GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

# Comprehensive Guidelines on PROSPECTING REQUIREMENTS to Satisfy the Provisions of MM (R&D) Act, MCDR and MCR

NAGPUR

June 1994

GOVERNMENT OF INDIA

MINISTRY OF MINES

# INDIAN BUREAU OF MINES

# COMPREHENSIVE GUIDELINES ON PROSPECTING REQUIREMENTS TO SATISFY THE PROVISIONS OF MM(R &D) ACT, MCDR AND MCR

ISSUED BY THE CONTROLLER-GENERAL

INDIAN BUREAU OF MINES, NAGPUR

Price : (Inland) Rs. 30.00, (Foreign) £ 3.50 or $ 10.80

Printed at IBM Press\June 1994\1000

# Preface

According to the provisions of Section 5(2) of MM(R&D) Act, 1957 (amended), it is necessary to prove existence of mineral deposit in an area and according to rule 22(3)(i) of MCR 1960 generate adequate information on the same for preparing a mining plan to be approved by IBM for getting the lease granted or renewed in favour of a lessee. Mining plans, received in IBM under MCR and also under MCDR contain exploratory data which are more often than not inadequate for the preparation of a proper and sound mining plan. To overcome these difficulties, it was felt necessary to formulate comprehensive guidelines on prospecting requirements which may be used in connection with prospecting or exploration work undertaken for the purpose of preparation of mining plans required to be submitted under the above rules. It is hoped that these guidelines would much help in streamlining the processing of mining plans in IBM. The guidelines are of a general nature whose application to the specific site conditions would always remain a matter to be finally decided by the Exploration Geologist or Engineer.

This publication is a compilation which contains details on (i) prospecting requirements as per the outline/guidelines already issued by IBM; (ii) sampling of mineral/ore zones : existing instructions, (iii) identified stages of prospecting/exploration, (iv) exploration for small opencast mines/deposits. These details are supported by Annexures which would act as an exhaustive reference material to guide in detailed exploration activities to be carried out in the identified areas.

It is hoped that the publication will be found useful by the organisations engaged in the exploration of mineral deposits, the RQPs, the entire mining industry in general and also be a valuable reference work for the academic institutions.

The officers connected with the preparation of this publication are Shri M.S. Murthy, Regional Mining Geologist, assisted by Shri S. K. Patnaik, Junior Mining Geologist and Shri M. D. Kalvit, Senior Technical Assistant (Mining) under the overall guidance of Shri O. P. Sachdeva, Chief Controller of Mines, and Dr. R. Chakravarty, Chief Mining Geologist.

The draft publication was edited by Shri R. Namasivayam, Sr. Editor and computerised in floppy by Shri A. N. Sonkusale, Stenographer Grade II.

Nagpur
18-3-1994

**O.P. SACHDEVA**
**Ag. Controller-General**

# Contents

# PART-I : GUIDELINES

## 1. Prospecting Requirements Stipulated under Statutes

### 1.1 Under MM(R&D) Act, 1957 (amended)

1.1.1 Prospecting/exploration requirements laid down in section 5(2) of MM (R&D) Act, 1957 (amended) are as below :-

"No mining lease shall be granted by the State Government unless it is satisfied that -

(a) there is evidence to show that the area for which the lease is applied for has been prospected earlier and the existence of mineral contents therein has been established;

(b) there is a mining plan duly approved by the Central Government for the development of mineral deposits in the area concerned."

1.1.2 It may be mentioned that there is no statutory compulsion for obtaining PL over the area proposed to be applied for ML in the MM(R&D) Act and MCR. This is to provide for the facility for acquiring exploration data from different sources.

### 1.2 Under MCR 1960

1.2.1 The Rule 22 (3)(i), (e) (i) of the Mineral Concession Rules (MCR) 1960 which reads as below also clarifies the details to be incorporated in the mining plan based on prospecting and exploration of the area applied for grant or renewal of mining lease:-

Rule 22 (3)(i) "Every application for the grant or renewal of a mining lease shall be accompanied by

(e) " a mining plan duly approved by the Central Government or duly authorised officer. The mining plan shall incorporate :-

(i) the plan of the area showing the nature and extent of mineral body, spot or spots where the excavation is to be done in the first year and its extent; a detailed cross-section and detailed plan of spot(s) of excavation based on the prospecting data gathered by the applicant or any other person; a tentative scheme of mining for the first five years of the lease;

(ii) details of the geology and lithology of the area including mineral reserves of the area.

(iii) the extent of manual mining or mining by use of machinery and mechanical devices;

(iv) the plan of the area showing natural water courses, limits of reserved and other forest areas and density of trees, if any, assessment of impact of mining activity on forest, land surface and environment including air and water pollution; details of scheme for restoration of the area by afforestation, land reclamation, use of pollution control devices and such other measures as may be directed by the Central or the State Government from time to time;

(iv) (a) annual programme and plan for excavation from year to year for five years.

(v) any other matter which the Central Government may require the applicant to provide in the mining plan;

Provided that in the case of application for grant of a mining lease, the mining plan duly approved may be submitted within a period of six months after the precise area which is proposed to be granted is communicated to the applicant by the State Government;"

1.2.2 Similarly mining plans are required to be submitted at the time of renewal and transfer of lease.

## 2. Prospecting Requirements as per IBM's outline/guidelines issued

2.1 The outlines of mining plan and the guidelines in respect of the outline for the mining plan including environmental management plan were already circulated to all concerned with the approval of the Ministry of Mines. The guidelines issued for preparation of mining plan vide paras 3.0 to 3.5 give the details of coverage on geology, exploration and reserves of the applied area to be incorporated in the mining plan (see extracts at Annexure-A).

2.2 The mining plan is built around the concept of having mineable reserves of 'Proved' category for a period of 5 years at least with an in-built provision for continuing exploration to increase the reliability of the reserves. As this concept was causing some practical difficulties particularly in respect of fresh mining leases, it has been decided that in such cases, mineable reserves can be a combination of 'Proved' plus 'Probable' reserves i.e 'Demonstrated' reserves provided that at least 40% of the reserves to be mined in the first 5 years shall be in the 'Proved' category (the remaining 60% being in the 'Probable' category) in the case of mechanised mining projects, and at least 25% of the reserves to be mined in the first 5 years in the 'Proved' category (the remaining 75% being in the 'Probable' category) in the case of mining proposals other than mechanised mining projects. For categorisation for this purpose, a proposal shall be considered as mechanised mining project if it conforms to the definition of "mechanised mine" as given in the footnote of table under rule 42 (6)(d) of MCDR 1988. The significance attached to the terms 'Proved' and 'Probable' shall be as per the reserve classification given in IS 12595 : 1989 (see Annexure-B).

2.3 Sufficient degree of detailed exploration in the designated mining area shall be undertaken immediately on commencement of mining operations. By this the status of exploration and categorywise reserves estimation is maintained as at the commencement of the mining operations in spite of progressive depletion of reserves. And also sufficient additional categorywise reserves shall be established so that detailed mining scheme for the next 5-year period can be prepared on the same basis at least if not on improved basis as enunciated above, well before the completion of the initial 5-year period of mining.

2.4 In the spirit of the provisions of the rule 14 of MCDR, 1988 which reads "The prospecting and mining operations shall be carried out in such a manner so as to ensure systematic development of mineral deposits, conservation of minerals and protection of environment" and based on careful evaluation of the status of reserves, formulation of scheme of exploration to enable conceptual mine planning for the deposit as a whole and phasewise development and mining of the deposit should be given careful attention. The scheme of exploration should be need-based and its implementation should be phased out with in-built provisions for review, based on the results of exploration at each successive stage and/or progress of mine development".

2.5 The prospecting requirements for preparation of a reasonably good mining plan for the existing mines under the MCDR' 88, in regard to the quantum and quality shall continue to be guided by the contents of above paras 2.2 to 2.4. The existing/operating mines/leases shall make every effort to carry out and complete the Stage-I exploration extending over the entire lease area at least phased out over 2 to 5 year period, if not already done and/or data not procured from the other exploration agencies who have carried out prospecting operations for generating the basic data. At least a part of Stage-II exploration shall also be carried out and completed within the overall perspective of paras 2.2 to 2.4 and 3.1 of these guidelines. Concentration of stage-II exploration/detailed exploration should be in the areas in and around the operational area/working quarries depending on the extent of information available from the opened up quarries, to estimate the reserves to meet the requirements as laid down in para 2.2 above. The prospecting/exploration operations shall be phased out within the overall spirit of rule 14 of MCDR and as elaborated in para 2.4 above.

2.6 While the exploration in opencast workings mostly attempts to improve the confidence levels of the available resources and making available the proved reserves to meet the future production programmes, the exploration in respect of underground workings shall aim at maintaining a balance between the production requirement and the rate of stoping, rate of stope preparation, rate of preparation of stope blocks and keeping enough developed/proved reserves ready for preparation of stope blocks. Depending on the situation the above rates may need be identified in terms of quantum/volume of exploration or linear meterage of development. The ratio and proportion of the quantum of different operations enunciated above shall vary with deposit, methods of underground development and stoping operations. Simultaneously, an appropriate exploration (surface/underground) may be initiated for augmenting the reserves from the concealed/blind ore zones.

2.7 While case studies should have been more appropriate for fixing up the optimum levels of production and development in the case of underground mining operations, it is felt that individual mines may have to be dealt on a separate footing based on the productivity norms and economics thereof in respect of the concerned units.

2.8 The scheme of exploration should reflect the geological and structural complexities of the deposits and lead to establishment of classifiable reserves as specified in IS 12595 :1989. Weightage should be given to the quality of information obtained /collected from the drill holes, pits, trenches, etc. Proper siting of location of drill holes, etc. common co-ordinates system for plans, borehole inclination and their survey for azimuth, core recoveries, etc. are of great importance. It may be cautioned that whenever steep dips are encountered, e.g. $+65^{o}$ the results of vertical drill holes should be accepted with circumspection. It is preferable to drill inclined holes wherever formation dip is at angles greater than $40^{o}$-$45^{o}$ from horizontal. Core sampling procedures adopted should be checked based on the guidelines elaborated in Annexure-C.

2.9 The mining plans are to include conceptual mining plan envisaging the ultimate pit limits/ boundaries and the overall in situ, and also include, mineable reserves and anticipating life of the mine (to be determined on the basis of the techno-economics of mining in depth) along with sequence of extraction, waste dumping sites, etc. and overall exploration requirements. In determining the ultimate pit limit boundary, a final slope angle between $30^{o}$ and $60^{o}$ would be applicable in a large number of cases, but where pronounced ground stability problems are involved, geo-technical investigations may be necessary to determine the slope angle/design of the ultimate pit limit.

## 3. Sampling of Mineral/Ore Zones - Existing Instructions

3.1 Systematic and reliable chemical and physico-mechanical analysis data is basic to the preparation of a mining plan. The mineral/ore zones exposed in the working quarries should be sampled over its entire width at suitable intervals along the strike length. The samples may be sub-divided wherever geology differs, or and visual differences in ore types/grade variations are observed. The mineralisation exposed in the face should be preferred for locating the sampling points and in case the drawal of face sample is otherwise difficult or impractical then only floor sampling may be carried out after cleaning the floor properly. Appropriate corrections for apparent and true widths may be incorporated where necessary. Sample locations should be shown on plans and sections for appropriate correlation of grade variations along with the widths(true).

3.2 Samples so collected shall be analysed for major radicals in respect of all samples and 20 to 25% of the samples must be analysed for all the radicals necessary for determining the end-use of minerals/ores. 5 to 10 percent of the samples should be analysed for possible associated minerals/trace elements/minor metal contents, wherever warranted. The details of radicals to be analysed for different minerals are given at Annexure-D.

## 4. Stages Identified in Prospecting/Exploration

4.1 In consonance with the spirit of provisions of the MM(R&D) Act, MCR and other regulations, the exploration requirements shall be commensurate with the production plans and pattern of mineral utilisation and may be classified into two stages :-

**STAGE-I :**

4.1.1 Preliminary exploration spreading over the entire leasehold/area applied for (essentially designed to evolve a conceptual mining plan for the total period of the lease or life of the deposit) comprising detailed surface geological mapping on appropriate scale and minimum exploratory openings to suffice for a rapid evaluation of tonnage and grade so as to result in an estimate of the in situ mineral reserve at least under possible category. Where mining has been done in the past in the area in question and/or in adjoining area in its vicinity/incorrelatable distances or sufficient escarpments/nallah cuttings exist to provide necessary information, the need for such exploration may be minimised.

**STAGE-II :**

4.1.2 Detailed exploration will be required over an identified portion of the area (leasehold/applied area) to be covered under production programme for the initial five years and the ensuing period to be implemented phasewise, essentially designed to determine mineable Proved and Probable categories of reserves for supporting the production requirements of the first and the ensuing five-year period, in accordance with the stipulations made under para 2.2 above. The basic data on configuration for estimating the area and volume of the mineralised zone, average chemical analysis, grade distribution, recovery factors of saleable/usable grade of mineral extent & distribution of marginal & sub-grade minerals, if any, Rock Quality Determination (RQD), hydro-geological and beneficiation characteristics where necessary, etc. should be collected during this stage.

4.1.3 It will be seen from the above that before commencement of actual mining, the Stage I and at least a part of Stage II exploration should have been completed. Where requisite exploration has not been carried out and reserves not estimated in accordance with the stipulation given in para 2.2 above, the same shall be carried out and completed upto the satisfaction of IBM before commencing actual mine development and regular production work as a part of the mining plan, provided that at least reserves in the probable category sufficient to sustain production in the first five years are already available. On the other hand, where sufficient reserves in the probable category for the five-year period of mining do not exist already, prior additional exploration shall be necessary before mining plan can be prepared and approved.

4.1.4 Mineral production in the ensuing 5-year period shall determine the quantum of exploration and guide exploration activity.

4.1.5 The anticipated economic depth of working has a strong bearing on intensity of exploration to be undertaken at depths. Therefore, at the outset an attempt shall be made to arrive at such optimum depth of the pit/quarry proposed to be developed or being developed which shall be guided by techno-economics of optimum extraction of available mineral wealth in depth in the property. Exploration up to such depth may be conducted in one or more stages. The approach and methodology to be adopted for the same should be indicated in the mining plan in the form of over all exploration strategy where the mineral deposits extends further in depth i.e. below the economically mineable depth, the depth persistence shall be ascertained by test drilling/pitting at one or two selected locations till the ore body bottoms before the pit or quarry reaches the optimum depth as determined above.

