Government of India
Ministry of Mines
Geological Survey of India

Exploratory Drilling Guidelines for NMET Funded Projects

Mission-II: Natural Resources Assessment
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1. Background

In pursuance of the Mines and Minerals (Development & Regulation) [MMDR] Amendment Act 2015, the National Mineral Exploration Trust (NMET) was set up vide., gazette notification No. G.S.R. 633 (E) dated 14.8.2015. The NMET has started receiving payments of a sum equivalent to 2% of the royalty paid in terms of the minerals listed in the Second Schedule as per the provisions of the MMDR Amendment Act 2015.

The NMET has a Governing Body and an Executive Committee. The overall control, periodical reviews and policy directions of NMET are vested with its Governing Body chaired by Minister of Mines. The Executive Committee chaired by Secretary, Ministry of Mines is responsible to manage, administer and supervise the day to day activities of NMET.

The Rules governing the NMET have been notified vide gazette notification No. G.S.R. 632 (E) dated 14.08.2015. As per the Rules the funds accrued to NMET will be utilized primarily for the purpose of regional and detailed mineral exploration, inter-alia, by:

a) Special studies/ projects to identify, explore, extract, beneficiate and refine deep seated or concealed mineral deposits.
b) Regional and detailed exploration for strategic and critical minerals.
c) Detailed exploration in areas where regional exploration has been completed.
d) Facilitating ground and aerial geophysical survey and geochemical survey in obvious geological potential areas.
e) Organising capacity building of personnel engaged in exploration in Centre and States.

The main beneficiaries of NMET fund are the State Governments as the amount is to be utilized exclusively for the purpose of exploration, which aims at identification of mineral blocks for grant of mineral concessions by States.

Preparation of comprehensive guidelines for exploratory drilling for the mineral exploration projects taken up under NMET funding was suggested by the 5th Executive Committee vide. Letter number 10/14/2017-NMET/382 dated 29.11.2017. The matter was again discussed in the 6th Executive Committee meeting, held on 11th January 2018, wherein it was advised that TCC, NMET would develop these guidelines. Accordingly, documentation in this regard has been made by the TCC, NMET for comments from the concerned agencies before its finalization.

2. Significance of Exploratory Drilling

Diamond drilling is the most important phase of exploration and it is a very expensive method for collection of information on subsurface data. More than any other exploration technique it provides the exploration geologist with the most concrete and accurate material upon which an economic evaluation of a block/ area can be made. It also provides a detailed, continuous, look at the subsurface geology. Drilling is an important and integral procedural component in mineral exploration to (i) ascertain the subsurface configuration of the ore body (ii) to bring out three-dimensional model of the ore deposit (iii) to know resource of blocks at the defined cut off grades for ultimate exploitation and (iv) arrive at the grade of the deposit. However, drilling can be expensive and because of this, it has become the most critical phase of exploration. Drill costs vary depending on hole depth, rock types, core size, etc. The core size may be fixed depending upon the mineral commodity. The drill cores depict invaluable data on geological setup and a treasure of information that can be used in future for establishing a generalized stratigraphic sequence of the area and other studies. The governing factors of quality mineral exploration report are core recovery, borehole deviation, analysis of number of radicals, QA-QC, preservation for further studies. The cores preserved for posterity may be useful in the search for mineralization and building understanding on various geoscience parameters in future supported by advancement of technology.

The well-known justification for core preservation is to save the costly basic data, i.e., the physical end product of exploration, reducing duplication of expenditure and to allow future Geoscientific studies with advent of evolving new concepts. The drill core samples, combined with indirect methods like geophysics and geochemistry may provide glimpse of the bedrock for a substantial area and may limit the need for additional/ unwanted drilling. The cores obtained in any mineral investigation project, may be useful to re-evaluate the mineral prospect in light of the changing economics and geological concepts. The advancements in mining and metallurgical technology and rise in prices of metals may render some deposits presently un-economic or sub-economic to become economically more viable in coming days and it may be needed to restudy the sub-surface data and reanalyse the core samples of the explored deposit / prospect. The drill cores preserved in the library will obviate the need to re-drill in the already explored area.

Various exploration agencies take-up G4, G3 and G2 stage mineral exploration programmes under NMET funding. There is a need to have uniformity in the data storage and its retrieval pattern. To have clarity in recording the borehole data, proper interpretation, meaningful resource estimation, core preservation at proper places (National Drill Core Libraries of GSI) etc., these draft guidelines has been prepared.

The boreholes may be drilled vertically in horizontal or shallow dipping formations and inclined in moderate to steeply dipping ore bodies. In tabular low dipping bodies, like, iron ore/ bauxite/ limestone etc., a square or rectangular grid pattern considering strike/ orientation of the ore bodies is opted. In narrow basemetal/gold/PGE, etc., vein deposits, inclined boreholes are planned to intersect the ore body at different levels along cross-sectional lines at specified intervals.

Consideration should also be made for drilling based on the ground accessibility issues like steep slope in dip direction for which angular holes can be drilled in various directions from the same drill pad (i.e. fan drilling).
Drilling data is to be presented in a standardized format

Standardized format for drilling data

Borehole Number	Co-ordinates (UTM East North Zone/ Lat & Long)	Elevation (m)	Inclination of Borehole	Azimuth (D)	Length (m)	R.L. of collar/bottom	Core size

Significant drill intercepts are to be given separately with assay value, core structural orientations and core recovery percentage.

Drill Intercepts

Area	Drill Nor.	Hole	Intercepts(m) Interval (m) From/to	Orientation Comments	Core Recovery%	Assay (g/t / ppm / %)

In case, if the resource estimation and 3D modelling is to be carried out using suitable software, the information in 4 typified spreadsheets / table viz. i) Collar file, ii) Assay file, iii) Litho file and iv) Deviation file of each borehole has to be prepared, which can directly be imported while making resource estimation or modelling. The columns of collar file are Hole id, Easting, Northing, Elevation, Azimuth, Inclination, Total Depth, Remarks (Under remark column, one can mention other relevant details). The columns of assay file are Hole id, From, To, Assay 1, Assay 2 etc (if there are more assay values). Litho file should have Hole id, From, To, Lithology description, Litho id, Remark. Deviation file should include Hole id, from, To, Inclination, Azimuth. Some of the deviation measuring borehole camera units create such files.

Topography is an important aspect in the resource modelling. Hence, it is necessary that the BH collars be surveyed very accurately either with a Differential Geographic Positioning System (DGPS) or Total Station with respect to any established and recognized Bench Mark (BM). Under no circumstances, the BH collar should be surveyed by a handheld GPS. Due to various atmospheric aspects and inherent error factors, the resulting errors in X, Y and Z axes are up to 10-12 meters and the Elevation readings in handheld GPS in particular are not acceptable at all.

