to 113 m and the cumulative meterage 999 m; (iii) logging of cores of the above boreholes, and analysis of 1,014 core samples.

The total exploration work that has been completed for this block (Ajita lease) is topographical survey and geological mapping of the area followed by core drilling in 14 boreholes and the analysis of core samples. Logging of the boreholes recovery and their documentation has also been carried out. Determination of bulk density of the ore was done. The detailed survey of the quarry on 1:500 scale for the preparation of the excavation plan was carried out.

3.3.1.6 Sukri Leasehold Manoharpur Iron Ore Mines

The Sukri-Lutur leasehold in Singhbhum district of M/s IISCO comprising 609.544 ha falls in the Chakradharpur Sub-division, Chiriya taluka, Thana Manoharpur, near village Marangponga, Bihar. Exploitation of iron ore in this leasehold has been continuing since 1965. Tectonically, the structural configuration of the iron ore group has been interpreted as a synclinorium plunging towards NNE. The total region amply displays the effects of superposed folding on two almost perpendicular axes. Three types of rocks have been identified in this area. They are BHQ with concentration of quartzite portion in selected zones giving the appearance of quartzite bodies, iron ore and laterite. To isolate the zones of concentration of ore mineralisation and delineate the orebodies and to estimate the qualitative and quantative ore reserves of the leasehold, the following exploratory works have been completed by the lessee.

1) Topographic survey of the entire leasehold on 1:4000 scale
2) Geological mapping of the total leasehold on 1:4000 scale.
3) The detailed survey of selected ore zones around the existing quarries on 1:500 scale and
4) Drilling of test pits in Block-I on a grid at an interval of 30 m and analysis of the representative samples of each pit.

3.3.2 Karnataka

3.3.2.1 Kudremukh Iron Ore Mine[12]

On the basis of earlier preliminary works carried out by Department of Mines and Geology, Karnataka in Kudremukh Gangamula region, the detailed exploration works of Aroli area (Kudremukh deposit) was taken up by M/s NMDC in the year 1966-67.

On availability of topographical map of the area on 1:5000 scale, the detailed exploration was planned in systematic grid pattern of 50 x 50 m. These grids are numbered from S-0 to S-85 along north-south and W-0 to W-75 in east-west direction. The core recovery in the top capping of soft ore formation was poor in wet drilling operation and therefore it was planned to proceed with former drilling programme by dry drilling. The Master Plan of dry drilling operation was drawn giving priority to 200 m x 100 m spacing initially followed by 100 x 100 m and 50 x 50 m in subsequent stages. A total 5,882m dry drilling at 200 m x 100 m was done by 91 boreholes spread over different parts of the deposit during the period from the second half of 1966 to the second half of 1968. The shortcoming of wet drilling regarding core recovery was successfully met with by dry drilling by which 100 percent recovery was achieved in soft formation. Thus, with the help of dry core drilling samples, representative assay values were obtained. In the course of drilling during 1966-68, pitting and aditing works were in progress simultaneously. In all, 8 deep pits, varying from 10 to 14 m in depth scattered in different parts of the deposit were sunk, to know the extent of overburden and type of ore and 6 adits in different horizons were driven for a total length of 390 m with a view to establishing the variation in nature of the formation at different horizons and for bulk sampling from the core of the orebody. In the year 1968-69, during the course of pilot plant studies, 24 bulk samples from pits, and 3 adits for a total length of 177 m were driven for detailed tests in pilot plant to establish techno-economic feasibility. Thus, the total quantum of pitting and aditing done for detailed exploration of the deposit was as follows :

Deep pit	:	8
Bulk sampling	:	24
Adits	:	9 (565 m)

During the year 1968-69, in pilot plant scheme, a total 5 trenches, 1 m wide, 2 m deep, for a total length of 7,051 m were excavated cutting across the whole deposit from east to west. The objective of trenching was to ascertain the nature of soil or gangue covered and to know the structural behaviour of the deposit. Extensive sampling all over the deposit from the surface as well as from the exploratory features was done throughout the prospecting and pilot plant studies.