## 5. Guidelines for Exploration of different Minerals

5.1 General guidelines for exploration of different minerals extracted from IBM's publication "Elements of Mineral Exploration" (1980) (incorporating some amendments) is placed at Annexure-E, for information. However, the following may be clarified in this regard :-

5.1.1 The above set of guidelines are in respect of primary mineral occurrences in virgin areas and wherever old and/or existing workings with dependable relevant exploratory data and records are also available, the requirements of exploration would get reduced commensurate with the amount and quality of data available.

5.1.2 The above general guidelines may be viewed as a composite set, to be followed sequentially. The requirements in individual cases may vary and involve the use of two or more of the methods enumerated depending on the scale of mining operations, the level of mechanisation and the intricacies of the geological and mining parameters.

5.1.3 Sampling procedures to be followed and the radicals to be analysed in respect of different minerals and ores shall however conform to Annexures-B & C, and

5.1.4 The quantum of exploration to be undertaken on the basis of these guidelines will be guided by the principles enunciated in paras 2.2 and 4.1 to 4.1.5 above.

## 6. Exploration for small opencast mines/deposits

6.1 Exploration requirements in the case of mining plan of small opencast mines without beneficiation facilities shall continue to be guided by IBM's circular No.3/91 dt. 17.9.91 issued under file no.N-11013/64/MP/89-CCOM and the relevant extracts are reproduced below for ready reference.

"Geological information of the mineral deposit gathered from old or existing workings, nalla cuttings and outcrops/escarpments, examination of the adjoining mines, if any, and as also study of the regional geology of the area through reconnaissance by an experienced geologist accompanied by chemical analysis of adequate number of representative samples from the unweathered zones along with detailed geological mapping of the area can be considered adequate for assessment of reserves for the purpose of mine planning in case of regular, bedded outcropping deposits of simple nature, i.e. without appreciable structural disturbances or geological complexity and with, more or less, uniform tenor or grade distribution (if duly established on the basis of such an examination) in the case of small lease area with limited scale of operations. However, in all other cases, there may be a need for more formal exploration involving trenching, pitting or drilling as per the needs".

"Mining operations will be allowed to be carried out for the first five years provided mineral reserves for this period have been established on the basis of outcrops,etc. as mentioned above. However, minimal exploration involving deep pitting and/or non-core drilling/core drilling, as may be necessary for preparing a conceptual mining plan for the entire lease period as also for planning mining for the next five years' period (in case necessary on genuine technical reasons) should be provided for and included in the mining plan, for carrying out the same concurrently over the period of five years of actual initial mining with further exploratory work spread over the remaining life of the mine in accordance with the future production plans".

# PART - II: ANNEXURES

**ANNEXURE-A**

## EXTRACTS/FROM THE GUIDELINES REGARDING GEOLOGY, EXPLORATION & RESERVES ISSUED TO RQP'S FOR PREPARATION OF MINING PLAN

### 3.0 Geology & Reserves

This will indicate the location of the deposit with latitude and longitude (with Survey of India Toposheet Number), broad physiographic features, lithological formations encountered, structural features, nature of mineralisation and a short summary of the earlier work carried out, if any. The object for which the property is being developed may please be indicated.

**3.1 Physiography**

This should contain a description about relief of the area, such as prominent physiographic features, drainage pattern, PWD road passing through the area, natural water courses, situation of villages, forest areas and agricultural land.

**3.2 Geology**

Summarised account of the regional geology of the area such as lithology, succession of rocks, structural disposition of the ore body, the controls of mineralisation, effects of weathering, nature of the wall rocks, their physical and chemical characteristics, dip and strike of the mineral deposit and wall rocks.

**3.3 Details of Exploration**

**(i) Already carried out in the area**

It should contain a description of the exploratory operations such as pitting, trenching, aditing, boreholes, their spacing, quantum of work carried, method of sampling and analytical results. In case of core drilling, collar level, inclination, depth of drilling, mineral/ore intersection, core recovery and lithologs, should be given in a statement form.

The results of the exploratory operations should be synthesised and brought out in the form of geological map of the deposit on the topographic map of the lease area prepared on a scale of 1 : 1,000 or 1 : 2,000 and contour lines at an interval of 3 to 10 m depending upon the topography of the area. At strategic point cross section should be prepared on a scale of 1 : 200.

**(ii) Proposed to be carried out**

The future programme of exploration may be broadly indicated taking into consideration the future production programme.

**3.4 Method of Estimation of Reserves**

This should broadly take into account the physical limits of the ore body such as strike, width and the probable depth extension, structural behaviour and the control of mineralisation, cut-off grade and recovery. Based on the experience gained at the time of exploration the reserves may be classified broadly into proved, probable and possible categories. In opencast workings the reserves held for every successive slice, the thickness of each slice should correspond to the height of each bench may be indicated. In underground workings levelwise reserves need be given.

**3.5 Geological Reserves and Grade**

Based on the exploration work carried out a broad estimate of the reserves and grade may be indicated including submarginal grades up to the geological limits of the ore body.

# Indian Standard
# CLASSIFICATION OF TERMINOLOGY FOR EXPLORATION OF MINERAL DEPOSITS
## Section 1 Reserves and Resources

## 1 SCOPE

This Section 1 specifies the definitives for a classification of terminology pertaining to reserves and resources of economic mineral deposits subjected to appraisal through mineral exploration.

## 2 CRITICAL DEFINITIONS

Five critical terms are being enunciated for appreciation of the terminological classification laid down in this standard. The scheme of classification thus envisaged, has been designed with due consideration towards the intensity of exploration and hence it has achieved the degree of certainty in assessments made thereof. The critical terms are as follows.

### 2.1 Ore

A solid and natural aggregate of one or more minerals, from which one or more metals or economic minerals can be extracted profitably and may encompass industrial minerals and rocks, for example, clays, abrasives and salt.

### 2.2 Deposit

An anomalous portion of earth's crust, where natural incidence of minerals or metals is high enough over the normal crustal abundance to be economically mineable.

### 2.3 Resource Base

A subjectively projected order of tonnage of ore minerals with least data on prognosis but with optimistic interpolations of alternative geological interpretations, so as to form the broad canvas for any long term planning.

### 2.4 Resources

A concentration of solid, liquid or gaseous materials on earth or any other celestial body in such form that commercial extraction of the commodity is either possible at present or feasible within the foreseeable future, through a technology which has either existed on the drawing board or has found application on laboratory scale.

### 2.5 Reserve

A calculable tonnage of ore or metal including those that are believed, though not conclusively established, to exist within given mineralized boundaries and divisible into the categories of 'Developed', 'Proved', 'Probable and Possible', depending upon their degree of assurance on existence [see IS 5028 : 1969 Glossary of mining terms (planning & surveying)'], as perceived from a higher to a progressively lower order, inferred from geological appraisals.

## 3 RESERVE CLASSIFICATION

Reserve of ore being a connotation of calculable tonnage with variable degree of assurance on the estimates, warrants a classification devised with greater exactitude in definitives. A four-fold classification, as under, should cover adequately.

### 3.1 Developed Reserve

3.1.1 This category includes the very best of the economically exploitable sections or parts of the deposit wherein, the degree of geological assurance on tonnage, grade and other physico-chemical -cum-metallurgical parameters are decidedly the highest. These reserves should be blocked out and be kept ready for immediate exploitation with quality and quantity estimated on mine development preparatory to industrial production. Ore blocking out is to be in suitable dimension, guided by the nature of physico-chemical characters of the deposit including beneficiability, if needed, as well as the method of working to be adopted in actual mining; with developmental mining carried out preferably on four sides of the block thus designated. Open-cuts, and/or cross-cuts for a systematic sampling must be provided at suitable and regular intervals. The error of estimation of tonnage should not exceed 10 percent.

3.1.2 Samples collected from open-cuts and cross-cuts should be subjected to laboratory scale and pilot plant tests for determination of process parameters, namely handling, communition, beneficiation, agglomeration, for the ore. The reserve estimate has to be based upon cut-off grade which could sustain the current industrial requirements. Ore below the cut-off as well as the waste rock within the ore body, have to be sized up with commensurate degree of assurance in reference to mode of distribution and the relation with mineable ore. It is desirable that reserves, grade and waste quantity are indicated benchwise or levelwise for facilitating production planning and quality control system during the mining period to follow.

3.1.3 If the best known part of a deposit is not to be taken up for immediate mining for any geological, techno-economic or marketing reasons, or alternatively if some part of the deposit was partially mined in past and with further exploration acquired higher degree of assurance though not being set for immediate mining; even then the term 'Developed Reserve' should be applied for the reserves thus estimated and may include recoverable reserves as in vogue for the tonnage being ushered in for concurrent exploitation.

## 3.2 Proved Reserve

This category will have to encompass conclusions on all main geological aspects of the deposit or part thereof, in matters such as tonnage, grade, physico-chemical and metallurgical parameters. Though strictly a geological ore reserve, the reserve included herein, must have total evaluation of the type of occurrence, shape and structure of the deposit including attitude and tenor, etc. in different segments of the blocks under the purview of 'Proved Reserve'. The configuration of the mineral body should be defined by adequately spaced boreholes and/or exploratory openings. The information collected should be sufficient to facilitate preinvestment decisions on production planning, mine development, capacity projections and preparation of feasibility records with techno-economic options, alternatively delineated after studies on anticipated recoverable mine produce. The error of estimation in tonnage should be in the range of 10 to 20 percent.

## 3.3 Probable Reserve

This category implies a clearly lower status to the ore reserves in terms of degree of assurance, in spite of being still within the direction of economic considerations. Here the tonnage and grade are computed, based partly on the data retrieved from 'Developed' or 'Proved' blocks on extensions and partly from geological knowledge of analogous ore or mineral bodies within the metallogenetic province or epoch. This category thus must include the currently non-produceable parts of the deposits being exploited, developed or under feasibility study, besides the deposit which too may become producible with marginal improvements in economic and/or technological fronts. Peripheral portions of large iron ore deposit could exemplify the former while medium to small base metal prospects of India could illustrate the later kind of probable reserve, provided mineral exploration has been undertaken commensurate with desirable accuracy of vital conclusions thus enumerated. The error of estimate of tonnage should be in the range of 20 to 30 percent.

## 3.4 Possible Reserve

This category includes reserves estimated after exploration which may suffice for a rapid evaluation of tonnage, grade and physico-chemical characters of a deposit; based on assumed continuity of ore from geological evidences and/or widely spaced exploration openings, corroborating geophysical/geochemical survey data, large-scale geological maps and/or rather disconnected surface informations from pits, cliff sections, mine faces and similar suggestive interpretations; if available. The 'Possible Reserves' may have an error level of 30 to 50 percent.

# 4 RESOURCE POTENTIAL

This includes tonnage estimates and grade prediction, etc., made on mineral bodies, which may be taken as incidences, prospects, reported occurrences, suspected emplacements on geological premises or hypothetical and imaginary ore bodies, not necessarily established to conclusively to be existing. Thus the 'Resource Potential' will enfold within its ambit, both 'Resource' as well as 'Resource Base' and shall have futuristic implications rather than present day utility.

# 5 CONFIDENCE OF ESTIMATION

5.1 Classical statistics based upon the concept of randomness of sample input and geostatistics based upon the concept of regionalization in geological variable have varied approaches to resource evaluation. The techniques of treating sampling data from geologically chosen points or mathematically decided spots of drawing, shall be realistically applied to project into the realms of the unknown and would end up in reliable forecast. The techniques in this field are too exhaustive for enumeration or even exemplification. These also change both with respect to the nature of the geological model, namely, the deposit, as well as with the individual judgements of the experienced geoscientists. The confidence level of these estimation thus have variations, both natural and generated.

5.2 Statistical approach for estimating the reliability in a quantified manner is also an applied field within the domain of ore reserve estimation. The error standardisation in a porbabilistic model has been receiving impetus, due primarily to the increasingly large investment in planned projects and the consequent risk hazard inherent with mineral deposits. The adjudication of quantified risk factor before an investment decision, has been greatly facilitated with modern statistical techniques on treatment of samples and their results. The methodology in vogue has a much diversified application.

**ANNEXURE-C**

# SAMPLING

## 1.0 DEFINITION

1.1 "Sampling is the process of taking a small portion of an article such that the consistency of the portion shall be representative of the whole" - (Baxter and Parks).

## 2.0 OBJECTIVES

2.1 The different types of mining geological studies expected to be carried out would not be complete unless mineral assemblages in rocks and ores in a mine are fully identified.

## 3.0 GENERAL PRINCIPLES

3.1 In all cases of sampling, it has to be ensured that a sample drawn for the purpose of laboratory study is truely representative of the entire body. In order to attain this, it is necessary to choose proper places for sampling. Any sample representing a very rich ore portion, or a lean portion of an ore body loses its representative character. Theoretically, different samples collected from various parts of the ore body can be combined into a single composite sample to give a representative picture of the whole ore body. This, however, is not proper since it is also necessary to know the average grade of rich and lean portions of the ore body separately. Hence it would always be adviseable to mark the site for samples and width of the sampling area on a plan of the area/mine before actual field work relating to sampling.

## 4.0 ESTIMATION OF SAMPLE SIZE

Geological samples have often to be collected from heterogenous masses. Materials particularly when loose, tend to be mixed, the individual particles showing great diversity in sizes. A representative sample should have proportionate amount from each fraction. In order to achieve this it is adviseable to follow the Richards-Chechette procedure which generalizes the amount of starting sample to be collected to achieve this proportionate representation. The procedure is as given below :

Richards Chechette formula reads, $Q = KD^2$

Where Q=Reliable weight of the sample in kg.

D = Diameter of the largest particle in the sample in millimeters.

K = Factor of homogeneity which will have values as shown in table 4.0.

**TABLE 4.0**

**HOMOGENEITY OF ORE**

| Sl.No. | Ore Type | Factor of Homogeneity(K) |
|---|---|---|
| 1. | Homogeneous | 0.05 |
| 2. | Non-homogeneous | 0.10 |
| 3. | Very non-homogeneous | 0.20 to 0.30 |
| 4. | Extremely non-homogenous | 0.40 to 0.50 |

4.1 The constant K is determined on the basis of the irregularity of distribution of the ore constituents of the concerned material. Table 4.1 gives certain worked out examples of sample sizes which can be followed.