As it is not possible to survey each and every BH collar by a DGPS, it is more practicable to survey the BH collars with a Total Station with reference to a local BM. It is suggested to have at least three permanent BMs erected within the prospect area and surveyed with DGPS for their locational accuracy in respect of the three coordinates, X, Y and Z. The BH collars and the topography of the area must be surveyed with respect to these BMs. The BMs should be kept well maintained and well protected.

3. Drill Core Sampling

Drill core is collected in core barrels of 3m to 6m length and it is dried and preserved in a core box made of GI sheet or casted PVC box as per run with proper numbering using a wooden / metal or PVC block. Cores are stored usually in book form method. RQD to be determined at this point. The core obtained in the mineralized zone is vertically split into two halves after logging, by core splitter (automated mechanised core cutters preferred) and one-half of the cores are retained in the core box for future reference. The other half is reduced to a size of about 10mm, coned and quartered. One half of representative sample (two opposite quarters) is stored properly (in case of G3 stage, the same will be used for the ore beneficiation studies during G2 stage of the same block), and the other half of the representative sample is powdered to requisite fine mesh size (#120 or #200 mesh size) coned & quartered again for analysis and the rest of the powder is kept as duplicate sample. Riffle splitting and Chinese grid sampling is also an effective way of reducing sample size with thorough homogenisation.

However, if the size of the core is small, say BW size, then half of the core may have to be powdered to get the required amount of sample for analysis. For iron, manganese and chromite, average core (sample) length may be taken as 1m, but sample lengths may be smaller and is decided based on change of ore types, ore / waste contact etc. In case of iron ore, waste bands > 50 cm should be separately sampled. If within the 1m sample there are repetitive bands of waste with thinner intervening ore zones, they may be sampled together, as that the entire sample may analyse as waste or low-grade ore. Any gangue intercalations occurring in the form of shale, chert etc., has also to be sampled and analysed. If the gangue intercalation (non-mineralised portion) is more than 1.5 to 2m and it is continuous then, it may not be sampled for analysis. However, it has to be considered while estimation of resource and grade depending on stoping width/ bench height. In case of soft strata, the % of lumps and fines may also be need to be defined for better understanding of the mineralised zone.

For mechanized mines, even of 1.5 to 2m of gangue intercalation especially for bulk mineral commodities will not be separated out from the ore and this will dilute overall ROM grade. Hence all materials within ore zone shall be sampled and analyzed which will have implication on resource and grade.

Although core splitter is usually used, the core can be also being cut longitudinally by diamond saw cutter for uniform cutting and the sampling will ensure equal distribution of mineralisation in both halves. Since the surface so obtained is smooth, its photo can be preserved which would help in better understanding of litho-textural and small scale structural features on the core, if any.

For soft, friable and powdery ore as in the case of iron, manganese, bauxite, chromite etc. the drill core sample is collected from the whole 1m length without any bias and thus around 1kg of sample is collected. The left out mixed sample may be preserved for further reference. However, if size of the core is small, then, 600 to 700 gm sample is collected, powdered to requisite mesh size, cone and quartered and around 250gm of sample is sent for analysis. Regarding the mesh size, -120 size fractions is preferred for bulk minerals and -200 size fractions for precious metals / low grade high value critical and strategic minerals. A few sampling should be carried out before and after (Hanging wall and Foot wall side) mineralised zones to see the continuation of mineralisation and also to exactly demarcate the mineralised zone. The sample should be of uniform length and two different lithologies must not be mixed in the same sample.

Determination of weighted average and arithmetic average of assay values of analyses of samples is to be determined for ore resource estimation. In weighted average assay, the assay values are weighted by taking into account the volume or weight of the sample of a given length. It truly reflects value for given volume or length unlike arithmetic average, where value and only the number of samples are considered.

Weighted average = {∑ [Assay value of each sample x length of respective sample in meters] / Total Length of all samples}.

Following measures are considered important to enhance drilling quality and efficiency:

- To develop techniques to maximize core recovery in difficult strata condition by introducing mud technology, reverse circulation, vacuum suction, etc.
- To introduce non-core drilling by Down the Hole Hammer (DTH) method to supplement core drilling to effect faster and cheaper drilling. However, DTH drilling

can be best used in low dipping or horizontal strata /ore bodies. Sometimes, combination drilling i.e. both core drilling and DTH drilling is possible in some advanced drilling rigs. It helps in obtaining core of the ore zone whereas, non-ore zones can be cut by DTH method.

- To maximize core recovery in difficult strata condition, a triple tube can also be used in wireline drilling.
- To strengthen existing borehole surveying techniques.
- To control deviation and to introduce controlled directional drilling with proper deflectors and to introduce Dyna drills for getting multiple intersections.
- Provision for re-drilling should be there if deviation exceeds permissible limits.
- To strengthen pencil hole geophysical logging techniques based on the mineral commodity.
- To introduce increasing use of large diameter drills.
- Quality control and quality analysis at each stage needs to be checked.

On completion of drilling, the site is restored to an extent to its original landscape by filling up of the sumps and setting right the other disturbances. Borehole logs are skeletonized and preserved for posterity. Drill core management is an intrinsic aspect in all types of mineral exploration. Drill cores have a significant scientific value as a physical record of a mineral resource as well as a stratigraphic column, characterizing the host rocks and hence form an invaluable asset value for future exploration programmes. Given the effort and cost invested in retrieving it, drill cores preservation and management is an absolute essentiality in mineral exploration.

4. Borehole Deviation

Borehole deviation, its measurement and correction are to be undertaken in each borehole operation. In most of the cases, there is a deviation of borehole from the planned path. Deviation occurs due to following causes:

- Geological – Boreholes tend to follow line of least resistance in a direction normal to bedding. Different physical characteristics of strata, weak structural zones, such as joints, faults and voids, etc. cause deviation.
- Technical-faulty setting of drill machine, substandard drilling tools and their improper applications may cause deviation. Change in r.p.m of machine, flushing intensity may also contribute for deviation.

In order to ascertain deviation particularly in deep boreholes (>250m), it is recommended that boreholes may be surveyed for azimuth and angle deviation till the pattern of deviation is established. Accurate measurements of borehole angles at close intervals may be carried out by (i) Etching method using hydrofluoric acid; (ii) mass borehole canson compass; (iii) Tropari drill hole surveying instrument; (iv) photographic angle recording device; (v) Surwel gyroscope instrument; (vi) dip-meter; (vii) Digital Multi-Shot Borehole Deviation system (Multi-shot camera for deviation survey) and (viii) Optical borehole deviation measuring instrument such as Reflex Maxibore. The advantage of Reflex Maxibore type of instrument is that the measurements recorded within the cased zone is also accurate, whereas the same recorded by multishot camera is not considered as the compass in cased zone gets deflected by the iron casings.