Exploration Details

Topographical survey	:	4605 ha. ; 5 m interval.
Regional mapping	:	4945 ha.
Geological survey	:	1:1000 by plane table and Alidade
Core drilling	:	41,355 m.
No. of boreholes	:	524
Trenching		7051 m - 5 No.
Aditing		565 m - 9 No.
Pitting		Deep pits : 8 Shallow pits : 24

During 1976-77, when the project was cleared for construction and development, it was envisaged to go for further core drilling in closer spacing of 100 m x 100 m and 50 m x 50 m imperative for mine planning and quality control, respectively. Core drilling at this stage was planned on 100 m x 100 m and 50 m x 50 m grid pattern and operation started in the year 1976-77 by departmental drilling unit of M/s KIOCL. Keeping in view the total quantum of drilling, services of other authoratitive drilling units from NMDC, GSI and MECL were also deployed in a phased manner. Total quantum of drilling done during the year 1976-77 to March 1991 was 30,695 m in 396 boreholes. All drill core samples are preserved in core boxes.

3.3.2.2 Sandur - Donimalai Area

Sandur schist belt in Bellary district[13] is about 60 km long stretches in NNW-SSE direction and its maximum width is about 15 km. It is horse-shaped. Donimalai forms the SE portion of Sandur schist belt.

Sandur schist belt of which Donimalai comprises the SE portion is a greenstone belt in which the position of volcanic rocks exceeds that of sedimentaries. The shelf facies comprising intercalated bands of quartzites alternating with metabasalts and amphibolites are confined to the western margin of the western limb. Discontinuous limestone bands are found around the orthoquartzite bands. The limestone band exhibits excellent stromatolite structures above this manganiferous phyllites and banded iron formations occur. The central portion of Sandur schist belt comprises metavolcanic rocks which are highly deformed but subjected to chlorite schist grade of metamorphism. In Donimalai area, manganese phyllites and stromatolitic limestone are absent. Metavolcanic unclassified shaly formations with intercalations of tuff beds, chert bands and banded iron formations are the principal rock types of Donimalai area. These limb units are intruded by dolerite. Quartz veins are emplaced ubiquitously.

The BIF of the area is highly developed. There is excellent preservation of banding in the BIF, characterising general low energy environment though there are local high energy environments giving rise to slump structure intra-formational breccia and micro-breccia. Clusters are generally absent in BIF bands, except for small lenses of shale occurring locally in the BIF. The BIF consists of alternate bands of chert and iron oxides. The iron oxide consists of martite pseudomorph after magnetite. The relicts of magnetite are present in the iron oxide bands, showing that the precursor stage of banded haematite/jasper rock has been banded with magnetite-jasper rock. The carbonate facies are not developed in the BIF and also siderite was not noticed in the BIF. Black shales, the black cherts with sulphides occur as highly localised pockets in the BIF. Their properties to the total BIF can virtually be treated as negligible. Limestone bands consisting of stromatolites occur in the lower horizon to the BIF. The role of microbiota in the precipitation of iron bands has been advocated unequivocally by several workers.

The 3W deposit of Donimalai during 1993 - 94 was investigated thoroughly. This is the smallest haematite deposit of the Donimalai iron ore deposit. The deposit extends over a strike length of 900 m conformable with NNW-SSE strike of the country rocks. The dip varies from 75 E to vertical. The width of the orebody varies from 30 to 70 m and is traversed by an oblique fault in the southern extremity due to which the width of the orebody reaches a maximum of 200 m in the southern part. The orebody consists of a number of small shale bands parallel to the strike. Progress of 202.1 m borehole drilling was achieved. Total expenditure involved was Rs. 3.11 lakhs.

