Mineral exploration as a tool to enhance mine economics

A case for Sandur-Hospet-Bellary Mining Sector

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Mineral exploration…

- Mineral identification
- Evaluation
- Exploitation

Mineral exploration…

Re-evaluation of existing deposits to reassess them due to change in

- Economic Criteria
- Market Scenario
- Processing Technology
- Business Environment Or
- Threshold Parameter

Steps involved…

- Literature survey
- Review of previous work
- Collection of field topographical data
- Collection of field geological data with sampling
- Integration of all the data layers in GIS platform
- Data analysis
- Evaluation of the mineral deposit

Regulatory Framework…

- The Mines and Minerals (Development and Regulation) Amendment Act, 2015
- Minerals (Evidence of Mineral Contents) Rules- 2015 (MEMC-2015)
- Mineral Conservation and Development Rules-2017 (MCDR-2017)

Stages of Mineral exploration…

Minerals (Evidence of Mineral Contents) Rules- 2015 defines four stages in mineral exploration which are drawn from the United Nations Framework Classification (UNFC) version-1997 and Committee for Mineral Reserves International Reporting Standards (CRIRSCO) Template.

- Reconnaissance Survey (G4)
- Preliminary Exploration (G3)
- General Exploration (G2)
- and Detailed Exploration (G1)

Resource Categories…

Reflecting the degree of geological assurance, they are categorised as

- Reconnaissance Mineral Resource
- Inferred Mineral Resource
- Indicated Mineral Resource and
- Measured Mineral Resource

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Mineral Reserves/resources as per UNFC

- Proved Mineral Reserve (111)
- Probable Mineral Reserve (121 and 122)
- Feasibility Mineral Resource (211)
- Pre-Feasibility Mineral Resource (221 and 222)
- Inferred Mineral Resource (333)

Regulatory Compliance…

MEMC Rule-2015, for areas considered for grant of mining lease should have conducted at least General Exploration (G2 level) to establish Indicated Mineral Resource (332);and prepared at least a Pre-Feasibility Study (F2) report to establish Probable Mineral Reserve (121 and 122)

MCDR-2017, a detailed exploration program (G1 level) over the entire potentially mineralised area under the mining lease to be completed in first five years from the date of opening of the mine and for existing leases within five years from the date of commencement of MCDR.

History and Practice…

In the Sandur Schist Belt, exploration activities were carried out

- Regional exploration by GSI in Ramgad Range during 60s.
- After that Lease-wise exploration by Goan mining companies
- Exploration by GSI in Devadari Range
- NMDC has also undertaken exploratory work in Ramgad Range
- Exploration in the leasehold areas by KSMCL (then MML) mainly Thimmappanagudi mining lease by RC drilling.


N
HOSPET
PAPINAYAKANHALLI
T.B. DAM
RESERVIOR
DAROGI
KERE
TORANGALU
KUDTINI
JOGA
MARIYAMMANAHALLI
BELLARY
GUNDA
TARANAGAR
BELAGALLU
RAMGAD
R.S
INDEX
YOUNGER GRANITES
YOUNGER GNEISS COMPLEX
SANDIR SCHIST BELT
OLDER GNEISS COMPLEX
SANDUR
YESHWANTNAGAR
OBALAPURAM
DEVGIRI
NOT TO SCALE

History and Practice…

- However, exploration activity was in regional scale with large spacing between boreholes
- Need for systematic work in a grid pattern of close spacing was not felt, may be due to the availability of plenty of high-grade material
- The reliability and accuracy of this data was questionable due to unsystematic exploration
- Hence, UNFC system was introduced by IBM as a mandatory methodology for estimation and reporting of mineral reserves and resources.
- Further it was strengthened by introduction of MEMC-2015, MCDR-2017

Need of exploration…

- The developmental stage of existing mining leases warrants detailed exploration (G1 stage)
- Three-dimensional delineation of the mineral deposit need to be established with a high degree of confidence.
- The process involves sampling of the deposit using boreholes drilled in closely spaced grids.
- This will help miner in formulating an efficient excavation program in line with the targeted production quantity as well as quality, also keeping an eye on mineral conservation aspect.