Corrective method has been developed to control or minimize the deviation by employing directional drilling technique. A special type of wedge is fixed to the wall of the borehole so that the bit takes up the desired course. All information related to borehole deviation measurements should be included in the Geological Report.

5. Determination of Bulk Density Using Drill Cores

The method by which bulk density is derived is crucial for understanding the tonnages of ore and metal in a resource. For example, an error in a bulk density estimation can have significant impact in calculating metal tonnage, especially so in higher grade deposits. It is imperative, also, that the correct technique is utilised in measuring bulk density for different commodities. The collection of bulk densities outside of the ore horizon is also needed as this will have impact on waste handling and mining.
The weathering, porosity, mineralogy or moisture content should be taken into account as these have an impact on bulk density measurement methods. Also, assay results are on a dry basis, so typically resource estimates require a dry bulk tonnage. Majority of field observations derive a wet bulk density, so the moisture content should also be derived (as this is important from a mining perspective); this is achieved through oven drying the sample and weighing again. With any methodology it is crucial that the process is documented and other bulk density methods are utilised to ensure that there is no bias in the results.

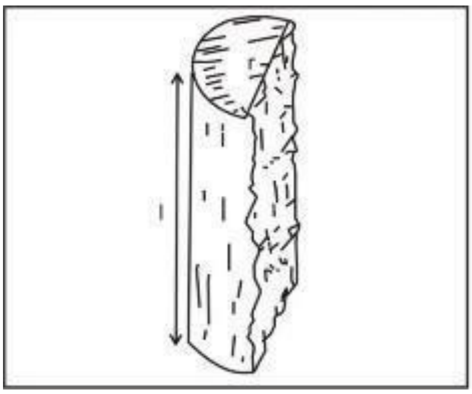
The bulk density can be determined by measuring the length of the core or half - split core. Vernier scale may be used to measure average radius and length of core pieces. Since diameter of the NX, BX, AX, NUT, AUT etc. bit size is known, therefore, the volume of the core can be computed by the following formula.

$V = \pi R^2 h$ (if the core is not split)

$V = (½)\pi R^2 h$ if the core is half split

V = Volume, R=Radius of core sample, h=height of core sample

Weigh the measured core and determine the bulk density by D_B=M/V where D_B is the bulk density and M is the mass of the measured core. This can be easily measured by Walker's Steelyard balance by computing weight in air and weight in water. To take weight in water, the core piece can be hung by a thread and made to immerse in a beaker full water and then take the reading. The average on very sizable number of determination may be taken to represent the in-situ tonnage factor (field measurement). The samples should be taken from all the variations of the grade, which are taken for lode computation for true representative of the lode or deposit. The bulk density need to be assessed initially at every stage or as per the litho units.



Split drill core with *l* length & *r* diameter for determination of volume of half core

6. Core Recovery and Grade Computing

Core recovery plays an important role in computation of ore resources. Therefore, the core recovery should be very high at least in the mineralized zone. In NX core the actual core-recovery by volume is 52.2% and BX size is 40%. However, for all practical purposes, the core recovery is measured length-wise i.e. by recovery = (Lr/L) x 100 where 'Lr' is core recovered and 'L' is run length. In case of dry drilling for soft powdery ore e.g. in case of iron ore, manganese ore, chromite ore, conventionally the recovery is considered as 100%, though theoretically it is not possible.

Category	Mineral Commodity	Approx. Expected
		Core Recovery %
	Iron Ore	> 90%
Ferrous Group	Manganese	> 90%
	Chromite	> 90%
	Gold	> 95%
Precious Metals and	Platinum Group of Elements	> 95%
Minerals	Diamond	> 95%
	Gemstones	
	Base metals (Cu, Pb and Zn)	> 95%
	Bauxite	> 90%
	REE and RM	> 95%
Non-Ferrous & Strategic	Tin	> 95%
Minerals	Tungsten	> 95%
	Molybdenum	> 95%
	Nickel and Cobalt	> 95%
	Potash	> 85%
	Phosphorite	> 85%
	Graphite	> 90%
	Limestone	> 85%
Industrial and Fertilizer	Baryte	> 90%
Minerals	Dunite	> 90%
	Wollastonite	> 90%
	Andalusite, Kyanite & Sillimanite	> 90%
	Clay Deposits	> 80%
	Dimension Stone	> 90%

If core recovery in the lode is more than 95%, then for the resource calculation purpose it may be taken as 100%. However, it will depend upon the nature of deposit, its occurrence and mineral content. If core recovery is less than 95%, correction factors have to be applied while calculating thickness of the lode. Mainly there are three options.

Dilution Method: In this method the assay value of recovered core is distributed in the whole run assuming that the part of core which is not recovered is barren; by this method the grade will go down the assay value.

$Gr = A^* \times L_1/L$

Where Gr = Grade

A = Assay value of sample,

L_1=length of the core recovered,

L = length of run

*Only in case where core recovery is more than 90%.

Reduced- Width Method: In this case the core loss is considered as voids and the lode width is taken as the length of the core recovered. Thus, the thickness of the lode will reduce; however, the grade will be as per assay value.

Equal Grade Method: This method is adopted where core recovery is more than 90% or 95%. In this method the grade of recovered length is taken as the grade of run with the assumption that the uncovered portion also contains the same assay value. Thus, the run length is the thickness of the lodes. In the loss of the core, the sludge samples may give some idea but that cannot be considered for the following reasons.

i) The sludge represents fully the uncased column in borehole rather than the bit end.
ii) The sludge collection contraption could only hold middling, with the slim falling running off and the heavier particles going down in the rock crevasses.
iii) The sludge extraction is the function of return water, which were minimized (water loss) near the fault or shear zone.

Failing to achieve the core recovery for the total mineralized zone of the borehole, the hole may be re-drilled.

7. The Need for preservation of Drill Cores.

Subsurface drilling operations in the country dominantly explore the depth persistence of an economic mineral commodity and enabling a 3D understanding and modelling of ore deposits. The spacing of drilling and depth intersections largely depend on the nature of the deposit as well as the stage (G4, G3, G2 and G1) at which the exploration is being carried out in accordance with Mineral (Evidence and Contents) Rules, 2015.