## TABLE 4.1
## THE QUANTITY OF SAMPLE REQUIRED AT DIFFERENT SIZES OF THE LARGEST PARTICLES IN THE SAMPLE (BASED ON FORMULA $Q = KD^2$)

| If the size of the largest piece (D) is (D) (mm) | $(D)^2$ (mm) | Then the quantity of sample in Kg to be collected for material of various homogeneity will be — Homogeneous (K = 0.05) | Non-Homogeneous (K = 0.10) | Very non-Homogeneous (K = 0.20 to 0.30) | | Extremely non-Homogeneous K = 0.40 to 0.50) | |
|---|---|---|---|---|---|---|---|
| 200 | 40,000 | 2,000.00 | 4,000.0 | 8,000.0 | 12,000.0 | 16,000.0 | 20,000.0 |
| 150 | 22,500 | 1,125.00 | 2,250.0 | 4,500.0 | 6,750.0 | 9,000.0 | 11,250.0 |
| 125 | 15,625 | 781.25 | 1,562.5 | 3,125.0 | 4,687.5 | 6,250.0 | 7,812.5 |
| 100 | 10,000 | 500.00 | 1,000.0 | 2,000.0 | 3,000.0 | 4,000.0 | 5,000.0 |
| 75 | 5,625 | 281.25 | 562.5 | 1,125.0 | 1,687.5 | 2,250.0 | 2,812.5 |
| 50 | 2,500 | 125.00 | 250.0 | 500.0 | 750.0 | 1,000.0 | 1,250.0 |
| 25 | 625 | 31.250 | 62.5 | 125.0 | 187.5 | 250.0 | 312.5 |
| 12 | 144 | 7.20 | 14.4 | 28.8 | 43.2 | 57.6 | 72.0 |
| 6 | 36 | 1.80 | 3.6 | 7.2 | 10.8 | 14.4 | 18.0 |
| 3 | 9 | 0.45 | 0.9 | 1.8 | 2.7 | 3.6 | 4.5 |

NOTE = If the final quantity of sample is as shown in the above table (i.e., two opposite quarters from the final core) remember that the last core will be double the above quantity and that much material should get broken to the required size.

4.2 However, it is not necessary that in any given circumstance the size of the starting sample will be according to its size distribution. In such cases the sample should be sized down to a smaller size and the weight to size ratio as per formula should be established at the first stage of sizing.

4.3 On the basis of the Richards-Chechette formula the starting size of samples can always be worked out. This is the minimum sample that should be collected to make it truly representative of the mass. Sometimes it becomes necessary to increase this sample size because the basic requirements of the pilot plant may be a few hundred tonnes but the representative sample may be only a few tonnes. This needs to be carefully examined and it should be ensured that the starting sample gets a chance to be mixed, coned and quartered at least twice to arrive at the desired sample which is to be sent for beneficiation studies.

## 5.0 EQUIPMENT FOR SAMPLING

5.1 A set of proper equipment is needed for sampling. A list of the basic items are as given in Appendix-I. However, it may be noted that for collection of large samples particularly from ROM and dumps, additional equipment will be necessary which should be improvised by the mining geologist in the field itself.

## 6.0 TYPES OF SAMPLING

6.1 Many types of sampling can be recognised. In the work of the IBM the following types of sampling are usually considered. (i) Grab sampling, (ii) Channel sampling, (iii) Chip sampling, (iv) Bulk sampling, and (v) Borehole sampling.

**6.2 Grab Sampling** : This is done from different blasts at the faces or small stacks of ore or dumps at random for information of a very general nature. Care should be taken to see that material of varying sizes is collected according to its proportion by weight in the blasted material or the stacks or dumps as the case may be. Several such grabs are mixed together to form a sample.

**6.3 Channel Sampling** : In this sampling a channel is cut across the face of the exposed ore, and the resultant cuttings and chips are collected as sample. The surface to be sampled is first cleaned to remove dust, soluble particle, etc. A thin layer of the exposed ore may be removed to avoid cutting the weathered ore. Then a channel outline, 5 - 10 cm in width and extending from the footwall to the hanging wall of the ore body, is drawn by a chalk or paint. Then, the channel is cut by a moil and hammer to a depth which should be equal to the width. The resultant pieces are collected carefully on a clean sheet of canvas or any other convenient receptacle. The sides and the floor of the channel should be smooth and uniform so that overcutting (and over representation) is effectively minimised. The channel may be divided into 1 to 2 m section or their multiples in the case of massive and more homogeneous ore bodies, or section of 30 to 50 cm in the case of more heterogeneous distribution and may be separated as per the physical characteristics of the ore.

**6.4 Chip Sampling** : When values are regularly distributed as in an iron ore outcrop, chip sampling can be very useful. In chip sampling, first the outcrop or face to be sampled is cleaned properly and a regular, rectangular or square pattern is made by drawing lines and along and across the outcrop at fixed intervals. Then, small pieces of ore are broken loose either from the centre of the grid or rectangle or at the intersection points of the lines. The ore pieces should have approximately the same shape, size and weight. After collecting the pieces are mixed together to form a sample. In case of highly unpredictable values, the practice of shifting the grid by half the width or /length of the grid is adopted to get another set of samples which may be treated independently and compared with the first set of chip samples.

**6.5 Bulk Sampling** : Bulk sampling is done in two specific cases. One situation is when a pilot plant test is to be done on an ore. The other is when an irregularly distributed constituent of the ore has to be determined accurately. Bulk samples may be made by collecting a portion from every blast continuously, or from shovels or cars in the case of mines. Bulk samples may be collected from a series of pits or a number of trenches, adits or underground drives in the case of prospects. For technological studies covering laboratory scale beneficiation tests, a bulk sample may be 100 to 250 kg in weight. In some complex ores samples up to 1,000 kg may be necessary whereas for pilot plant tests samples of 50 tonnes of material would be usually required. Bulk samples may be collected from dumps also. In all these cases the heterogeneity of the material should be studied and starting sample sizes worked out. The total volume of the starting sample should then be distributed to various separate openings, mines, dumps, etc. on the basis of desired proportions.

**6.5.1. Sampling of Rejects** : The sampling and screening play a very crucial role as these tests generate valuable information on grade and size rejects. The methodology for drawal of samples and screen testing is a complicated process. Details of for a few important minerals are given in Appendix-II as examples. Principles of sampling have already been discussed. In addition the following points may be kept in view :

i) Each pile of rejects should be thoroughly mixed for preparation and drawal of sample

ii) Stacks of a square base area on a fairly level ground and with maximum height of about 0.6 m may be made. The top surface of stacks should be levelled, as far as possible

iii) In case of stacks of 3 m x 3 m x 0.5m or less, five points for sectional sampling should be selected, one at the centre and four near the four corners but well inside the stack. Sample should be collected from each point by taking the whole section of the stack from top to bottom within area of a circle of 25 cm diam. In addition, one scoop of about 25 cm width and 20 cm depth should be made from top to bottom from the mid points of all the four sides. Entire material from the scoops is to be collected

iv) In case of stacks of area larger than 3 m x 3 m size sampling and scoop points should be suitably increased.

v) Entire material drawn from sectional and scoops points may be mixed together to make one sample of the stack. This sample is then subjected to screen analysis followed by preparation of samples from each of the screen fractions, adapting standard method of sample reduction. Weight of each fraction may also be recorded etc. Sampling of rejects for a few typical minerals is given in Appendix - II.

**6.6 Bore Holes Sampling** : Bore holes are drilled for collecting samples from various concealed parts of an ore body. Basically two types of materials come out of drill holes : (i) solid core, and (ii) cuttings of various types dry or sludge.

**6.6.1 Sampling of Solid Core** : After recovery of drill cores and their placement in a proper core box lithological logging is done to identify various formations broadly and also to identify various parts of the ore zone in detail. The selection of core for analysis has to be done with meticulous care. For this purpose the first and foremost necessity would be to recognise hangingwall and footwall of an ore body. In most of the cases samples may be drawn between hangingwall and footwall of any ore body to study the ore zone in detail. If the ore zone is uniform in character, i.e. it shows almost similar lithology it will be better to adapt a sampling technique which will give randomness to the sub samples. The whole core is seldom analysed together. With increasing emphasis on statistical processing of drill core analysis it has become a standard practice to take one metre length core (or a convenient equal sample length) for one sub sample. It has been found that this technique is robust enough and ensures randomness. In most cases, first and foremost the core from the ore zone is divided into one metre segments. This will normally leave some extra core length either in the footwall or in the hangingwall, which have a length less than one metre. This may be allowed to remain as such. After marking the one metre segments the core is cut into one metre length pieces and then split into two pieces longitudinally. In case the core is required for chemical analysis, geotechnical studies and ore dressing investigations (as are increasingly becoming the case) then it will be required to split the core into four equal segments, longitudinally. This is done by using a core splitter. First the core is split into halves, and then one split half is again split into two halves. Thus there are three split samples, one half split and two quarter splits. One quarter split sample is sent for analysis while the half core and the ramining quarter core are preserved for future use. The quarter split sample for chemical analysis is sized down in a pestle and mortar to 0.10 to 0.15 mm size and a sample of 220 gm is taken by coning and quartering. The remaining is kept as a duplicate for future use. The aim is to preserve as much of the core material as possible so that further verification and testing can be carried out in case of necessity without having to drill further bore holes in nearby sites.

**6.6.2 Sampling of Sludge** : Sludge is the cutting brought out by return water from the drill hole during drilling. Sampling of sludge is necessary when frequent core losses are experienced during drilling. There are various arrangements for sludge collection which are available with the core drill. In the process of collection of sludge and its sampling the following points may be kept in view :-

i) The sludge (in each case) should correspond to the exact core length from where core loss has occurred. This required a certain amount of precise collection which can be done by proper supervision at the drill site. Care should be taken to see that the sludge is not lost which often happens when drilling is in loose formation. However, it may be noted that sludge collection may be done only in very exceptional cases when due to factors beyond the control of the drilling engineer core losses are formidable. It is necessary to note that core and sludge cannot be averaged by weight. There is a separate procedure for combining core values with sludge values which is generally done by the following formula.

$$A = \frac{C}{L} \times \frac{D_1^2}{D^2} \cdot (A_1 - A_2) + A_2$$

Where A = Average assay

C = Recovered core

L = Length of the hole (relevant to the calculated portion)

D = Diameter of the hole

$D_1$ = Diameter of the core

$A_1$ = Core assay and

$A_2$ = Sludge assay

**6.6.3 Sampling of Drill Cuttings** : Drill cuttings may be of two types.

i) Cutting produced by normal small diameter drills and

ii) Cuttings produced by blast holes. In the latter process large volumes of sample material will be available. In sampling of ordinary cuttings, procedure followed for making segments, etc. may be done as prevalent in the case of core (or a convenient equal sampling lengths) for every one metre, there may be one sample. A difficulty normally experienced in sampling of cutting is that it gets mixed up with those of hanging and footwall materials. Further, sample materials of contiguous segments get mixed up. Therefore, such sampling should be done by the geologists at the site itself ensuring that materials taken out of the drilled bore hole or cutting receptacle are representative of the segment through which the drill bit had passed through. Cuttings may be analysed totally after sizing, coning and quartering down to the laboratory size of the whole material in a pestle and mortar as was mentioned in the case of core sampling. Sampling of cuttings from blast holes is a specialised job. This may be done by allowing the cuttings to accumulate around the collar of the borehole. The material accumulates in the form of a heap around the collar. This methodology is used only in active opencast mines and should be used only for augmenting already existing core results. In the normal case it is difficult to segmentise the sample. The whole sample also cannot be treated because there will be hundred of kilograms or in some cases a few tonnes of materials. Therefore, it is necessary to collect samples from cuts which can be formed on the wall of the heap after removing some portions by shovels. The materials in such cases being loose, cutting a channel or a groove is often difficult. However, with a little care uniform grooves can be cut and uniform amount of material can be removed. Usually, one or two samples from each heap may be collected separately. They may be combined for processing and chemical analysis.

## 7.0 PROCESSING OF SAMPLES

7.1 It is necessary to bring the size of the sample down to the requirement of the laboratory or test facility as the case may be. The material can be sized and reduced by coning and quartering. A flow chart for this is given in Appendix-III. Although the chart is for a relatively small sample, on a similar basis other charts can be worked out for smaller samples as well as for larger samples giving due weightage to the ratio of the size to total sample volume at every stage.

7.2 In the case of bulk samples from ROM, rejects and dumps it will be advisable that the sample is stored in a prepared even surface preferably with a concrete base and covered by fresh clean tarpaulin. The various sub-samples will be examined and first and foremost the larger fragments will be broken down to a uniform size. After this sizing the material can be mixed. A central heap can first be made of all the material. The first heap may be spread out and flattened and a central depression may be made by working the sample to all the four directions uniformly, then the material can be reheaped. This can now be repeated by pushing the material diagonally and then again reheaped. This may be done repeatedly 2 to 3 times to ensure proper mixing of all the material. Mechanical device like frontend loader, etc. if available can be made use of in this operation. If coning, and quartering is possible then this may be resorted to. Size reduction may also be achieved by a process of random shovelling. This can be done by handling the material by shovels and collecting material for the final sample by saving one shovel out of every so many. This can be mathematically worked out depending upon the total weight or volume of the starting sample and the total weight required to be sent for studies. Here again mechanical devices can be made use of in order to save time and labour.

## 8.0 ERRORS AND PRECAUTIONS

8.1 It has been observed earlier that sampling is subject to various types of errors, the most important sampling error relates to salting of samples. This error can easily be avoided. It is observed that such errors are generally made inadvertently. By observing precautionary practices the inadvertent type of errors could be avoided. The important points are discussed below:

8.2 Mixing up of extraneous material with a sample is a common source of salting. Extraneous material may be from any source, the most common source being from other samples. Take for example a channel is being sampled in sections. If the canvas is not properly cleaned after collection of one sample then the remnants of previous sample on the canvas may get mixed up with subsequent samples. This can happen during the processing of samples at various stages, such as sizing, coning, quartering and even bagging. For avoiding this error it may be ensured that after each sample is handled the receptacle should be properly cleaned so that all remnants from earlier samples are fully removed.

8.3 Errors which are common to sampling may also come from unsystematic sampling practices. The usual problem will be about the size of the sample groove or the size of the individual chip. It is therefore, necessary that size of sample groove and also size of chips will have to be standardised and properly maintained for all samples at all times.