3.3.2.3 Ramandurg Iron Ore Area

The large-scale geological mapping and few boreholes were drilled by NMDC during the early seventies. TISCO and NMDC are exploring possibilities for exploitation for the 130 Mt of Ramandurg iron ore mine in Bellary district[14] in Karnataka, which contains 60 percent Fe. TISCO wants to develop the mine as a captive source of iron ore for its proposed 3 Mt per annum steel plant on west coast of Karnataka.

3.3.3 Madhya Pradesh

3.3.3.1 Bailadila Iron Ore Deposits No. 10, 11-A, 11-C, 14

Detailed exploration of Bailadila Deposits No. 10 and 14 in Bastar district[15,16] taken up during 1960 by IBM was continued up to July 1962. NMDC has continued detailed exploration in south block of Deposit 10, since August, 1992. GSI has carried out detailed exploration work on Deposit No. 11A.

Deposit No. 10 and 11-A are the two adjacent deposits on the eastern ridge of folded mountain range of Bailadila. The two deposits are to be developed as one mine of 5 Mt per year capacity. Deposit 10 or 11-A can be approached from Bacheli by an all-weather road. Area is 309.34 ha.

Investigation of the deposit was initiated by IBM. The preliminary exploration of Bailadila Deposit No. 10 was completed during the period December 1960 to July 1962. The summarised exploration details are as follows :

Item of work		Quantum of work
Surveying	:	Topographic plan 1:2500 scale Area covered 2.1 sq. km.
Geological mapping	:	Geological plan on 1:2500 scale
Pitting	:	70 shallow pits, 30 deep pits
Aditing	:	Two adits; total 219.6 m
Core drilling	:	1427 m in 23 boreholes
Sampling	:	1318 samples.

Before developing Deposit 10 for mining, additional necessary exploration and geological works are being carried out by NMDC in this mining block between C.S-9 and C.S-16. IBM had carried out preliminary exploration of Deposit 10 only. NMDC planned detailed exploration consisting of geological mapping, core drilling, sampling and chemical analysis of borehole samples and computerised studies on exploration data for developing appropriate orebody model and mine plan.

Works carried out in South Block by NMDC include the following :

S.No.	Item of work	Quantum
1	Surface geological mapping	1.38 sq.km on 1:2000 scale
2	Core drilling	6501 m in 65 B.H. up to Feb '95
3	Sampling and chemical analysis	4,300 samples analysed till Feb.95 for Fe, SiO_2, Al_2O_3, LOI.
4	Chemical, physical & metallurgical tests on ore-type samples	Completed
5	Engineering survey	Detailed surveying, location alignments, etc for processing/handling plant, roads, etc.
6	Preparation of plan	Surface geological plan, cross-section and slice plans.

IBM conducted 828 m drilling in 13 boreholes in South Block. NMDC planned 65 boreholes at 75 m grid distributed evenly over the entire deposit in South Block between C.S-9 and 16. NMDC conducted 6,351 m drilling to have precise information on ore characteristics.

The sub-surface information obtained from a total of 7,329.35 m drilling in 78 boreholes with the following break ups has been the basis for assessment of the deposit in South Block between C.S-9 and 16.

	No. of boreholes	metres drilled
IBM	13	828
NMDC during 1978	3	150
NMDC current drilling (up to 30.6.1993)	62	6351
	78	7329

Bailadila Iron Ore Deposit No. 14 & 11-C are two distinct and highly mechanised opencast workings of the country. Bailadila range of hills covering Bastar plateau is a well-known mineralised zone for iron ores. There are 14 iron ore deposits in Bailadila iron ore ranges of hills, of which Deposits No.5, 14 and 11-C are in the production stages, and wherefrom good quality iron ores are being excavated in order to supply the same to the outside countries and to the internal buyers as well.

The concentration of iron ore in Bailadila Deposit 14 & 11-C is mainly haematite and it varies in iron content from 66.14 to 67.39 percent. Theoretically haematite should contain 70 percent Fe, but due to genetic impurities and addition of silica and alumina, it has recorded lower than the normal concentration. The lower Fe percentage in the iron ore is being compensated by occurrence of mainly SiO_2, Al_2O_3 and P and other rare elements.