The libraries will cater to the need of the exploration agencies, either in Govt. or in private domain (Annexure-I). The ready availability of drill core will be of significant help to exploration agencies in the formulation of exploration strategies and programs. Exploration programmes involving subsurface drilling operation is based solely on the understanding of the natural behaviour of the particular economic mineral being explored. This behaviour in turn leads to the understanding of the nature and tectonic setting of the mineral deposits. Therefore, a provision should be kept in the core library documentation for retrieving the cores belonging to a particular tectonic setting based on their genetic aspects. Drill cores needs to be submitted along with Annexures II to IV.

The skeletonised drill cores as well as the complete drill core for stratigraphic correlation/ purpose and future reference may be preserved at GSI Core Library, available at various Regions.

8. Proposed Percentage of Drill Core for Archiving

Taking cognisance to the fact that the exploration for base metal and gold throughout the world is very complex and depend solely on our understanding of the ore genetic processes vis-a-vis tectonic setting of the terrain, the following scheme of core preservation for different exploration projects is prioritised as below in the SOP of National Drill Core Library (2016),

- Base metal (Cu, Pb, Zn and associated Au & Ag) -25%
- Gold – 15%

- Coal – 10%
- Supergene deposits – Iron & manganese -10%
- Bauxite (Ga, REE) and Ni -5 %
- Orthomagmatic deposits (Cr, PGE, V-Ti magnetite) – 10%
- Strategic Minerals (Sn, W) and REE – 5%
- Limestone – 5%
- Diamond-5%
- Fertiliser and other industrial minerals -5%
- Others – 5**%**

9. Collection and Acquisition of Drill Cores (Guidelines for Selection)

The core libraries are established for the benefit of the general public, particularly the exploration industry. Hence it should be made obligatory for all exploration agencies to make submission of selected mineral cores compulsory, by amending the MMDR Act appropriately.

Core offered is to be evaluated by the Officer-in-charge of the library to establish its scientific, educational or economic use. As only a small percentage of cores generated from mineral exploration can be stored each year it is necessary to determine criteria for the selection of the core. To be acceptable to all, the core selection process has to be transparent. The selection process for mineral drill core is based on determining the priority that is using a series of selection parameters which will be determined from time to time. GSI being a nodal agency for maintaining the National Drill Core Library will be responsible for fixing selection parameters to assign the priority. Once drill core has been obtained from a particular deposit or location, that deposit or location is removed from the list of priorities. Additional core from deposit or location will only be collected if it is substantially better than the existing core.

10. Core box specification

For permanent preservation of drill core, it is necessary to preserve the core in galvanized iron GI sheet or standard PVC core boxes. Boxes of galvanized iron sheet (about 22-gauge thickness) having 90cm length, 30 cm width and 10 cm height with three adjustable partitions dividing the box longitudinally in four compartments are recommended. These boxes are suitable for handling and stacking them in the heavy-duty racks. Painting of the core boxes with red oxide may be done periodically in order to avoid rusting of the boxes.

11. Methodology for Preservation of Drill Core in Boxes

Before shifting the cores into the core boxes, it must be thoroughly washed with clean water and dried. Polythene sheet may be placed in each compartment of the core box so to avoid loss (in case of loose material) and contamination. This will also prevent direct contact of samples with core box especially for core boxes made with GI sheets and avoid rusting. The depth of the core should be written by good quality black oil paint or it can be engraved by hand machines on the GI sheet separators (*gutkas*) between each run of cores preserved in the core boxes. Each core piece should be marked to indicate the top side and individual core piece may be numbered for each sample separately and the number of core pieces in individual sample should be reflected in core register. This would help in arranging the core pieces in right sequence while examining and re-examining the same. Borehole number, depth of the core samples and box numbers must be written with black oil paint or can be engraved with punch machines on the GI sheet core boxes.

The sulphide rich zones of mineralization are prone for spontaneous oxidation during the wet periods of rainy season. The acids generated because of moisture can attack the galvanized iron sheet boxes and spoil them. To avoid the oxidation of sulphides a thin coating of transparent varnish can be put over the mineralized zones.

12. Skeletonization of Core

In many developed countries viz. USA, Australia and Canada, the drill cores are preserved in totality without preferential rejection of any portions. In South Australia mineral exploration licence holders are required by legislation to provide to the Department of State Development, geological samples including drill cores obtained during the course of operations. However, the concept of preservation of drill cores in India was initiated after the implementation of HPC (High Powered Committee). Because of the paucity of space and infrastructure facility it is almost impossible to accommodate the entire drill core that is retrieved from exploration projects. Hence drill cores generated during various exploration programmes are to be judiciously selected so that at an optimum cost all the vital information can be preserved scientifically. This process is generally ascribed as **Skeletonization**. As described in earlier sections, depending on the complexities of control of mineralization where there is ample scope for redefining during future dates, the skeletonization becomes tricky. In case of bedded or supergene deposits the intricacies are comparatively less and there is greater flexibility in skeletonization process. Although skeletonization largely depends on the present day understanding of the exploration geologist and largely under his discretion, it is always better to outline the following points to be observed during skeletonization.

- The entire drill core of at least one bore hole preferably drilled to the maximum depth and intersecting all the litho types in each exploration block for a better understanding of the behavior of the mineralization should be preserved without skeletonization. The selection of this un-skeletonized core would be done in consultation with the exploration geologist of the project by the scientists of the NDCL. It is also important to note that even holes that don't intersect mineralisation can be useful from a stratigraphic perspective.
- All the mineralized portions including the coal seams are to be included in skeletonized core. Although in basemetal and noble metal exploration mineralized zones less than one meter are not considered for resource calculations, these zones showing significant values are to be included.
- In case mineralized zones are separated by <3m wide non-mineralized parts, they are to be preserved as single continuous one.
- In case of low grade, high tonnage basemetal deposits, the whole mineralized zone is to be preserved.
- Selection of wall rock in case of basemetal and noble metal exploration play significant clues for deposit modelling, hence country rock of minimum 2m both from footwall and hanging wall are to be preserved.
- Core pieces depicting small scale structural features e.g. folds, faults and other interesting geological characters from non-mineralised portions should be preserved with depth marked on it.
- The simplest methodology would be to create a cross section through the deposit and take the most representative holes containing country rock (hanging and foot wall), alteration, mineralisation and any other features that characterise the deposit (e.g. shears etc.). An important aspect of a deposit can be its host stratigraphy and losing that information from a hole is detriment to the understanding of its character of formation or emplacement.