8.4 Collection of samples should be done with adequate care in all cases the collected sample should be kept on canvass or metal sheets prior to processing. Collection of samples from a dump is a relatively difficult task, sometimes calling for extensive excavations. The best method of collecting samples is by sinking pits from the top to the bottom and digging out all the material. The pit may sometimes yield samples which are larger than required in which case the material should be reduced to the appropriate size by coning and quartering. Pitting of very big dumps particularly on hill slopes should be done with adequate safety precautions to protect the life of sampler and also to maintain the integrity of the sample. Since the material is loose there will be always a tendency for it to slip down the excavation. This can be prevented by driving boards. Methodology for this is described in IBM's Publication, Bulletin No. 9, Elements of Mineral Exploration (pages 120 to 123).

8.5 It needs to be mentioned that systematic marking and maintenance of proper ledgers, and accounts about movement of sample from site to sampling shed and to different analytical agencies will ensure reliability of the analytical and other results. Labelling of the sample bags should be carefully done in such a way that the sample label never gets mutilated or crumbled during the process of long storage. Good durable material should be used for the purpose of labelling. Sample bags should have double lining. The inner lining may be of polythene material and the outer covering may be of cloth or another packaging material such as hessian or plastic or PVC material which are available in the market.

8.6 Sampling is subject to certain limitations due to sampling errors. Sampling errors may be of two types (i) random, and (ii) systematic. Of these, the random errors have lesser danger as it tends to cancel out each other whereas systematic errors accumulate to create gross errors. The errors accumulate due to four factors:

i) When check samples are taken from the same spot, there will be a natural divergence between the value of the principal sample and the control sample. This cannot be overcome.

ii) Errors accumulated due to measurement errors, poor facilities and equipment which can happen in remote areas and poor eye judgement of the sampler,

iii) Errors due to mistake in calculations, misprints and poor numbering, and

iv) Limitations of the assaying technique itself.

8.7 Of the four types of errors indicated above, the first two are random errors and the other two are systematic errors. In addition, errors may crop up because of intentional or unintentional salting of the sample itself. All these errors have to be avoided to the extent possible to get a reliable estimate of the orebody. Check sampling and repeated sampling help in avoiding some of the mistakes whereas great care at every stage of sampling alone can offset the other mistakes like salting.

## APPENDIX-I

# LIST OF EQUIPMENT FOR SAMPLING

| | | |
|---|---|---|
| 1. | Spring balance 100 kg or 50 kg capacity | 1 No. |
| 2. | Spring balance 10 kg (100 gm div.) | 1 No. |
| 3. | Screen 25 mm, 12 mm, 10 mm, 6 mm, sizes of 1.5 x 1.0 m dimension for screening tests.(of the required size) | 1 No. |
| 4. | Sieves 3 mm (18 mm or 2.0 cm) for preparation of samples | 1 No. |
| 5. | Measurement boxes (wooden) 40 cm x 40 cm x 25 cm for determination of bulk weights. | 1 No. |
| 6. | Sampling plate (steel) 22 cm x 22 cm x 12 mm for preparation of samples. | 1 No. |
| 7. | Steel mortar and pestle, for fine crushing and preparation of samples. | 3 Nos. |
| 8. | Steel stripe 1.2 m x 15 mm x 5 mm for sampling operation | 3 Nos. |
| 9. | Tarpauline 4 mm x 3 m for drawal and processing of samples. | 3 Nos. |
| 10. | Sledge hammer 2 kg | 3 Nos. |
| | " " 1 kg | 6 Nos. |
| 11. | Spades | 3 Nos. |
| 12. | Baskets/Iron pans | 7 Nos. |
| 13. | Shovels | 3 Nos. |
| 14. | Thick paper tags | |
| 15. | Sample bags 30 cm x 25 cm | |
| 16. | Steel tape. | |

(While these are some of the basic equipment necessary for any sampling, additional equipment may be required in many different types of specific cases. In all such cases the concerned mining geologist should improvise additional equipment to suit specific needs).

**APPENDIX-II**

# METHODOLOGY FOR SAMPLING AND SCREEN TESTS FOR MINERAL REJECTS OF A FEW IMPORTANT MINERALS

While discussing the methodology in a generalised manner, it was felt necessary to deal specifically with a few important minerals so as to bring out the crux of the problem together with a reasonable solution of the same. Moreover, the detailed methodology of important minerals would help to plan out the methodology for other minerals.

**i) Iron Ore**

a) In case of mechanised mines, it is expected that full details and records of rejects generated during mining and subsequent ore handling, stacking and utilisation or disposal of rejects (fines, and blue dust, if any) will be available, and no field tests would normally be called for. Here the attempts will be to collect all these data (if not already collected) and possibly drawal of some samples from the rejects from their screening plants for chemical and size analysis. The methodology to be drawn may be determined after discussions with the plant authorities and depending upon the facilities available.

b) In case of semi-mechanised or manually operated mines the sampling should, as far as possible, be done separately in respect of (i) low grade rejects, (ii) undersized rejects, and (iii) blue dust if any. Each of these rejects should be subjected to screening at 12mm (or 10mm) and 6mm and representative samples from each screen fractions should be drawn. In addition a representative sample for the entire material of the particular reject may also be drawn.

**ii) Manganese Ore**

a) Wherever the ROM ore is successfully screened and sorted for separation of block-rock, sized ore for jigging, and bed waste (as in MOIL mines in M.P. and Maharashtra), no screen test may be necessary. Sampling operations should be conducted on the different size fractions of the rejects e.g. (i) block rock (ii) bed rejects (iii) jig rejects at different jig size and (iv) raw ore (in case any particular fraction of the raw ore is not jigged at the moment).

b) In other areas where such practice is not followed, the rejects are to be subjected to screening tests on 25 mm, 12 mm and 6 mm screens, and representative samples are to be drawn from each screen fraction.

c) Wherever the manganiferous laterite overburden shows appreciable proportion of maganese ore as nodule, patches or streaks, or wherever the existence of bimetal ore (total Mn + Fe over 56 percent and Mn 5 - 20 percent) is suspected, such overburden material may also be subjected to screening and sampling as suggested at (b) above. A quantitative estimate of this material may also be made.

d) In case of North Kanara soft, siliceous manganese ore horizon, the concretionary manganese ore is won from the lower part of the siliceous horizon by successive screening up to 3 mm size. The top lean zones and the -3 mm fractions containing soft and fine ores are rejected. Separate representative samples may also be drawn from the rejects of the top leaner part of the zone (or if necessary by channelling at the face exposures) and also from the -3mm rejects from the economically workable zones.

**iii) Limestone and Dolomite**

a) The choice of screen size depends upon the lowest size of the saleable or acceptable product. Wherever the minimum size adopted is 40 mm, the rejects may be subjected to screen tests at 25 mm and 12 mm sizes. In other cases only 12 mm screen may be used. Representative samples of the different screen fractions are to be drawn.

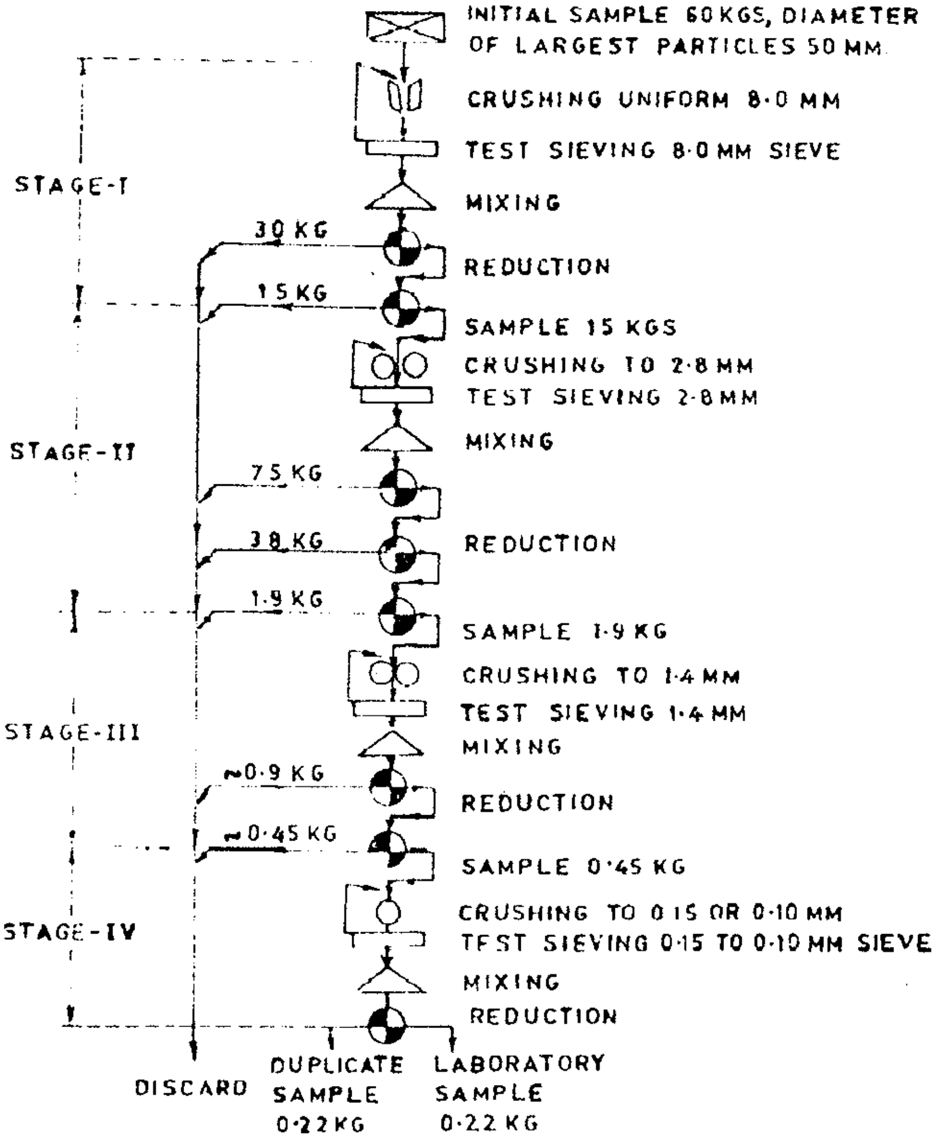
b) In cases where wobblers or such other contrivances are used at the mine site to eliminate clayey constituents, the generation of rejects at such spots may also be studied and samples of the rejects may be drawn. In such cases no further screen tests may be necessary for such reject fractions.

**iv) Clay (Chinaclay, Soapstone, Pyrophyllite, Asbestos etc.)**

Since the rejects generated are mostly on the basis of such physical properties like colour, plasticity, grit content, ceramic and refractory properties, lengths, distribution and grade of fibres, tensile strength, etc. and since these may not be determinable by the suggested conventional macro-size screening and chemical analysis screen tests and sampling for chemical analyses of the rejects from such minerals may not be of much relevance .Besides, our laboratory is not equipped to carry out the requisite physical or industrial tests for such minerals. Hence, these tests may be normally avoided, unless there is any specific reason to suspect possible improvement in grade or utilisation (with or without beneficiation) at a particular screen size. In such cases, however, screen testing at the requisite size may be carried out. But in all cases, the quantum of generation of such reject their types and specific properties or reasons for being rejected may be noted. In cases where the need for any chemical analysis, beneficiation ore tests for industrial utilisation is felt, specific recommendation to this effect may be made and depending upon the nature and magnitude of the problems, appropriate action may then be initiated with suitable agencies like C.G.C.R.I. etc. for conducting such tests.

**v) Other minerals like Bauxite, Magnesite, Kyanite, Barytes etc.**

The rejects may be subjected to screen tests on 12 mm (and also on 6 mm screen, if felt necessary) and representative samples be drawn from each of the screened fractions for chemical analyses.




FLOW SHEET FOR TREATMENT OF SAMPLES FOR CHEMICAL ANALYSIS

IBM/MMC/MISC/DRG No/277/83

ANNEXURE - D

## RADICALS TO BE DETERMINED FOR CHEMICAL ANALYSIS OF MINERAL/ORE

### INTRODUCTION

This note has been prepared with a view to providing general guidelines to the field Geologists, to have an idea of the range of Chemical Analysis of the mineral/ore expected to contain. The note gives mineralwise details of the radicals to be tested for. The radicals required to be tested according to the usage to which the ore is put to have also been given. For example, in respect of Bauxite used in (i) Chemical and Petroleum industry, (ii) Metallurgical purpose, (iii) refractory, (iv) abrasive, (v) Alumina cement industry; radicals to be tested for have been indicated. At the end complete list of radicals including trace elements etc. for the mineral is given. At places, besides chemical analysis important physical characteristics desired are also included. The total number of 45 important minerals have been covered in this note. Every attempt has been made to include all the radicals. However, the list need not be taken as complete in itself and may be used as a guiding factor. Besides, proper discretion need be exercised while deciding the radicals to be analysed keeping both requirements and cost involved in conducting analyses/tests.

# INDEX

## 1. ANTIMONY

An important antimony bearing mineral is stibnite. Antimony is present in complex sulphide minerals like tetrahedrite and bournite. Antimony bearing mineral is generally analysed for sulphides of antimony, copper and lead.

**Chemical Analysis**

Antimony sulphide shall be crystalline of black variety in powdery or lump form.

(i) Antimony (Sb) (All in % by wt)

a) Total

b) Uncombined state.

(ii) Sulphur (S) (Total and uncombined)

(iii) $Sb_2O_3$

(iv) Metals other than sulphide (Pb, Zn, Cu, etc.)

(v) Volatile matter

(vi) Acidity

(vii) Matter insoluble in aquaregia

(viii) Grit

Uses : Antimony is used in explosive and pyrotechnic composition.

## 2. ARSENIC

For arsenic, the principal minerals are arsenopyrite (FeAsS), Realgar ($As_2S_2$), Orpiment ($As_2S_3$) and many arsenites are sulpha- arsenides of Pb, Cu, Au and Sn. The radicals generally analysed are As, Pb, Cu, Au, Sn and S.