The preliminary appraisal of Deposit No. 14 was undertaken by IBM during November - December 1961. The detailed prospecting operations in Deposit No. - 14 of Bailadila iron ore range were taken up by IBM during January 1963 and the field operation continued up to December 1963. The exploration work comprised the following :

1) Geological mapping on 1:2500 scale showing 3 m contour interval for the area of the deposit 1500 m x 600 m x 1200 m.
2) 72 pits were dug, out of which 33 were deep pits.
3) A total 1,140 m drilling was carried out in 13 boreholes (distributing mostly between cross-section I and XIII). Holes were put at 200 m apart.
4) One 81 m adit was driven on the cliff side at 1088 mRL.
5) The exploration by IBM was primarily aimed at proving the reserve of lumpy hard ore and as such no separate estimate of blue dust was made at that time. However, detailed sampling of boreholes, pits, etc. and tests to determine specific gravity and lump recovery were conducted. Most of the boreholes ended in either hard ore or blue dust.

NMDC carried out further exploration to delineate the orebody for quality control. The work comprises -

1) Detailed geological mapping on scale 1:1000.
2) Additional trial pits in blue dust and float ore-bearing zone.
3) Drilling 60 holes at 100 m grid interval, totalling 4,500 m drilling.
4) Preparing cross-sections from CS-I to CS-XII and bench slice plans.
5) Re-assessment of IBM's reserve.

Drilling covering a total 112,414 m in 178 borehole was carried out in Bailadila iron ore range as a part of the programme of the blue dust investigation in recent years and to update its reserve figures. Besides 39 boreholes already drilled earlier in blue dust zone covering 1,500 m depth, NMDC has drilled 36 boreholes totalling 4,026 m drilling in blue dust zone. All these boreholes were drilled dry with complete core recovery. A total 36 shallow pits (1.5 m x 1.5 m x 5 m) were sunk in different mining benches where main blue dust zone was exposed.

From 36 boreholes drilled, 797 core samples were prepared. Each sample represented 2 m length unless there was a variation in ore characteristics. Besides, 89 composite core samples each representing 6 m length were prepared.

Pit samples from 36 pits were subjected to fractional analysis on different size fractions, i.e. 9.5 mm, 6 mm, 8 mesh, 28 mesh, 48 mesh, 65 mesh, 100 mesh. Individual fraction has been chemically analysed for Fe, SiO_2, Al_2O_3 and LOI for blue dust.

The overall distribution of blue dust is mainly of three types :

Type of blue dust	Distribution %
1) Coarse-grained	3.53
2) Medium-grained	25.88
3) Fine-grained	70.59

This is based on fractional size analysing 6 m composite sample of all boreholes.

3.3.3.2 *Rajhara Iron Ore Mine* [14,17]

Rajhara Iron Ore Mine is situated in Balod taluka of Durg district, M.P. The total lease area is 291.498 ha. Rajhara iron ore deposits along the eastern edge of Dilli Rajhara iron ore belt belong to the sedimentary metamorphic formation of Dharwar age. By exploratory drilling, this complex has reserves of about 200 Mt of iron ore out of which 48.72 Mt are under proved category as on 1.4.1993 and the reserves are likely to last for about 25 years at the present rate of mining.

3.3.3.3 *Mahamaya Iron Ore Mine* [17]

The iron ore deposit of Mahamaya mine is situated at a distance of 108 km from Bhilai in Durg district of Madhya Pradesh. The total lease area is 1,572.67 ha and the whole lease area lies under forest land. The iron ore deposit of Mahamaya belongs to Archean age, and is in Dharwarian system which is associated with lower ferruginous shales and banded haematite quartzite. The general strike of the deposit is N-S while the dip is almost vertical to 60° towards east. The total mineable reserves as on 1.4.1993 are 10.84 Mt.