13. Reporting and Recording of Drill Core Data

The standard format on storage of drill cores involves the study of core, sampling and use of the remaining core for storage. Based on the existing practice the mineralised core along with 2m of hanging wall and foot wall side core are preserved in the core boxes, apart from this the entire cores of one representative borehole of the block investigated, is preserved. An excel file is attached as an example how the skeletonised core table is created and stored. Further it can be improved based on the latest OCBIS Annexure-III.

Subsurface Exploration - Borehole Details

Sl	Field Name
1	Prospect Name
2	Block Name
3	Basin Name
4	Commodity
5	Mineral Belt/ Coal Field Name
6	Borehole No.
7	Date of Commencement
8	Date of Completion
9	Toposheet No.
10	Latitude
11	Longitude
12	R.L. of Collar
13	Azimuth
14	Inclination
15	Drill Unit No.
16	Drill Type
17	Remarks
18	Location Information
19	Water Level
20	Water Level Record Date

Subsurface Exploration–Run Information: [Multiple Entries against a single borehole]

Sl	Field Name
1	Depth (from)
2	Depth (to)
3	Run length
4	Core length
5	Core loss
6	% Recovery

Technological Subsurface Exploration -Deviation: [Multiple Entries against a single borehole]

SI	Field Name
1	Depth
2	Azimuth
3	Angle

Subsurface Exploration -Litholog: [Multiple Entries against a single borehole]

SI	Field Name
1	Depth (From)
2	Depth (To)
3	Lithology
4	Length Adjustment
5	Adjusted Length
6	Final Depth
7	Core Dip
8	Core Size
9	Description
10	Super Group
11	Group
12	Formation
13	Member
14	Structure
15	Alteration

Subsurface Exploration -Mineralization: [Multiple Entries against a single borehole]

SI	Field Name
1	Depth (from)
2	Depth (to)
3	Description
4	True Width
5	Name

Subsurface Exploration - Core Samples (CS): [Multiple Entries against a single borehole]

SI	Field Name
1	Sample No.
2	Date of Collection
3	Depth (From)
4	Depth (To)
5	Sample length
6	Lithology (Descriptive)
7	Remarks

In addition, the following details needs to be incorporated:

Subsurface Exploration – Borehole Details

- Name of exploratory agency undertaking the work;
- The name of Geologist who has logged the core;
- Name of drilling contractor and driller;
- An additional column for Easting & Northing UTM co-ordinates to be added for drill hole collar file, along with applicable UTM Zone and Datum.

Technological Subsurface Exploration – Deviation

- Should include the type of device used for orientation (very important to understand especially in magnetic sequences)

Other general observations and information that should be included:

- DGPS survey should be compulsory for each borehole upon completion of drilling with the DGPS co-ordinates recorded as final co-ordinates (potentially both GPS & DGPS co-ordinates should be included);
- Measured physical properties on core and down hole geophysical wireline logging or EM survey should be submitted in standardised digital formats (for entire hole);
- Borehole no. should be a common field for all layers to make a Relational database; and
- For complex geological areas (or in fact any angled core hole) oriented core drilling shall be carried out. Structural data (alpha, beta & gamma) shall be recorded in a separate table from oriented core.

14. Core Labelling

The top of the core should be shown on each piece of core with an arrow written in a black, waterproof marker. The arrow will indicate which end of the core is nearer the ground surface. Other core markings may include locations of mechanical breaks and drilling footages.

15. Core Box Labelling

Each core box needs to be properly labelled. On the top left corner of the outer core box, the project name, site location (city and state), and project number should be written. On the lower right corner of the outer core box, the borehole number (e.g., MW1, BH2), core box number (e.g., 1 of 2, 2 of 2), and the interval of the core run contained in the core box should be written.

The side panels should be marked as indicated in following Figure. The inside of the core box cover should be marked as indicated in the next Figure. It is important to use proper-sized wooden core boxes for rock core storage.

After labelling the box and before closing the box for final storage or shipment, wooden spacers should be inserted into each compartment that contains rock core. This will prevent lateral movement of the cores, which could damage the rock material during handling. After properly logging, labelling, and packing the cores, the core boxes should be stored in a dry location, preferably off the floor on a pallet. The boxes can be stacked to a reasonable height so as not to be unstable, with end labelling facing out.

16. Drilling Logs Documentation

When drilling boreholes, the project geologist should maintain a log that describes each borehole. With current day access to Landsat imagery holes can be plotted using GPS co-ordinates on current Landsat (or LiDAR) imagery.
The following basic information should be entered on the heading of each drilling log sheet.

- Borehole/well number;
- Project name;
- Site location;
- Dates and times that drilling was started and completed;
- Drilling company;
- E & E geologist's name;
- Drill rig type used to drill the borehole;
- Drilling method(s) used to drill the borehole;
- Bit and auger size(s);
- Depth of auger/split barrel sampler refusal;
- Total depth of borehole;
- Water level at time of completion measured from top of inside casing (TOIC); and
- A well location sketch.

17. Technical Information

During the drilling of a borehole, specific technical information about the unconsolidated material and rock encountered should be recorded on the drilling log sheet.

The following minimum technical information should be recorded:

- Depth that sample was collected or encountered;
- Sample number assigned (if applicable);
- The number of blow counts required to drive the split barrel sampler 2 feet at 6-inch intervals
- Description of soil components
- Description of rock profile
- Rock qualitative designation (RQD)
- Rock penetration time;
- Core run number (if applicable) and percent recovery; and
- Organic vapour readings in the sample.

Some of the parameters such as *RQD, organic vapour, rock penetration time, number of blow counts required to drive the split barrel sampler 2 feet at 6 inch intervals,* would only be collected if they were specifically required and are not typical of exploration phase core drilling. The geotechnical information, if needed to be collected in a standardised manner as per the requirement.