A. Complete Chemical Analysis for sulphide ore

| | | |
|---|---|---|
| (i) $SiO_2$ | (ii) As (Metallic) | (iii) AsS |
| (iv) $Fe_2O_3$ | (v) $Al_2O_3$ | (vi) $Na_2O$ |
| (vii) $K_2O$ | (viii) $H_2O$ | |

B. Complete Chemical Analysis for Oxide Ore

| | | |
|---|---|---|
| (i) $SiO_2$ | (ii) As (Metallic) | (iii) AsS |
| (iv) $As_2O_3$ | (v) $Fe_2O_3$ | (vi) $Na_2O$ |
| (vii) $K_2O$ | (viii) $K_2O+Na_2O$ | (ix) $H_2O$ |
| (x) $SnO_2$ | (xi) PbO | |

Arsenic used in the sharpnel bullets, percussion pellets for cartridges. Arsenic is used in laboratories and for pigments.

## 3. BAUXITE

Bauxite forms the main source for aluminium metal. It consists of gibbsite. Boehemite and diaspore in various proportions.

Bauxite is generally analysed for LOI, $SiO_2$ (Total), $Al_2O_3$, $Fe_2O_3$, $TiO_2$, Ca, MgO, $P_2O_5$, $V_2O_5$ and Mn.

**Chemical Analysis for :**

**I. Chemical & Petroleum Industries**

| | | | |
|---|---|---|---|
| (i) $Al_2O_3$ | (ii) $SiO_2$ | (iii) $Fe_2O_3$ | (iv) $TiO_2$ |
| (v) $P_2O_5$ | (vi) MnO | (vii) CaO | (viii) LOI |

**II. Metallurgical**

| | | |
|---|---|---|
| (i) $Al_2O_3$ | (ii) $SiO_2$ | (iii) $Fe_2O_3$ |
| (iv) $V_2O_5$ | (v) $P_2O_5$ | (vi) LOI |

**III. Refractory**

| | | |
|---|---|---|
| (i) $Al_2O_3$ | (ii) $SiO_2$ | (iii) $Fe_2O_3$ |
| (iv) $TiO_2$ | (v) LOI | |

**IV. Abrasives**

| | | |
|---|---|---|
| (i) $Al_2O_3$ | (ii) $SiO_2$ | (iii) $Fe_2O_3$ |
| (iv) $TiO_2$ | | |

**V. Alumina Cement Industry**

| | | |
|---|---|---|
| (i) $Al_2O_3$ | (ii) $SiO_2$ | (iii) $Fe_2O_3$ |

**VI. Complete Chemical Analysis**

| | | | |
|---|---|---|---|
| (i) $Al_2O_3$ | (ii) $SiO_2$ | (iii) $Fe_2O_3$ | |
| (iv) $TiO_2$ | (v) $V_2O_5$ | (vi) $P_2O_5$ | |
| (vii) LOI | (viii) MnO | (ix) CaO | (x) S |

## 4. CADMIUM

For refined cadmium (metal is recovered from ores)

| | | | | |
|---|---|---|---|---|
| (i) Cd | (ii) Zn | (iii) Cu | (iv) Pb | (v) Fe |
| (vi) Ni | (vii) Total impurities | (viii) As+Sb+Ti | | (ix) As |
| (x) Sb | (xi) Ti | | | |

## 5. CHROMITE

**I. Metallurgical Ferrochrome/charge chrome**

| | | |
|---|---|---|
| (i) $Cr_2O_3$ | (ii) $SiO_2$ | (iii) $Al_2O_3$ |
| (iv) S | (v) P | |

**II. Refractory Grade** : (for manufactue of refractories the chrome ore should be hard and lumpy)

| | | |
|---|---|---|
| (i) $Cr_2O_3$ | (ii) $SiO_2$ | (iii) $Fe_2O_3$ |
| (iv) FeO | (v) CaO | |

**III. Chemical Industry (on dry basis)**

| | | |
|---|---|---|
| (i) $Cr_2O_3$ | (ii) $SiO_2$ | (iii) $Al_2O_3$ |
| (iv) FeO | (v) CaO | (vi) MgO |

**IV. Complete chemical analysis**

(i) $Cr_2O_3$ (ii) $SiO_2$ (iii) $Al_2O_3$
(iv) FeO (v) $Fe_2O_3$ (vi) CaO (vii) MgO
(viii) S (ix) P (x) Ni (xi) CO
(xii) Pt (xiii) $TiO_2$

Chromite sand - for foundaries

Chemical Analysis

(i) $Cr_2O_3$ (ii) $SiO_2$ (iii) $Fe_2O_3$ (iv) CaO
(v) pH (vi) Acid demand value (vii) Fusion point
(viii) Moisture content (ix) clay content

Physical characteristics

(i) Grain shape - subangular in shape.
(ii) Grain Fineness. Grain should be passed through IS sieve.
710, 500, 355, 250, 212, 150, 106, 75 and pan.

## 6. IRON ORE

Important iron ore minerals are hematite and magnetite. Others include goethite, limonite, sidorite. The ore subjected to analysis for Fe (total), FeO, $Fe_2O_3$, $Al_2O_3$, CaO, MgO, $SiO_2$ $TiO_2$ and P, S and LOI.

**I. for Iron and Steel Industries**

(i) Fe (ii) $SiO_2$ (iii) $Al_2O_3$,
(iv) $Al_2O_3/SiO_2$ (v) P

Physical Characteristics

1. Size : (i) 10 - 15 mm for blast furnace.
(ii) 50 - 150 mm for steel melting shop.
- 10 mm for sintering fines.
- 1 mm preferably (-100) mesh for polletisation (fines)

**II. Hydrogenation of vegetable oil**

Type of iron ore used - spathic iron ore ($FeCO_3$)

(a) Chemical analysis

(i) $Fe_2O_3$ (ii) CaO (iii) Ca (iv) Mg (v) LOI

(b) Physical properties

(i) Spongy structure.
(ii) Colour - light yellow.
(iii) Should not sinter below $100^oC$.
(iv) Size - 1 to 2-1/2".

Ore should be strong, hard and free from laminations.

**III. Welding rod and electrodes**

Type - Micaceous hematite.

**IV. High density aggregates for pipe coatings**

Physical properties

(i) Proctor density - 200 $lbs/ft^3$ with 2.5% tolerance.

(ii) Specific gravity - 4.8

(iii) Moisture - 4%

(iv) Size - 10 mm

(75 to 95 % Below 5 mm).

**V. For making concentrate and pellets**

Magnetite soft and weathered ore containing on an average 3% Co for concentration.

**VI. For Coal Washing**

Magnetite content - 75% (Min) by weight.

Size - 1.25 to 5.00 cm.

**VII. Complete Chemical Analysis**

| | | | |
|---|---|---|---|
| (i) Fe (Total) | (ii) FeO | (iii) $Fe_2O_3$ | (iv) $SiO_2$ |
| (v) $Al_2O_3$ | (vi) $Al_2O_3 / SiO_2$ | (vii) CaO | (viii) MgO |
| (ix) $TiO_2$, Va, Pt, Co, Ni | | (x) $CO_2$ | (xi) Ca |
| (xii) Mn, Cu, Pb, Zn, | | (xiii) Mg | (xiv) P |
| (xv) S | | | |

## 7. MANGANESE ORE

Common minerals in manganese ore are psilomelane, pyrolusite, braunite. Others are manganite, jacobsite, hausmanite, sitaparite, spessartite, etc. Manganese ores are analysed for Mn, $MnO_2$, $SiO_2$, $Al_2O_3$, $Fe_2O_3$, P, BaO, CaO, MgO and LOI.

**I. For Manganese Alloy**

(i) Mn (ii) Fe (iii) $SiO_2$ (iv) P

**II. Iron and Steel Industry** : Size should be 10 mm to 40 mm.

(in exceptional case 5 - 6 mm)

(i) Mn (ii) Fe (iii) $SiO_2$ (iv) P

(v) $Al_2O_3$

**III. Battery Manufacture**

(a) (i) $MnO_2$ (ii) Fe (iii) Cu (iv) Ni

(v) CO (vi) Acid insol

(b) Size - 200 mesh.

**IV. Chemical Industries**

(a) (i) $MnO_2$ (ii) $Fe_2O_3$ (iii) $SiO_2$

(b) Size - 200 to 250 mesh.

**V. Glass Industry**

(i) $MnO_2$ (ii) $Fe_2O_3$ (iii) $SiO_2$

(iv) $Al_2O_3$ (v) BaO (vi) CaO (vii) MgO

**VI. Manganese dioxide for explosive pyrotechnic composition**

(a) Type: There shall be three types of material depending upon the particle size namely.

Type A - Particle size not greater than 600 micron.

Type B - Particle size not greater than 150 micron.

Type C - Particle size not greater than 75 micron.

(b) For all types A, B and C

Chemical Analysis : (For all in % by Wt)

(i) $MnO_2$ (on dry basis)

(ii) Water solubles in chloride (as NaCl)

(iii) Moisture contents (on dry basis)

(iv) Matter insoluble (in water)

(v) Grit (on dry basis)

**VII. Complete Chemical Analysis**

(i) Mn (ii) $MnO_2$ (iii) $Fe_2O_3$ (iv) $SiO_2$

(v) $Al_2O_3$ (vi) P (vii) Cu (viii) CO, Ni, As, Pb, Cr, S

(ix) BaO (x) CaO (xi) MgO (xii) LOI

(xiii) Acid insolubles (xiv) Water solubles, Chlorides (as NaCl)

(xv) Moisture (xvi) Matter soluble in water

## 8. COPPER

Chalcopyrite is predominant copper bearing mineral. The other minerals are covellite, tetrahedrite, chalcocite, cubanite, vallerite, cuprite and native copper.

The radicals determined in Cu ore are Cu, S, Fe, $SiO_2$, CaO, MgO, Se, MO.

Complete Chemical Analysis

(i) Cu (%) (ii) S (iii) $Fe_2O_3$ (iv) $SiO_2$

(v) CaO (vi) MgO (vii) Mo/Sn (viii) Se

(ix) Ni (x) CO (xi) Au (dwt/tonne)

(xii) Ag (dwt/tonne) (xiii) Insolubles (xiv) $P_2O_5$

## 9. GOLD

Complete Chemical Analysis

(i) Au (ii) Cu (iii) Zn, Ag (iv) As
(v) Sb (vi) Te (vii) Carbonaceous matter
(viii) $WO_3$

## 10. MOLYBDENUM

Principal molybdenum bearing minerals are molybdenite and wolframite, molybdenum concentrate recovered from polymetallic (base metals) ores, uranium ores, radicals analysed for Mo ores are : MoS, $WO_3$, Sn, $Fe_2S_3$, Pb, Cu.

Complete Chemical Analysis

(i) MoS (ii) $WO_3$ (iii) Sn (iv) Iron pyrite ($Fe_2S_3$)
(v) Pb (vi) Cu (vii) Zn viii) Ni
(ix) Acid insoluble.

## 11. NICKEL

Principal nickel bearing minerals are pentlandite garnierite and niccolite. It is also associated with copper ore, laterites, etc.

Complete Chemical Analysis

(i) Ni (ii) Fe (iii) Mg (iv) $SiO_2$
(v) As, Co (vi) S (vii) Cu (viii) LOI
(ix) Moisture content

## 12. TIN

Cassiterite ($SnO_2$) is the chief ore of Tin.

Chemical Analysis

(i) Sn (ii) Ta (iii) Nb (iv) Li
(v) Ni (vi) Co (vii) Mo (viii) Cd
(ix) V (x) W (xi) Ti (xii) Gangue

## 13. TITANIUM

Titanium bearing ore are ilmenite and rutile. Radicals generally analysed are : $TiO_2$, Fe, FeO, $Fe_2O_3$, $SiO_2$, CaO, MgO, $Al_2O_3$, $Cr_2O_3$ and Mn.

**I. For Titanium dioxide pegment and titanium.**

Sponge Metal

(i) $TiO_2$ (ii) $Fe_2O_3$ (iii) CaO (iv) MgO
(v) $Al_2O_3$ (vi) $Cr_2O_3$ (vii) $P_2O_5$ (viii) Mn
(ix) V (x) $Nb_2O_5$ (xi) Rare earths

**II. For arc welding electrodes**

| | |
|---|---|
| (i) $TiO_2$ | (ii) $Fe_2O_3$ |

**III. Complete Chemical Analysis**

| | | | |
|---|---|---|---|
| (i) $TiO_2$ | (ii) $Fe_2O_3$ | (iii) CaO | (iv) MgO |
| (v) $Al_2O_3$ | (vi) $Cr_2O_3$ | (vii) $P_2O_3$ | (viii) Mn |
| (ix) V | (x) $Nb_2O_5$ | (xi) Rare earths | |

## 14. TUNGSTEN

Chief ore minerals are wolframite (Fe Mn) $WO_4$ and scheelite ( Ca $WO_4$).

Complete Chemical Analysis of :

| Wolframite | & | Scheelite |
|---|---|---|
| (i) $WO_3$ | | (i)$WO_3$ |
| (ii) $SiO_2$ | | (ii) $SiO_2$ |
| (iii) $Al_2O_3$ | | (iii) $Al_2O_3$ |
| (iv) Fe (Sol.) | | (iv) CaO |
| (v) Fe (Insoluble) | | (v) MgO |
| (vi) CaO | | (vi) Ti |
| (vii) MgO | | (vii) As |
| (viii) Mn | | (viii) Mn |
| (ix) Sn | | (ix) P |
| (x) P | | (x) Cu |
| (xi) Sulphur (S) | | (xi) Sulphur (S) |
| (xii) Insolubles | | (xii) Insolubles |
| (xiii) LOI | | (xiii) LOI |

## 15. POLYMETALLIC ORES (BASE METALS)

Pb - Zn - Cu - Ag - Au

Base metal ores

Complete Chemical Analysis

| | | | |
|---|---|---|---|
| (i) Cu | (ii) Cd | (iii) Ni | (iv) Pb |
| (v) Sb | (vi) Mo | (vii) Zn | (viii) Co/Sn |
| (ix) Ag (in Pb-Zn ores) | | (x) Ga (in Pb-Zn ores) | |
| (xi) Fe | (xii) As | (xiii) Hg | (xiv) Au |
| (xv) Ba | (xvi) Gangue minerals. | | |

## 16. APATITE/ROCK PHOSPHATE

They are analysed for LOI, $CO_2$ , $SiO_2$, $Al_2O_3$, $P_2O_5$, $Fe_2O_3$, CaO (free), CaO (total), MgO, F and $V_2O_5$.