3.3.3.4 *Rowghat Iron Ore Mine*

Iron ore investigation in Rowghat area[6,18] Narainpur tahsil, Bastar district, was taken up during 1971-72. During 1975-76, large-scale mapping over an area of 2 km^2, 400 m pitting and 2,000 m drilling were done. Subsequently, 18 boreholes amounting to 1,545 m drilling and 40 m pitting were carried out and 1,486 geochemical samples were analysed. Based on the exploratory data, about 190 Mt ore under all the categories has been estimated by GSI. The area is taken up by BSP and the forest clearance is yet to be granted.[18A]

3.3.4 Orissa[19]

Orissa is endowed with vast iron ore resources (3,565 Mt about one-third of the country's reserves). It is proposed to develop a fully mechanised mine at Gandhamardan for annual production of 5 Mt of r.o.m. ore. Recently, the Government of Orissa has taken some positive steps to establish a new iron and steel plant near Daitari with Chinese technical collaboration.

3.3.4.1 *Barsua Iron Ore Mine*

Exploration in all the five areas in Sundergarh district[20] was completed by 1972. As the deposit is geologically not complicated, no additional exploration has been programmed. However, for better quality control, sampling boreholes have been regularly drilled in the quarry benches from time to time. Such drilling is guided by the specific need of mining and therefore cannot be considered as a part of exploration. The exploration of Block C, Taldih sector, which now forms part of the Barsua mine has been completed while exploration work of

Block A is not yet completed.

3.3.4.2 Deposit B,F & G in Malangtoli Block

Iron ore deposits of Malangtoli in Keonjhar and Sundergarh districts[21] form a part of the Singhbhum-Keonjhar-Bonai group of iron ore deposits and occupy the southern tip of the famous horse-shoe-shaped Bonai synclinorium. The pre-Cambrian schistose rocks in which the whole clan of deposit is nested include schists, tuffs, phyllites, basic rocks, banded haematite quartzites, jaspers which have been classified into the iron ore series.

Mithurda, Kriyakudar and Malangtoli in Sundergarh district and Sirkagutu, Kaijoda, Samarsuau, Barhapashi, Pirt Pokhari, Haudiblanga, Rentashahi, Basantpur, Kumarasahi, Mahantasahi in Keonjhar district cover 5,226 ha. In these areas, the exploratory operations were carried out during 1963-1968 by GSI and 1972-76 by NMDC. The salient details of such works are as follows :

Summary of work done by GSI from 1963-68 (14 blocks):

(a) Geological mapping	:	20.0 sq. km.
(b) Total drilling	:	20,826 m in 560 boreholes
(c) Deep pits	:	20 No.; 265.50 m
(d) Shallow pits	:	296 No.; 533.50 m

Summary of work of exploration by NMDC in 'B' 'F' and 'G' Blocks from 1972-78.

(a) Geological mapping	: 11 sq. km.
(b) Contour survey	: 11 sq. km.
(c) Drilling	: 6,997.15 m in 149 boreholes
(d) Aditing	: 30,345 m in 3 adits
(e) Bulk samples drawn and tested on pilot plant scale	: 400 tonnes
(f) Engineering survey for the layout of different plants and shops, colonies siding, etc.	: Completed

After synthesising the results of exploratory activities like various plans and sections, etc. the reserves were estimated. Further, GSI has carried out a total 7,133 m core drilling in the 8 deposits (A,C,D,E,H,I,J,K) by 105 boreholes and established geological reserves of about 100 million tonnes. So far, GSI has drilled 11,250 m in B,F & G Blocks of this area and found that the core recovery is poor. The average grade of lumps is 62.79 % Fe. As the drilling results yielded very poor core recovery, it is necessary that these blocks be subjected to further exploratory activity so as to get more authentic characters of these deposits.

3.3.4.3 Gandhamardan Iron Ore Mines

The Gandhamardan iron ore deposit is situated at a distance of 16 km west of Keonjhargarh town. The nearest railway station is Banaspani at a distance of about 80 km by road. The mine is also well connected with Paradip port by road with a distance of 245 km.