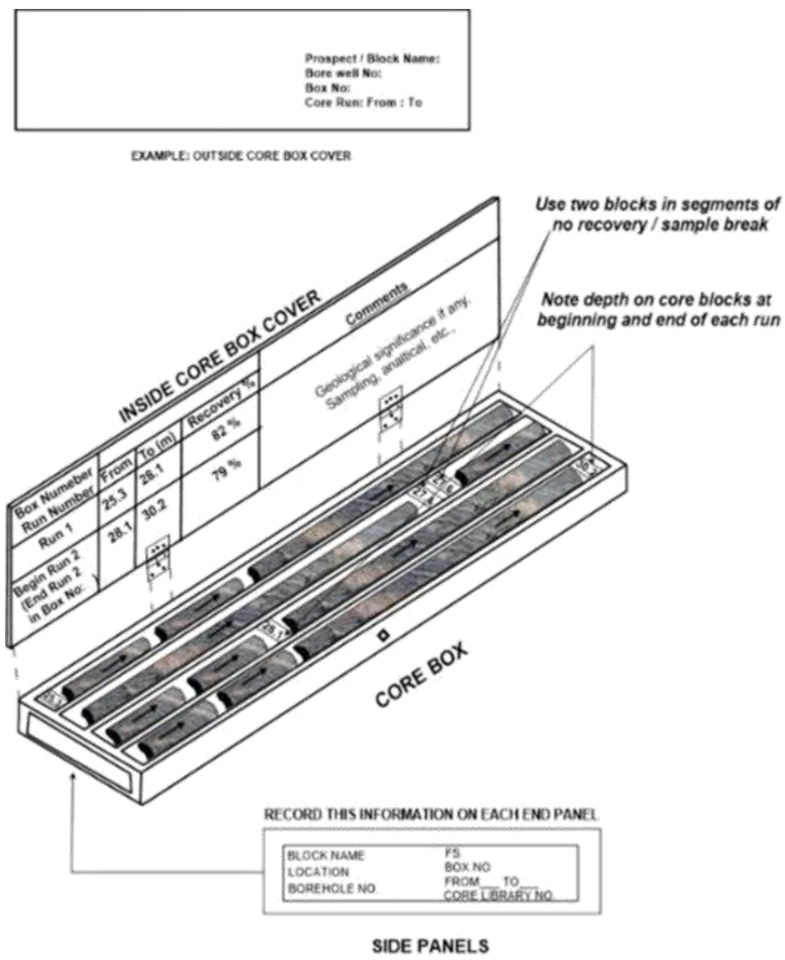
18. Rock Description

Each stratigraphic unit in the core shall be logged. A line marking the depth of the top and the bottom of the unit shall be drawn horizontally. In classifying the rock, the geologist should avoid being too technical, as the information presented must be used by numerous people with widely divergent backgrounds.

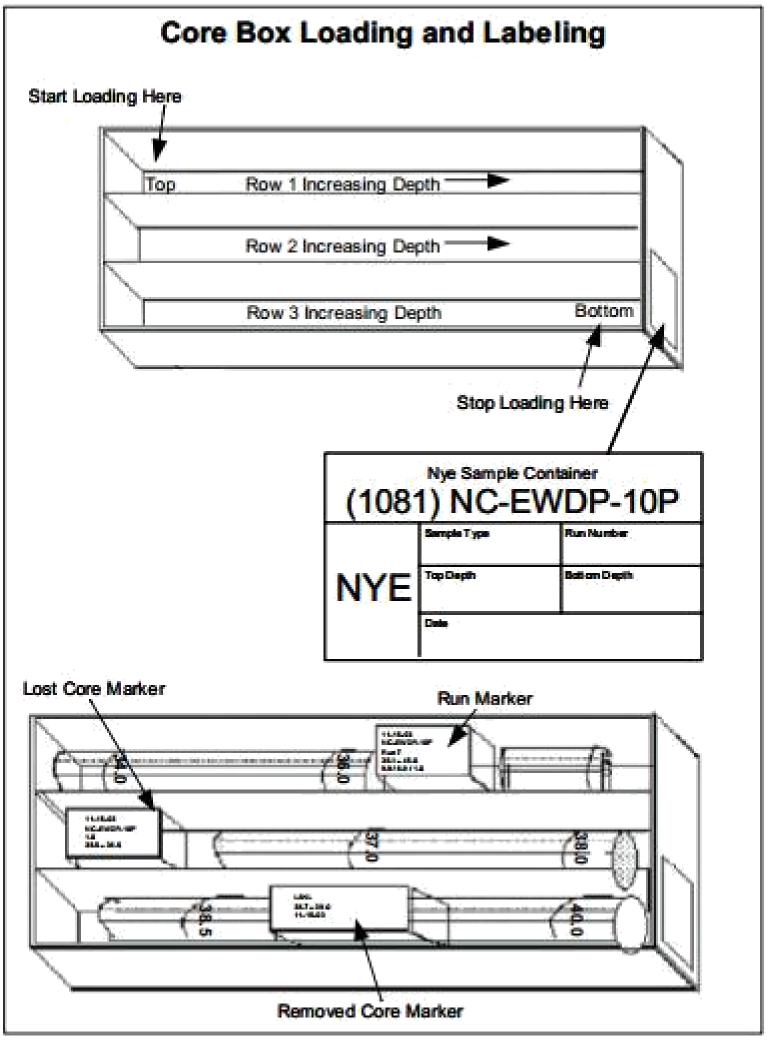
The classification and description of each unit should be given in the following order, as applicable:

- Unit designation (Formation)
- Rock type
- Hardness
- Degree of weathering
- Texture
- Structure
- Colour
- Solution and void conditions
- Swelling properties
- Slaking properties and
- Additional description, such as mineralization, size, and spacing shale seams, etc.

Variations from the general description of the unit and features not included in the general description shall be indicated by brackets and lines to show the depth and the interval in the core where the feature exists. These variations and features shall be identified by terms that will adequately describe the feature or variation so as to delineate it from the unit. These may be zones or seams of different colour, texture, etc., from that of the unit as a whole, such as staining; variations in texture; shale seams, gypsum seams, chert nodules, calcite masses, etc.; mineralized zones; vuggy zones, joints, fractures; open and/or stained bedding planes; faults, shear zones, gouge; cavities' thickness, open or filled, nature of filling, etc.; or any core left in the bottom of the hole after the final pull.



In a core box, usually the top left corner of the upper most row indicates the 'from' depth and the right bottom corner of the lowest row indicates 'to' depth of the core length kept in the particular core box.



19. Creation of Easily Retrievable Database

The database on broad geography, borehole details, Geology (Lithology, structure), petrology, mineralization, analytical data, isotopic data etc. created while logging and skeletonization of core may be prepared in line with Core Library Information System of OCBIS in preparation by Mission-III. The sample CLIS. excel file is attached and may be modified as per requirement. Further based on the recommendation of the HPC the National Drill Core Libraries should have details as follows.

- Information regarding the drill core sample preparation process, despatch, assay techniques carried out and QAQC process should also be captured.
- RCC pillars need to be fixed at each drill hole location as per existing GSI standard practice; and
- Every state needs to establish a core library for better preservation of core.