**I. Fertilizer Industry**

(i) $P_2O_5$ (ii) CaO (iii) MgO (iv) $SiO_2$,
(v) $Fe_2O_3$ (vi) $Al_2O_3$ (vii) F (viii) Cl (ix) $CO_2$
(x) LOI (xi) Moisture

**II. Soil reclamation grade (for ground rock phosphate)**

(a) (i) $P_2O_5$ (ii) CaO (iii) $Fe_2O_3$
(iv) Absolute citrate solubility index (v) Moisture content.
(b) Physical Characteristics
(i) Mesh size 100, (ii) Rock phosphate should be of sedimentary origin.

**III. Phosphoric acid**

(i) $P_2O_5$ (ii) CaO (iii) MgO iv) $SiO_2$
(v) $R_2O_3$ (vi) F (vii) Cl (viii) $H_2O$
(ix) Moisture content

**IV. Elemental Phosphate**

(i) $P_2O_5$ (ii) $SiO_2$ (iii) $Fe_2O_3$ (iv) $Al_2O_3$

**V. Beneficiation grade**

(i) $P_2O_5$

**VI. Complete Chemical Analysis**

(i) $P_2O_5$ (ii) CaO (free & total) (iii) MgO
(iv) $SiO_2$ (v) $Al_2O_3$ (vi) $Fe_2O_3$
(vii) $R_2O_3$ (viii) F (ix) Cl, S, (x) $CO_2$
(xi) $H_2O$ (xii) LOI (xiii) $V_2O_5$

## 17. ASBESTOS

(Crysotile variety) : for making Asbestos content product.

Physical Characteristics

(i) Form : Fibre

(ii) Specific gravity 2.4 - 2.0

**(iii) Tensile strength : 80,000 to 1,00,000 lbs/sqr inch.**

**(iv) Moisture - objectionable having an adverse effect on processing (i.e. screening** and air separation).

For ambhibole variety : In addition to above, analysis for MgO, $SiO_2$, $Fe_2O_3$, CaO, moisture content should be carried out.

## 18. BARIUM MINERALS

Baryte and witherite are chief minerals for barium.

**Barytes** : Some complex Cu, Pb and Zn polymetallic ores contain barytes as associated mineral. The radicals generally analysed for barytes are $BaSO_4$, $SO_3$, $SiO_2$, $Fe_2O_3$, $Al_2O_3$ (combined), CaO, MgO and matter soluble in water, Cu, Pb, Al, Zn and S and specific gravity.

**I. Use in Chemical Industry**

(i) $BaSO_4$ (ii) $SiO_2$ (iii) Al
(iv) $Fe_2O_3$ (v) $CaCO_3$

**II. For Oil Well Drilling**

(i) $BaSO_4$

Physical Characteristics

(i) Fineness:

(a) Passing through 75 microns IS sieve - 97 (min)

(b) Passing through 53 microns IS sieve - 95 (min)

(ii) Relative density at 27°C - 4.15

(iii) Performance - To pass test

**III. Barium Sulphate Pigments for paints**

(i) $BaSO_4$ (ii) $BaCO_3$ (iii) Volatite matter (VM)
(iv) Residue on sieve (v) Oil absorption (vi) Colour
(vii) Matter soluble in water (viii) pH of Ag extract
(ix) Relative density at 25°C (x) Particle shape

**IV For Explosive**

(i) $BaSO_4$

Barytes should be white to off-white coloured and in dry powder form.

**V. Glass Industry**

(i) $BaSO_4$ (ii) $SiO_2$ (iii) $Al_2O_3$ (iv) $Fe_2O_3$

Physical Characteristics

(i) Parcticle size - 30/80 mesh.

(ii) Colour - White or light shade preferred.

**VI. Rubber Industry : Bleached barytes is preferred**

**VII. Bleached barytes**

(i) Colour

(ii) Sieve residue : (a) through 75 m micron IS sieve

(b) through 150 micron IS sieve
(iii) Relative density at 27°C
(iv) pH
(v) Moisture content
(vi) Matter insoluble in water
(vii) Mn
(viii) Cu
(ix) Fe

**VIII. Complete Chemical Analysis**

| | | | |
|---|---|---|---|
| (i) $BaSO_4$ | (ii) $SiO_2$ | (iii) $Al_2O_3$ | (iv) $Fe_3O_4$ |
| (v) $CaCO_3$ | (vi) $BaCO_3$ | (vii) $SO_3$ | (viii) Mn |
| (ix) Cu | (x) pH | (xi) Moisture content | |
| (xii) Matter insoluble in water | | (xiii) $SrSO_4$ | |

Physical Parameters

(i) Relative density (ii) Sieve residue (iii) Particle shape and size
(iv) Colour

## 19. BENTONITE

**I. In foundary, oil well drilling and chemical industry**

Chemical Characteristics

(i) Copper (as CuO)
(ii) Manganese (as MnO)
(iii) Calcium oxide - CaO (as replaceable $Ca^{++}$)
(iv) Loss on drying (max and min)
(v) pH
(vi) Colour index
(vii) Swelling power
(viii) LOI

Matter soluble in water

Physical Characteristics

(i) Fineness (dry and wet)
(ii) Viscosity at 30°C (apparent and plastic)
(iii) Filtration loss

**II. Iron ore pelletisation for binding**

(i) Na (ii) CaO (iii) pH

Physical Characteristics

(i) Swelling Index
(ii) Size - below 75 mm

Complete Chemical Analysis

(i) $Al_2O_3$ (ii) $SiO_2$ (iii) CaO (iv) MgO
(v) $Fe_2O_3$ (vi) $TiO_2$ (vii) CuO viii) MnO
(ix) LOD (x) LOI (xi) $Na_2O$, $K_2O$
(xii) Matter insoluble in water (xiii) Moisture content
(xiv) pH (xv) Colour index (xvi) Grit content
(xvii) Oil absorption (xviii) P.C.E.

## 20. BALLCLAY

For Ceramic Industries

A Complete Chemical analysis (% by Wt)

(i) $Fe_2O_3$ (ii) $TiO_2$ (iii) $Fe_2O_3 + TiO_2$
(iv) $Al_2O_3$ (v) LOI (vi) $SiO_2$

B. Physical Characteristics

(i) Material shall be in form of lump or powder, free from dust or any foreign material, highly plastic.

(ii) (a) Size : Coarser than 25 micron - 2% (max)
Finer than 25 micron (20% max)
Coarser than 2 micron (20% max)
Finer than 2 micron - 75% (min)

(b) Grit - not more than 2%, shall remain on 45 micron IS sieve.

(iii) Fired colour.

(iv) Water of plasticity - 30%

(v) Attenberg number - Not less than 13.

(vi) Linear shrinkage - Not more than 3%.

(vii) Maturity - Not more than 3%.

(viii) Strength - Dry Modulus of Rupture not less than 25.0 $Kg/m^2$

(ix) Colour after firing - White to light cream

## 21. CALCITE

**I. Ceramic Industry :**

(i) $CaCO_3$ (ii) $Fe_2O_3$ (iii) $TiO_2$, Colour - snow-white.

**II. Chemical Industry**

(i) $CaCO_3$ (ii) Fe (iii) As (iv) Pb (v) Chloride

**III. Cosmetics**

(i) $CaCO_3$ (ii) Fe (iii) Mn (iv) Cu (v) Moisture.

Physical Characteristics

(i) Size - 200 mesh.

**IV. Electrodes**

(i) $CaCO_3$ (ii) $SiO_2$ (iii) P (iv) S

Physical characteristics

(i) Size - 200 to 300 mesh

**V. Glass Industry**

(i) $CaCO_3$ (ii) $Fe_2O_3$ (iii) $MgCO_3$

Physical Characteristics

30 to 80 mesh size of particles

**VI. Complete Chemical Analysis**

| | | |
|---|---|---|
| (i) $CaCO_3$ | (ii) $Fe_2O_3$ | (iii) $TiO_2$ |
| (iv) $SiO_2$ | (v) $MgCO_3$ | (vi) Mn |
| (vii) As | (viii) Pb | (ix) Cu |
| (x) P | (xi) S | (xii) Acid insoluble |
| (xiii) LOI | | |

## 22. CORUNDUM

I. For Abrasives : $Al_2O_3$

II. For Foundry : $Al_2O_3$

III. Complete Chemical Analysis

| | | |
|---|---|---|
| (i) $Al_2O_3$ | (ii) $Fe_2O_3$ | (iii) $SiO_2$ |
| (iv) $TiO_2$ | (v) CaO | (vi) MgO |

## 23. DIASPORE

Complete Chemical Analysis

| | | |
|---|---|---|
| (i) $Al_2O_3$ | (ii) $Fe_2O_3$ | (iii) $SiO_2$ |
| (iv) $TiO_2$ | (v) LOI | |

## 24. DIATOMITE

Diatomites used in soft abrasives, as filler, in filtration and in manufacture of glasses and insulation products.

Chemical Analysis as follows

| | | | |
|---|---|---|---|
| (i) $SiO_2$ | (ii) $Al_2O_3$ | iii) $Fe_2O_3$ | (iv) $TiO_2$ |
| (v) CaO | (vi) MgO | (vii) $Na_2O$ | (viii) LOI |

## 25. DOLOMITE

**I. Refractory Industry**

(i) MgO (ii) $SiO_2$ (iii) $Al_2O_3$ iv) $Fe_2O_3$

Physical Characteristics : The mineral should be compact, homogenous, fine grained and non- decrepitating on calcination.

**II. Flux in Iron-Steel Industry**

(a) Blast Furnace

(i) MgO (ii) $SiO_2$ (iii) $Al_2O_3$ (iv) $Fe_2O_3$ (v) CaO

Physical Characteristics : Size - +25 mm

Form - Noncrystalline.

(b) SMS grade and Fe-Mn Industries

(i) $CaCO_3$ (ii) $SiO_2$ (iii) $Al_2O_3$ iv) MgCO3

Physical Characteristics : Form - Noncrystalline

**III. Glass Industry**

(i) $SiO_2$ (ii) $Al_2O_3$ iii) Fe content

Physical Characteristics : Size - 30 to 80 mesh

**IV. High Magnesium Lime Manufacturing**

(i) $MgCO_3$ (ii) $CaCO_3$ (iii) Other constituents

**V. Complete Chemical Analysis**

(i) MgO (ii) $SiO_2$ (iii) $Al_2O_3$ iv) $Fe_2O_3$
(v) CaO (vi) $CaCO_3$ (vii) $MgCO_3$ viii) S
(ix) P (x) LOI (xi) Acid insoluble

## 26. FELDSPAR

**I. Ceramic Industry**

(i) $SiO_2$ (ii) K (iii) Na (iv) CaO (v) MgO

**II. Abrasive**

(i) $SiO_2$ (ii) $Al_2O_3$ (iii) CaO (iv) $Na_2O$ (v) $Fe_2O_3$
(vi) LOI

**III. Electrodes (used as flux)**

(i) $SiO_2$ (ii) $K_2O$ (iii) $Na_2O$ (iv) $Al_2O_3$ (v) LOI

Physical Characteristics : Size - 0.2 to 0.06

**IV. Glass Industry**

(i) $SiO_2$ (ii) $Na_2O + K_2O$ (iii) $Al_2O_3$ iv) $Fe_2O_3$
(v) K-feldspar (Orthoclase)

Physical Characteristics : Size - 30 to 80 mesh.

**V. Refractory**

(i) Alkalies (ii) $Al_2O_3$ (iii) $Fe_2O_3$ (iv) LOI

Physical Characteristics : Size - 2.5 to 10 cm.

**VI. Complete Chemical Analysis**

(i) $SiO_2$ (ii) $K_2O$ (iii) $Na_2O$ (iv) CaO
(v) $Fe_2O_3$ (vi) $Al_2O_3$ (vii) MgO (viii) K/Na ratio
(ix) LOI (x) Rare earths.

## 27. FIRECLAY

Chemical Analysis of plastic and nonplastic clay

(i) $SiO_2$ (ii) $Al_2O_3$ (iii) $Fe_2O_3$
iv) $TiO_2$ (v) LOI (vi) PCE (in ortons)
(vii) Fusion point ($6^o$) (viii) LOD

## 28. FLUORITE

**I. Metallurgical grade**

(i) $CaF_2$ (ii) $SiO_2$ (iii) $CaF_2$ (effective)
(iv) $CaCO_3$ (v) $Fe_2O_3$ (vi) S (vii) Pb

**II. Chemical Grade**

(i) $CaF_2$ (ii) $SiO_2$ (iii) $CaCO_3$ (iv) S
(v) $BaSO_4$ (vi) $P_2O_5$ (vii) Berylium (Be)
(viii) Mixed oxides $R_2O_5$ (ix) Free moisture
(x) Organic matter (xi) Chlorides (Cl)

Physical Characteristics

1. Retained on 500 IS sieve.
2. " " 312 IS sieve.
3. " " 75 IS sieve.

**III. Glass Industry** : $CaF_2$

Physical Characteristics : Size - 75 -150 mesh in most cases.

**IV. Ceramic Industry**

(i) $CaF_2$ (ii) $SiO_2$ (iii) $CaCO_3$ iv) $Fe_2O_3$

**V. Complete Chemical Analysis**

(i) $CaF_2$ (ii) $SiO_2$ (iii) $CaCO_3$ iv) $CaF_2$ (effective)
(v) $Fe_2O_3$ (vi) S (vii) Pb (viii) $BaSO_4$
(ix) $P_2O_5$ (x) Be (xi) Mixed oxides $R_2O_5$
(xii) Free moisture (xiii) Organic matter
(xiv) Chlorides (Cl) (xv) Zn (xvi) Acid insoluble.