It is being operated by OMC since last three decades. The mine initially covers 4 leasehold areas, namely Gandhamardan Block 'A' (618.76 ha), Gandhamardan Block 'B' (1,590.87 ha), Suakati Block C' (99.81 ha) and Sundermundi Block 'D' (18.21 ha). The blocks A & B have been explored in detail since 1993. While the blocks C & D are devoid of exploitable reserve, exploitation is confined to blocks A & B only.

The Gandhamardan iron ore deposit forms a part of famous Singhbhum-Keonjhar-Bonai belt consisting of metasedimentary formations considered as equivalent to Dharwarian age. The major rock types are gritty quartzite, dolerite, volcanics, tuff and banded iron formation. The iron ore formations consist of banded-haematite-jasper,banded-haematite-quartzite and banded haematite-shale. The formation contains high grade iron orebodies with alternate ferruginous and siliceous bands.

The detailed exploration was carried out at Gandhamardan, Puthulpani and Jagar deposits, details of which are given below:

Gandhamardan main orebody : Exploration in detail was carried out by OMC in Gandhamardan main orebody. Prior to that, no exploration was conducted except preliminary work by GSI. The entire area of 420 km^2 has been surveyed on the scale of 1:15000. The survey work has been carried out by the Survey of India. A topographical map has been prepared by OMC on the scale of 1:5000 covering the ore-bearing area for 4.5 km^2 at 5-m contour interval. The deposit was geologically mapped for 4.5 km^2 on 1:5000 scale demarcating the ore and waste contact, different ore types, laterites, etc. Deep and shallow pits were sunk to delineate the ore and waste contact and to examine the overburden and distribution of different ore types. Total 80 pits were dug, 37 in North Block and 43 in South Block. These pits were dug at 200 m grid intervals. Boreholes were drilled in 10 m square grid pattern with one side of the square parallel to the trend of the orebody by exploratory core drilling. Most of the boreholes have been drilled up to the bottom of the deposit with some exceptions of those closed within the orebodys. A total 6,265 m was drilled in 153 boreholes. In the North Block, 3,342 m drilling was completed at 84 locations while in the South Block, 2,923 m drilling was completed at 69 locations. The average core recovery of all boreholes worked out to be 76 percent. Total 6,474 samples were analysed for SiO_2, Al_2O_3 and LOI out of which 3,487 samples were from North Block and 2,723 samples from South Block. Ten percent lot has been analysed for P & S and 5% for complete analysis. Thirty polished sections of different rock types and 17 polished sections of different ore types have been studied.

Puthulpani deposit covering 0.24 sq.km. has been surveyed on 1:2000 scale by M/s OMC Ltd. The topographical mapping has been carried out at 10 m. contour interval. The entire area has been geologically mapped on 1:2000 scale by M/s OMC Ltd and ore and waste boundaries and other surface, geological and structural features, such as dip and strike of beds, joints, faults, etc. have been demarcated on the geological map. OMC has explored the Puthalpani deposit with the help of core drilling. A total 140 m drilling has been carried out in 4 boreholes. The core samples/logging for each run were prepared and analysed for Fe, SiO_2, Al_2O_3 and LOI. A total 57 samples have ben analysed for Puthulpani deposit. OMC has mapped the upper Jagar area on 1:500 scale demarcating surface geological and structural features and ore and waste boundaries. The deposit has been explored by core drilling. OMC has drilled a total 55 m in 2 boreholes. The core samples for ore types, run-wise, were prepared and analysed for Fe, SiO_2, Al_2O_3 & LOI. A total 57 core samples have been analysed for upper Jagar deposit.

The Surjagarh hill deposit, Gadchiroli district, Maharashtra was prospected by DGM in the sixties. The recent exploration work in Bhandara, Chandrapur and Gadchiroli districts indicated 14 isolated iron orebodies and the probable and possible reserves are of the order of 128 Mt from the Archaean and Proterozoic sequences.[2,3]

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