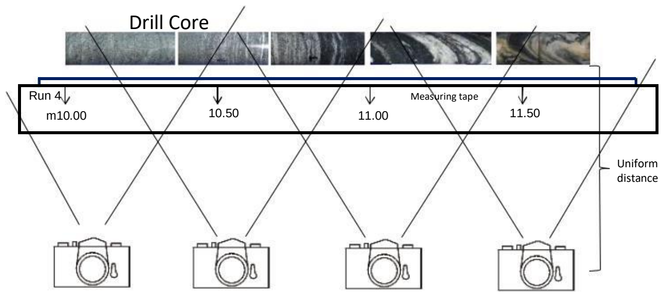
20. Provision of Photographic Record

The complete borehole should be photographed. The Geologist will take representative digital photographs of the individual core runs and additional photographs of important portions of the cores (Structural features, fragmented zones, changes in lithology, etc.) where applicable. In general, a geologist has a scope of taking core photos at three junctures.

a) Immediately after the core is taken from the barrel – run wise.
b) Once the cores are arranged in the core boxes, with details of borehole, measuring and core markings.
c) After core study and sampling are over, once the remaining cores are skeletonised in the GI core boxes and ready to be preserved in the core library with relevant markings. Thus the information collected systematically via photos would be a valuable record in time. Core photos are of great value for providing a visual record of the borehole, through lithology and depths and provide significant geological features/information.

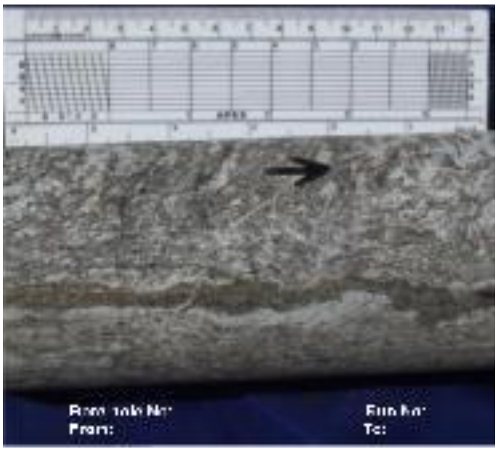
Core Photography (Immediately after the core is taken from the barrel – run wise): To ensure a useful and to create a reliable photo record of the cores, the presentation of the core should be as thorough and consistent as possible.
The following procedure can provide a useful photo record of the cores:

- Clean the core surface to enable clear identification of lithology
- Take photos preferably with high resolution digital camera with a flash at a constant distance and at consistent lighting with visible overlap to minimise distortion covering approximately 0.5 to 1.0m lengths of a core.
- See that the core is moistened with water immediately prior to photographing (only for hard core samples) in order to bring out the true colour and fabric of the core
- The photo should include project name, borehole number, depths, core marking preferably 0.5 m interval, measuring scale or tape running along the full length of the core.
- Additional detailed photos can be taken for significant structures or sedimentary features with scale.



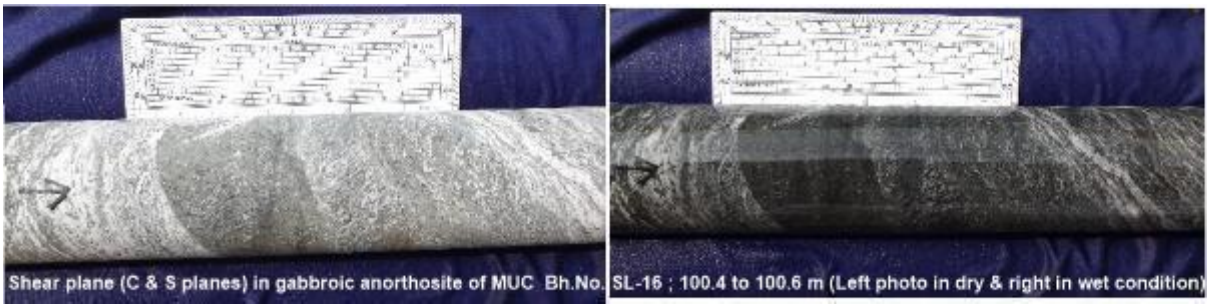
Photographs of core while logging (additional photographs): Photographic evidence of the core on the logging table prior to being broken and sampled or placed just after drilling in core boxes is essential. These photos are taken after the core has been marked up for orientation, defects, depth as given in the general procedure above. All logging table photographs should be taken with the following:

- a scale/measuring tape with 50cm intervals clearly marked; and
- a photograph board with borehole name, run number, run depths.
- Where space is available photos should also include – project name or location, sample number and boundaries, photo number and date.



Photographs of Geological Features within the Core (additional photographs): Photographic evidence of any anomalous geological features within the core is a value-added information. The photo should be annotated with borehole number, type of feature and depth.

Photographs of core can be taken preferably before sampling (during core logging) and after sampling (i.e., after skeletonised core along with storage core box).



Shear plane (C & S planes) in gabbroic anorthosite of MUC Bh.No. SL-16 ; 100.4 to 100.6 m (Left photo in dry & right in wet condition)

Once the cores are arranged in the core boxes, with details of borehole, measuring and core markings are done.

Photos should be taken after cleaning and arranging according to the run in a pattern and at a consistent standard distance from the core box. Spacers should be used to define the start and end of core runs and any sampled intervals removed from the core.

Photographic evidence of the core after being place in the core boxes provides a useful record. These photos are usually taken after logging and often after reconciliation of core loss etc. They can show different information to photos taken on the ore table as depths may have been adjusted and samples may have been taken. The core may also have dried out and started weathering. Wetting the core may enhance the appearance of the core in a photo but this must be done consistently. Photos are preferably taken inside a core shed under standard lighting conditions. If the core is photographed in the field, then the photographs should preferably be taken to reduce the dawn and dusk colour cast (e.g. generally between 9am and 3pm). Align the boxes so that the sun strikes the boxes from the same direction. Avoid shadows due to yourself or trees. Taking the photographs in the field avoids the effect of core breakage due to traversing rough ground back to the core shed.

All core box photographs should be taken with the following:

- a scale/measuring tape with 10cm intervals clearly visible;
- borehole name, box number, and box depths clearly marked on box or board; and
- run number and run depths.

- details of project or location;
- sample numbers and boundaries;
- photo number; and
- date.

Note the breaks that have occurred in the core during boxing or transportation as they are not marked.

After core study and sampling are over, once the remaining core are skeletonised in the GI core boxes and ready to be preserved in the core library with relevant markings. Photographs of the skeletonised core duly arranged in GI core boxes may be taken and a field photography log can be prepared as attached in Annexure – IV.

Annexure-I : **Guidelines from CHQ for preservation of drill core-1997**
GOVERNMENT OF INDIA

No. /Follow-up/ ID(HQ)/HOD/96-97/46P Dated, 2ndMay, 1997

From
The Director General,
Geological Survey of India,
27, Jawaharlal Nehru Road,
Kolkata

To
The Dy. Director General,
Geological Survey of India, Central Region,
Nagpur.