## 29. GARNET

As Abrasives : (i) Hardness (ii) Specific gravity

## 30. GRAPHITE

**I. Crucibles**

(i) Fixed Carbon (FC) (ii) $SiO_2$

Physical Characteristics : 1. Form - Flaky

2. Size - (-) 120 to (+) 80 mesh.

**II. Abrasives**

(i) Fixed Carbon (FC)

**III. Battery grade**

(i) Fixed Carbon (FC) (ii) Iron (Fe) (iii) $H_2O$

(iv) Ash content

**IV. Foundry facing material**

A. Moisture

B. Analysis on dry basis

(i) Fixed Carbon (FC) (ii) Nongraphitic carbon

(iii) Ash (iv) Volatile matter

**V. Paints**

(i) Volatile matter (ii) Ash content (iii) Pb content

(iv) Matter insoluble in water (v) Colour, staining and tone

(vi) Oil absorption

**VI. Refractory**

(i) Fixed Carbon (FC) (ii) Ash (iii) Fusion point

**VII. Lubricant**

(i) Nongraphitic carbon (ii) Ash content

(iii) Petroleum, other solubles (iv) Water soluble matter

(v) Loss on heating

**VIII. Pencils**

(i) Fixed Carbon (FC) (ii) Ash content

Physical Characteristics

1. Form should be amorphous.
2. Size - 300 mesh.
3. Nature of ore

**IX. Atomic reactor, bushes of aircraft & Electric motors**

(i) Fixed Carbon (FC)

X. Complete Chemical Analysis

(i) Fixed Carbon (FC)
(ii) Ash content
(iii) Non-graphitic carbon
(iv) $SiO_2$
(v) Fe, Pb content
(vi) $H_2O$
(vii) Oil absorption
(viii) Volatile matter
(ix) Moisture
(x) Water soluble matter
(xi) Petroleum and other solubles
(xii) Fusion point
(xiii) Colour, staining and tone

## 31. GYPSUM

I. Surgical plaster, Ammonium sulphate, fertilizer, pottery, cement, reclamation of soil and extender in paints.

Complete Chemical Analysis

| | | | |
|---|---|---|---|
| (i) $CaSO_4, 2H_2O$ | (ii) NaCl | (iii) $Na_2O$ | (iv) MgO |
| (v) $Fe_2O_3$ | (vi) $Al_2O_3$ | (vii) $CO_2$ | (viii) Free water, LOI |
| (ix) $SiO_2$ & other soluble matter | | (x) Oil absorption | (xi) Lead & its |
| compound | (xii) Colour | | |

Physical Characteristics

1. Fineness
2. Form - physical and microscopic both.

## 32. KYANITE - SILLIMANITE

Aluminosilicate refractory minerals includes Andalucite, Kyanite, sillimanite. It is generally analysed for Moisture, LOI, $SiO_2$, $Al_2O_3$, $Fe_2O_3$, $TiO_2$, MnO, CaO, MgO, $Na_2O$, and $K_2O$. Chemical analysis for individual minerals as given below.

**KYANITE**

**I. Refractory**

(i) $Al_2O_3$ (ii) $Fe_2O_3$ (iii) PCE (ortons)

Physical Characteristics : Size - 25 mm to 300 mm

**SILLIMANITE**

**I. Refractory**

(i) $Al_2O_3$ (ii) $Fe_2O_3$ (iii) $TiO_2$, (iv) LOI
(v) PEC

Physical Characteristics

Size of lump should be 2.5 to 100 cm.

Complete Chemical Analysis

| | | |
|---|---|---|
| (i) $Al_2O_3$ | (ii) $Fe_2O_3$ | (iii) $TiO_2$, |
| (iv) CaO | (v)MgO | (vi) $Na_2O + K_2O$ |
| (vii) MnO | (viii) LOI | (ix) PCE (Physical). |

## 33. LIMESTONE

### I. Cement Industry

(i) CaO

(ii) Silica modulus i.e. $\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$

(iii) Hydraulic Modulus i.e. $\frac{CaO}{SiO_2+Al2O_3+Fe_2O_3}$

(iv) Iron Modulus i.e. $\frac{Al_2O_3}{Fe_2O_3}$

(v) MgO (vi) $SO_3$ (vii) $SiO_2$

(viii) Lime saturation factor.

### II. Iron and Steel Industries

(a) Metallurgical Flux in blast furnace - B.F. Grade

(i) CaO (ii) CaO + MgO (iii) $SiO_2$

(iv) Total Acid insolubles

Physical Characteristics : Size - (+) 25 mm in general.

(b) SMS grade (fettling in the steel melting shop)

(i) CaO (ii) MgO (iii) $SiO_2$ (iv) Acid insolubles

Physical Characteristics : Size - (+50) mm in general.

### III. Glass Industry

(i) $CaCO_3$ (ii) $MgCO_3$ (iii) $CaCO_3 + MgCO_3$

(iv) $Fe_2O_3$ (v) Total non volatile matter insoluble in HCL

(vi) Moisture.

### IV. Chemical Industries

For manufacture of bleaching powder, caustic soda, calcium carbide and sugar industries.

| | | | |
|---|---|---|---|
| (i) CaO | (ii) MgO | (iii) $SiO_2$ | |
| (iv) $Fe_2O_3$ | (v) $Mn_2O_3$ | (vi) $CO_2$ | (vii) S |
| (viii) P | (ix) $Al_2O_3 + Fe_2O_3$ | (x) $SiO_2 + Al_2O_3 + Fe_2O_3$ | (xi) LOI |

**V. Complete Chemical Analysis**

(i) CaO (ii) MgO (iii) $SiO_2$
(iv) $Fe_2O_3$ (v) $Al_2O_3$ (vi) $Mn_2O_3$ (vii) $V_2O_5$
(viii) $CO_2$ (ix) $SO_3$ (x) P and S (xi) Silica Modulus
(xii) Iron Modulus (xiii) Hydraulic Modulus
(xiv) Lime Saturation Factor (xv) Moisture (xvi) Acid insolubles
(xvii) LOI (xviii) Non-volatile matter insoluble in HCL.

## 34. MAGNESITE

**I. Electrode**

(i) MgO (ii) $SiO_2$

**II. Glass**

(i) MgO (ii) CaO (iii) $Fe_2O_3$ (iv) $Al_2O_3$

Physical Characteristics : Size - 60 to 80 mesh.

**III. Chemical Industry**

(i) MgO (ii) CaO (iii) $SiO_2$ (iv) $Fe_2O_3$
v) $Al_2O_3$ (vi) LOI.

Physical Characteristics : White lumps, free from dust and other foreign matters.

**IV. Refractory Grade**

(i) MgO (ii) CaO (iii) $SiO_2$ (iv) $CaO/SiO_2$

Physical Characteristics : Size + 10 mm.

**V. Complete Chemical Analysis**

(i) MgO (ii) CaO (iii) $SiO_2$ (iv) $Fe_2O_3$
(v) $Al_2O_3$ (vi) $CaO/SiO_2$ (vii) LOI
(viii) Acid insolubles (ix) PEC (in ortons) (physical).

## 35. OCHRES

Red Ochres (Red iron oxide)

Complete chemical analysis (for paint & rubber industries)

(i) FeO (ii) $Fe_2O_3$ (iii) $Al_2O_3$ (iv) $MnO_2$
(v) CaO (vi) MgO (vii) $SiO_2$ (viii) $TiO_2$
(ix) $P_2O_5$ (x) Mn (in trace) (xi) Cu (in trace)
(xii) Alkalies ($Na_2O$, $K_2O$) (xiii) Water (combined)
(xiv) Volatile matter (xv) Residue on sieve
(xvi) Oil absorption (xvii) Alkalanity (as NaOH)
(xviii) Acidity (as $H_2SO_4$) (xix) Matter insoluble in HCL
(xx) Relative density (xxi) LOI.

## 36. PYROPHYLITE

In Refractory, Ceramic and Insecticide Industries

Complete Chemical Analysis

(i) $Al_2O_3$ (ii) $SiO_2$ (iii) $Fe_2O_3$
(iv) $TiO_2$ (v) Alkalies (vi) pH (Physical) (vii) PCE (in ortons)

## 37. PYRITES AND SULPHUR

(a) PYRITE ($FeS_2$) is analysed for Fe from where S and $FeS_2$ could be calculated.

**I. For Chemical Industry (for both grades I & II)**

(i) Sulphides (as S) (ii) Iron (as Fe)
(iii) Arsenic (as As) (iv) Moisture

**II. Soil Reclamation grade and Beneficiable grade**

(i) S. content.

**III. Complete Chemical Analysis for Pyrites**

(i) S (ii) Fe (iii) As (iv) Moisture
(v) Insoluble (vi) Cu (vii) Gangue (viii) P
(ix) $Al_2O_3$ (x) $SiO_2$

(b) SULPHUR (native)

For manufacture of $H_2SO_4$ acid

Chemical Analysis

(i) S (ii) C (iii) $H_2O$

Ore should be free from Arsenic, Tellurium and Selenium.

Complete Chemical Analysis for Sulphur

(i) S (ii) C (iii) $H_2O$
(iv) As (v) Te (vi) Se

## 38. QUARTZ/SILICA SAND

**I. Glass Industry**

(a) Chemical Analysis for manufacture of grade I, II, & III glasses.

(i) $SiO_2$ (ii) $Fe_2O_3$ (iii) $Al_2O_3$
(iv) $TiO_2$ (v) LOI

(b) Physical Characteristics

Size -1 Retained on 1 mm IS sieve - nil.

2. Retained on 600 microns IS sieve - 1%.
3. Passing through 600 microns IS sieve - but retained on 300 microns IS sieve - 50%.
4. Passing through 125 micron IS sieve - 5%.

**II. Foundry Industry**

Chemical Analysis

| | | |
|---|---|---|
| (i) $SiO_2$ | (ii) $Fe_2O_3$ | (iii) $Al_2O_3$ |
| (iv) CaO | (v) MgO | (vi) Alkalies |

Physical Characteristics

1. Sintering temperature : 1685°C to 1710°C.
2. Grain shape : Subangular to rounded.
3. Grain fineness : shall have well/defined grading with 70% and above of the sand grains retained by 3 adjacent sieve.

**III. Sodium-Potassium silicate industry**

| | | |
|---|---|---|
| (i) $SiO_2$ | (ii) $Fe_2O_3$ | (iii) $Al_2O_3$ |
| (iv) CaO | (v) MgO | (vi) CaO + MgO |

Physical Characteristics : Size - 20 to 100 mesh.

**IV. Ferro-Alloy Industry**

| | | | |
|---|---|---|---|
| (i) $SiO_2$ | (ii) $Fe_2O_3$ | (iii) $Al_2O_3$ | |
| (iv) CaO | (v) MgO | (vi) P | (vii) As |

Physical Characteristics : Quartz should have thermal stability at 1200°C or more.

**V. Complete Chemical Analysis**

| | | | |
|---|---|---|---|
| (i) $SiO_2$ | (ii) $Fe_2O_3$ | (iii) $Al_2O_3$ | (iv) CaO |
| (v) MgO | (vi) $TiO_2$ | (vii) P | (viii) As |
| (ix) Alkalies | (x) LOI. | | |

## 39. QUARTZITE

**I. Refractory Industries**

| | | |
|---|---|---|
| (i) $SiO_2$ | (ii) $Al_2O_3$ | (iii) $Fe_2O_3$ |
| (iv) Alkalies | (v) PCE (in ortons) | (Physical) |

Physical Characteristics

1. Form : mostly crystalline.
2. Fired quartzite lumps should be clean, white & spot free.
3. Specific gravity : Fired quartzite lumps in conventional Klins at 1430°C with proper firing schedule should have less than 2.45 specific gravity.

**II. Flux in Iron and Steel Industries**

| | |
|---|---|
| (i) $SiO_2$ | (ii) $Al_2O_3$ |

Physical Characteristics : Chips 10 to 80 mm.

**III. Complete Chemical Analysis**

| | | |
|---|---|---|
| (i) $SiO_2$ | (ii) $Al_2O_3$ | (iii) $Fe_2O_3$ |
| (iv) Alkalies | (v) PCE (in ortons) | (Physical). |

## 40. CHINACLAY

Clays are analysed for LOI, $SiO_2$, $Al_2O_3$, $TiO_2$, MnO, $Fe_2O_3$, CaO and MgO.

**I. Textiles and paper coating, rubber, filler in paper and in insecticide**

(i) CaO (ii) $Al_2O_3$ (iii) $Fe_2O_3$
(iv) MnO (v) pH value of aquous extract.
(vi) Residue on 50 micron IS sieve. (vii) Loss on Ignition
(viii) Matter soluble in water (ix) Matter soluble in HCL
(x) Oil absorption (xi) Colour reflections of blue light 3040 $A^0$.

Physical Characteristics

1. Particle smaller than 10 microns in diameter.
2. Particle smaller than 2 microns in diameter.
3. Relative density at $27^0$C.

**II. Ceramic Industry**

(i) $SiO_2$ (ii) $Fe_2O_3$ (iii)$Al_2O_3$
(iv) LOI (v) PCE (in ortons).

Physical Characteristics

1. Plasticity.
2. Fixed colour at $1200^0$ C.
3. Size - 200 to 300 mesh.

**III. Complete Chemical Analysis**

(i) CaO (ii) $Al_2O_3$ (iii) $Fe_2O_3$ (iv) MnO
(v) $SiO_2$ (vi) MgO (vii) $TiO_2$
(viii) pH (obsqueous extract) (physical) (ix) LOI (x) PCE (Physical)
(xi) Matter soluble in water (xii) Matter soluble in HCL
(xiii) Residue on 50 micron IS sieve.

## 41. SALT AND EVAPORITES

Complete Chemical Analysis

(i) NaCl (ii) KCl (iii) CaO (iv) MgO
(v) Ba (vi) $SO_4$ (vii) Cl (viii) S

## 42. TALC/SOAPSTONE/STEATITE

**I. For paper, ceramic, textile and cosmetic industries**

(i) CaO (ii) MgO (iii) $Fe_2O_3$ iv) $Al_2O_3$
(v) $As_2O_3$ (vi) $SiO_2$ (vii) Cu (viii) Mn
(ix) Pb (x) Mica (xi) Carbonates
(xii) Chlorides (as NaCl) (xiii) Moisture and other volatiles
(xiv) Matter insoluble in HCL (xv) Matter soluble in water
(xvi) LOI (xvii) Sand and grit.

Physical Characteristics

(i) Colour (ii) Crystalline Structure (iii) Feel
(iv) Fineness (v) Brightness (vi) Bulk density
(vii) Bottling rate.

**II. Manufacture of French Chalk, Insecticide and Rubber**

(i) $CaO$ (ii) $MgO$ (iii) $Fe_2O_3$ (iv) $SiO_2$
(v) Ca (vi) Mn (vii) Chlorides (as NaCl)
(viii) Moisture and other volatiles (ix) Matter insoluble in HCL
(x) pH (xi) LOI.

Physical Characteristics

(i) Colour (ii) Feel (iii) Fineness
(iv) Bulk density

**III. Paint Industry**

Physical Characteristics

(i) Size - 300 mesh.
(ii) Form - Foliated, Fibrous and Lamellar

**IV. Complete Chemical Analysis**

(i) $CaO$ (ii) $MgO$ (iii) $Fe_2O_3$ (iv) $Al_2O_3$
(v) $As_2O_3$ (vi) $SiO_2$ (vii) Cu (viii) Ca, $K_2O$, $Na_2O$
(ix) Mn (x) Pb (xi) Carbonates (xii) Chlorides (as NaCl)
(xiii) Moisture and other volatiles (xiv) Matter insoluble in HCL
(xv) Matter soluble in water (xvi) pH (xvii) LOI
(xviii) Mica content.

## 43. VERMICULITE - used as insulating material

**I. Complete Chemical Analysis**

(i) $SiO_2$ (ii) $Al_2O_3$ (iii) $Fe_2O_3$ (iv) $FeO$
(v) $MnO$ (vi) $TiO_2$ (vii) $Cr_2O_3$ (viii) $CaO$
(ix) $MgO$ (x) $K_2O$ (xi) $Na_2O$ (xii) $H_2O$ (plus)
(xiii) $H_2O$ (minus) (xiv) LOI.

## 44. WOLLASTONITE

Complete Chemical Analysis

(i) $SiO_2$ (ii) $CaO$ (iii) $MgO$ (iv) $Fe_2O_3$

## 45. ZIRCON

(i) Zircon flour for use in foundries.

**I. Zircon flour obtained by crushing, flouring and washing of zircon sand.**

Chemical Analysis

(i) $ZrO_2$ (ii) $SiO_2$ (iii) $Fe_2O_3$

(iv) $TiO_2$ (v) $Fe_2O_3 + TiO_2$

(vi) Fusion point not below 2000°C

Physical Characteristics

**Grain fineness**

Grade I - completely pass through 75 microns IS sieve

Grade II - 90% pass through 75 micron IS sieve

Gradse III - used in foundry works

Grade IV - used in foundry sand mixes.

## GUIDELINES FOR EXPLORATION OF DIFFERENT MINERALS

Guidelines for exploration of different minerals given under extract are from the Bulletin No. 9 "Elements of Mineral Exploration" IBM, 1980 and as amended to suit the requirements wherever necessary.

It may however be clarified that :

a) The above set of guidelines are in respect of primary mineral occurrences in virgin areas and wherever old and/or existing workings are available and dependable relevant exploratory data and records are also available, the requirements of exploration would get reduced commensurate with the amount and quality of data thus available.

b) These general guidelines may be viewed as a composite set, to be followed sequentially. The requirements in individual cases may vary involving the use of two or more methods depending on the scale of mining operations, the level of mechanisation and the intricacies of the geological and mining geological parameters, and

c) Sampling procedures to be followed and the radicals to be analysed in respect of different minerals and ores shall however conform to the Annexure B & C.

## GUIDELINES FOR EXPLORATION - ASBESTOS

| | Method | Details of exploration | |
|---|---|---|---|
| | | Chrysotile asbestos of A.P.of | Amphibole variety asbestos |
| 1. | Mapping | 1:1000 to 1 : 4000<br>1:200 for underground workings | 1:1000 to 1 : 500 |
| 2. | Pitting | Not recommended | Random trial pits followed by systematic pitting in 10-15 metre grid. |
| 3. | Trenches | Not recommended | As necessary |
| 4. | Drilling | 100m x 80 m grid to be reduced to 50 m x 40 m grid as and when necessary | 30 m grid interval or larger for regional exploration |
| 5. | Exploratory mining | As per the directives issued by IBM | As may be necessary |
| 6. | Sampling | Visual sampling (As per the directives issued by IBM) | Bulk samples to be treated for obtaining fibre content. |

## GUIDELINES FOR EXPLORATION OF FIRE CLAY

| Method | Details |
|---|---|
| 1. Mapping | 1:2000<br>1:1000 |
| 2. Pitting | 50 m intervals along the strike 10 to 50 m along dip |

## GUIDES FOR EXPLORATION OF GRAPHITE, TALC, SOAPSTONE, PYROPHYLLITE-DIASPORE

| Method of exploration | Details |
|---|---|
| 1. Mapping/underground mapping | 1:1000 to 1 : 4000,<br>1 : 200 to 1 : 500 |
| 2. Pitting | May be given at suitable intervals |
| 3. Trenching | Cross trenching, 30-60 m apart may be given. |
| 4. Drilling | 50-100 m interval with a staggered pattern depending upon the mineralisation. |
| 5. Sampling | Trench sampling, core sampling and channel sampling. |

## GUIDES FOR EXPLORATION OF KYANITE

| Method | Details |
|---|---|
| 1. Mapping | 1:1000 to 1 : 5000 |
| 2. Pitting/trenching | 30 m interval, trench width varying from 1 to 2 m or more |
| 3. Sampling | From pits and trenches for Analysis and recovery tests. |

## GUIDES FOR EXPLORATION - MAGNESITE

| Method | Details |
|---|---|
| 1. Mapping | 1:2000 to 1 : 1000 |
| 2. Trenching | 50 m interval along the strike |
| 3. Drilling | 50 m and 100 m grid intervals |
| 4. Sampling | Channel and drill core samples |
| 5. Exploratory mining | As may be necessary. |

## General guidelines for exploration work for limestone and dolomite

## (Generally valid for bedded gypsum)

| Method | Simple type |  | Complicated type |  | Highly complicated type |  | Remarks |
|---|---|---|---|---|---|---|---|
|  | Regional exploration stage | Intensive exploration stage | Regional exploration stage | Intensive exploration stage | Regional exploration stage | Intensive exploration stage |  |
| 1. Mapping | 1:2000 to 1:5000 | 1:1000 to 1:2000 | 1:1000 to 1:2000 | 1:1000 | 1:1000 to 1:2000 | 1:1000 |  |
| 2. Drilling | 400-600 m Interval | 200-300 m grid | 300-400 m section interval, 1-2 boreholes in each section | 150-200 m section interval bore hole spacing of 0-300 m | 100-200 m sectionfinterval 1-2 bore holes in each section | 50-100 m section interval bore hole spacing 50-200 m |  |
| 3. Pitting | 2-4 Nos. for every sq. km. | 2-4 Nos. for every sq. km. | ------------- Not Recommended ---------------- |  |  |  |  |
| 4. Trenching | --------Not Recommended -------- |  | 150-200 m section interval | 75-100 m section interval | 100-200 m section interval | 50-100 m section interval |  |
| 5. Sampling | Core, blast and channel sample | Core blast and channel sample |  |  |  |  |  |

## General guidelines for exploration work for iron ore (hematite) (Excluding purely lateritic deposits)

| Method | Capping type deposits | | Reef type with appreciable dip | | Remarks |
|---|---|---|---|---|---|
| | Regional | Intensive | Regional | Intensive | |
| 1. Mapping<br>a) Underground mapping for adit | 1:2000 to 1:5000 | 1:1000 to 1:2000<br>1:200 | 1:2000 to 1:5000 | 1:1000 to 1:2000<br>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 bore hole in each section | 50-150 m section interval, 2-4 bore holes 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 1-2 Nos. on every third section lines to determine lump fine ratio, ore type distribution etc. | Upto 3 deep pits | 1-2 Nos. in alternate for every third section | |
| 4. Aditing | Not recommended | As necessary | Not recommended | As necessary | |
| 5. Sampling | Core and sludge, bulk sample from pit. | cores, sludges, 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, Geological Survey of India, Misc:Pub.No.33)

## General guidelines for exploration work for manganese ore

| | Method | Simple form strata bound deposits | | Banded deposits with complicated structure | | Lateritoid bodies | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | Regional exploration stage | Intensive exploration stage | Regional exploration stage | Intensive exploration stage | Regional exploration stage | Intensive exploration stage | |
| 1. | Mapping | 1:2000 to 1:5000 | 1:1000 to 1:2000 | 1:1000 to 1:2000 | 1:1000 to 1:2000 | | | |
| 2. | Underground mapping | Not recommended | 1:2000 | Not recommended | 1:100 to 1:200 | The main method of exploring lateritoid manganese bodies is by pitting and trenching, if possible by shallow drilling in order to delineate individual bodies including blind ore bodies. | | |
| 3. | Pitting/ trenching | As necessary | As necessary | 50-100 m trenching section interval wherever feasible | As necessary. | | | |
| 4. | Drilling | 200-400 m. section interval at 2 levels with 60 m vertical interval.. | 100-200 m section interval intersection at 2 levels at least | 100-200 m section interval at 2 levels with 60 m vertical intervals. | 50-100 m section interval at 2 levels at 60 m vertical interval | | | |
| 5. | Exploratory mining | Not recommended | Two levels across entire strike length | Not recommended | 2-3 levels 20-30 m vertical interval where necessary | | | |
| 6. | Sampling | Core and sludge channel and blast pit/core sample for laboratory study | Core and sludge channel and blast for pilot plant beneficiation stidies | Core and sludge channel and blast etc. for laboratory scale beneficiation | Core and sludge channel and blast for pilot plant beneficiation test | | | |

Based on Manual of Mineral Exploration, Geological Survey of India, Misc. Pub. No. 33.

## General guidelines for exploration work for chromite (methods for stratiform chromite generally satisfy barytes, excepting bedded deposits), fluorite, etc.

| Method | Stratiform deposits | | Podiform bodies | | Remarks |
|---|---|---|---|---|---|
| | Regional exploration stage | Intensive exploration stage | Regional exploration stage | Intensive exploration stage | |
| 1. Mapping | 1:2000 to 1:5000 | 1:1000 to 1:2000 | 1:2000 to 1:5000 | 1:1000 | To isolate ultrabasics and mappable chromite bodies, shear zones, zones of serpentinisation, etc. |
| 2. Drilling | 200-500 m intervals | 100 m intervals | 100-200 m section intervals; 1 to 2 boreholes in each section | 50-100 m section intervals at 3/4 levels down to a workable depth | Also study core recovery in the ore zone, lithology, occurrence of unsuspected ore bodies, etc. |
| 3. Trenching | As necessary to expose the concealed extensions | Not recommended | As necessary to explore the concealed sections along strike | Not recommended | - |
| 4. Pitting | 1-3 numbers across each representative ore type | 3-5 numbers for every mass/body | 2-4 numbers across for every represen-sentative ore type | 3-5 numbers for every mass/body | More helpful in vein and lens-like bodies. Recovery with depth should also be studied. |
| 5. Sampling | Core and sludge, bulk and chips from pits, etc. | Core and sludge bulk samples for grade analysis and beneficiation | Core and sludge, separate analysis for gangue-free ore, bulk samples from pits according to ore types | Core and sludge samples from pits for grade analysis for beneficiation | |

Based on Manual of Mineral Exploration, Goelogical Survey of India. Misc. Pub. No. 33.

## General guidelines for exploration of phosphorite

| Method | Flat or low dipping uniform bodies | | Complicated deposits with variable thickness etc. | |
|---|---|---|---|---|
| | Regional exploration stage | Intensive exploration stage | Regional exploration stage | Intensive exploration stage |
| 1. Mapping | 1:2000 - 1: 5000 | 1:1000 | 1:1000 | 1:1000 |
| 2. Drilling | 200-300 m grid | 100-200 m grid | 200-300 m section interval, 1-2 bore-holes per line to intersect 50/100 m levels | 100-150 m section interval, inter-section at 2-4 levels. |
| 3. Pitting | 4-10 Nos. per sq. km | 4-6 Nos. per sq. km. | ---Not recommended---- | |
| 4. Trenching | --------------Not recommended-------------- | | 200-300 m section interval | 100-150 m section lines. |
| 5. Exploratory mining | -------------------------------Not recommended--------------------------------- | | | Two levels development by drives/winzes, cross cuts at approximately 30 m. interval |
| 6. Sampling | ------------------------- | Core and sludge, blast and channel samples, bulk samples for beneficiation. | ----------------- | ———— |

Based on Manual of Mine ral Exploration, Geological Survey of India, Misc. Pub. No. 33

## General guidelines for exploration work for tin, tungsten and gold

| Method | Regional exploration stage | Intensive exploration stage | Remarks |
|---|---|---|---|
| 1. Mapping | 1:2000 to 1:5000 | 1:2000 to 1:5000 | Most gold deposits are however explored by the same methods as in sulphides. |
| 2. Surface drilling | 200-500 m section interval in two levels, 30 - 60 m vertically a part | 100-200 m section interval in 2-3 levels, 30 - 60 - 90 m vertical interval to trace and intersect mineralised zones. | |
| 3. Underground drilling | Not recommended | As and where necessary | |
| 4. Trenching | 200-500 m section intervals to trace old working | Not recommended | |
| 5. Exploratory mining | Not recommended | 3 or more levels over the entire/part strike length of ore body at 30 m level interval and winzes along suitable intervals. | |
| 6. Sampling | Core and sludge, blast and channel | Core and sludge, blast and channel, bulk sample from underground developments for beneficiation test. | |

Based on Manual of Minenral Exploration, Geological Survey of India, Misc. Pub. No. 33

## Mineral deposits associated with placer formations

Important placer deposits known in India are monazite bearing sands of Kerala, Tamil Nadu, Andhra Pradesh and alluvial tin deposits of Madhya Pradesh. Of these, the monazite bearing sands contain, in addition to monazite, a number of other minerals like sillimanite, zircon, ilmenite etc. These sands are essentially beach placers in which are concentrated the minerals from riverine sediments. All the other placers are of riverine alluvial origin.

| **Method** | **Details of Exploration** | |
|---|---|---|
| | Placers extending over 10 hectare area | Small placers |
| Mapping | 1:1000 to 1:4000 | 1:1000 |
| Pitting | 100 to 200 m grid | 50 m grid |
| Trenching | Not recommended | As necessary |
| Drilling | Not recommended unless it is a buried placer deposit | Not recommended unless it is a buried placer deposit |

Guides for exploration of pyrites (bedded type)

| **Method** | **Details** |
|---|---|
| Mapping 1:8,000 | |
| Pitting | To be done near surface to expose thickness. |
| Drilling | 500 m grid. |
| Exploratory mining Aditing | |

Guide for the exploration of diamond

| **Method** | **Details** |
|---|---|
| Mapping | 1:10,000 to 1:20,000. |
| Pitting | Widely adopted. No defined intervals. |
| Drilling | Useful in exploring vertical depth of pipes. No specific grid intervals are suggested. |
| Exploration mining | Short levels with connecting raises & winzes. |
| Sampling | Pits and bulk samples from mines. |