Sub: Skeletonisation of drill cores etc. - Follow up of the decisions of the 10[th] HOD meeting held at Calcutta on 5.3.97.

Sir,

In a follow-up of the decision taken on the Agenda No.16 para no.10.3.14, page no.8 of the minutes of the
10th HOD meeting held at Calcutta on 5.3.97, the following points are enumerated below regarding the skeletonisation of drill cores and its preservation made:

A) Skeletonisation :
a) at least two representative boreholes which have been subjected to thorough petro-mineralogy and chemical analysis with a view to establishing stratigraphy, lithological type and variation, mineralised zone, nature of wall rock alteration etc., should be preserved completely.

b) Cores of all boreholes which have intersected the mineralisation should be preserved in the following manner:

i) the mineralised zone/zones.

ii) the wall rock alteration and in beyond, the extent of alteration to be decided on the basis of petromineralogy and chemistry

iii) Portions of boreholes whose chemistry and petro-mineralogy is available other than the above.

c) Stratigraphic boreholes are to be preserved completely.
B) Mode of preservation:
After skeletonisation, the cores are to be preserved in core-boxes of good quality galvanised iron sheets (as per the drawing). The "Gutka's" are also to be of galvanised iron sheet. The core-boxes are to be stacked in a galvanised/painted iron shelf. The numbers' etc., are to be punched in the sheets so that the question of thin information being lost is eliminated. The thickness of the galvanised iron sheet should commensurate with the load to be carried (as cores are of various sizes are the enclosed diagram). To avoid the boxes etc. to be rusted, which would normally take a longer time, painting with red oxide may be taken recourse to periodically.
C) Place of preservation:
As long as the investigation is running, the cores are to be preserved at the site. After winding up the investigation, it should be sifted to the Regional/OF-Hq or at any centralised place selected by the Region for preservation with all the relevant details.

Sd/-
(M.Ramakrishnan)
Dy. Director General, (OP-I)
for Director General.

Core Information Form: (Please fill out separate sheet for each bore hole)

OPERATOR (Agency) ---
Bore Hole No. /Lease -----------------------------------, No. of Boxes -----------------
Field ----------------------, Area –. , District, State------
Lat & Long
Altitude (Msl)
Total Depth –
Purpose of Drilling – Mineral, Coal, Research, Engineering

Type of Material Donated
Drill Core – Full Dia, Thin slab, Thick Slab, Core Chips, and Cuttings
Thin section
Geochemical Data
Other Data and Type

Minimum Depth --- Maximum Depth Age Formation

Other pertinent information: ----------------------------------

I certify that to the best my knowledge, the information furnished herewith is accurate and correct to the best of my knowledge and freely transferred to Geological Survey of India, for use by any and all interested parties.

Date ---------------------------------------, Signature

Annexure - III

Proposed OCBIS Format for submission of borehole core details.

Name of Submitting Agency	**GSI/ MECL/ PSUs/Private/AMD etc with address details**
Purpose of Drilling	**Mineral Exploration/ Stratigraphic/ Geotechnical/ Energy Minerals**
Boreholes located in	**Freehold/ Forest/ ML/ Composite License/ RP**
Details thereof	

Drilling layer structure
Layer 1: Borehole Information
Layer type: Point

Sl	Field Name	Data Type	Description
1	BOREHOLE_Number	Text	
2	FSP No	Text	
3	Commodity	Text	
4	Name of prospect	Text	
5	Purpose of drilling	Text	
6	Name of prospect	Text	
7	Name of Geologist	Text	
8	FSP report Acc. No.	Text	
9	Year of Circulation	Text	
10	Name of prospect	Text	

Layer 2: Borehole location Information
Layer type: Point

Sl	Field Name	Data Type	Description
1	LAT	Text	
2	LONG	Text	
3	DATE_STARTING	Date	
4	DATE_CLOSING	Date	
5	SERIES_NUMBER	Text	
6	COLLAR_RL	Number	
7	TOTAL_METERAGE	Number	
8	RL_BOTTOM	Number	
9	Collar Azimuth	Number	
10	Collar Inclination	Number	
11	Area	Text	
12	District	Text	Text
13	State	Text	Text
14	Mineral Belt	Text	Text
15	WATER_LEVEL	Number	Number
16	DATE_W_RECORD	Date	Date
17	BASIN_Name	Text	Text
18	COAL_FIELD_Name	Text	Text
19	BLOCK_Name	Text	
20	SUPER_GROUP textbox	Text	

Layer 3: Deviation Information
Layer type: Point

Sl	Field Name	Data Type	Description
1	DEVIATION_DEPTH	Number	
2	Deviation AZIMUTH	Number	
3	DEVIATION_INCLINATION	Number	

Layer 4: Run Information
Layer type: Point

Sl	Field Name	Data Type	Description
1	Run_FROM_DEPTH	Number	
2	Run_TO_DEPTH	Number	
3	RECV_LENGTH	Number	
4	RECV_PCT	Number	
5	Run Core Size	Number	

Layer 5: Lithologs
Layer type: Point

Sl	Field Name	Data Type	Description
1	Lithology FROM_DEPTH	Number	
2	Lithology TO_DEPTH	Number	
3	Lithology contact angle	Number	
4	Lithology True Width	Number	
5	Lithology Name	Text	
6	Lithology DESCRIPTION	Text	
7	Lithology Formation	Text	
8	Lithology Group	Text	

Layer 6: Structure Information
Layer type: Point

Sl	Field Name	Data Type	Description
1	STRUCT_FROM_DEPTH	Number	
2	STRUCT_TO_DEPTH	Number	
3	STRUCTURE NAME	Text	
4	STRUCT_DESCRPTION	Text	

Layer 7: Structure Information
Layer type: Point

Sl	Field Name	Data Type	Description
1	MINERALIZATION_TYPE	Text	
2	HOST_ROCK_TYPE	Text	
3	Mineralization From Depth	Number	
4	Mineralization TO Depth	Number	
5	Mineralization Zone No	Number	
6	Mineralization Zone Width	Number	
7	Assay Value	Number	

Two separate layers (as Layer 8 and Layer 9) may be introduced for RQD and Core photography

Annexure - IV

Geological Survery of India				
Field Digital Photography Log				
Borehole No ; Date; Page No. Photographed by ; Checked by				
Photo No	Run Number	Depth interval		Comments
		From	To	
Camera downloaded data				
Date Transferred to No. of Photos File/ Photo name (along with changed or not)				