Steps of exploration…

- Surface Geological Data Generation
- Drill Hole Planning With Type Of Drilling
- Data Collection & Reporting
- Sampling And Analysis
- Mineral Estimation Procedures
- Report Preparation

Surface Geological Data Generation…

- Accurate topographic survey and geological mapping
- Larger scale (1:1000) mapping is important and recommended for where ore body is irregular and heterogeneous in nature
- Pitting and trenching used to collect data
- Representative samples collected from working benches for different lithologies to confirm the lithotypes mapped.
- Analytical data may be used for field check and updation of Geological map.

Drill hole planning…

- Drilling to be planned in a grid pattern and UNFC guidelines
- The grid interval recommended by MEMC Rules for Bedded stratiform and tabular deposits of regular and irregular habits under UNFC system are;

  G1 stage: 100m or closer for regular habit and 50m or closer for irregular habit

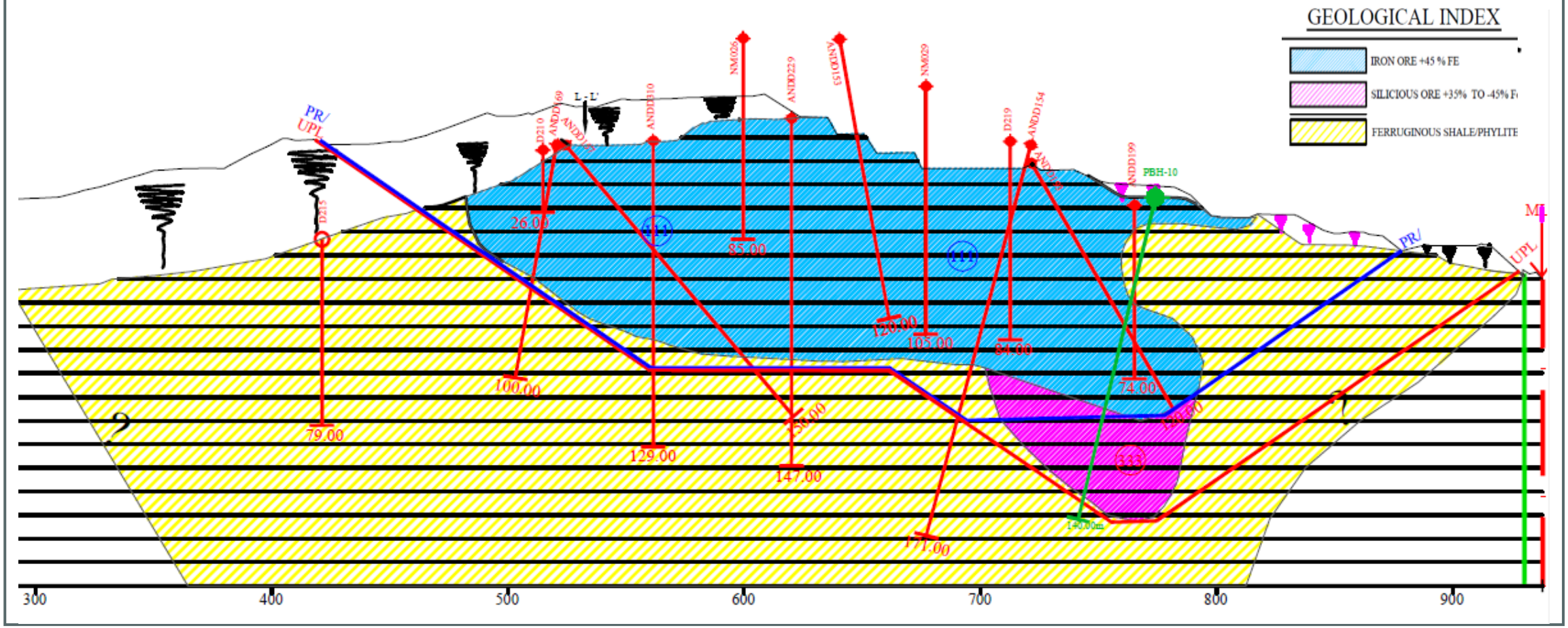
  G2 stage: 200m or closer for regular habit and 100m or closer for irregular habit

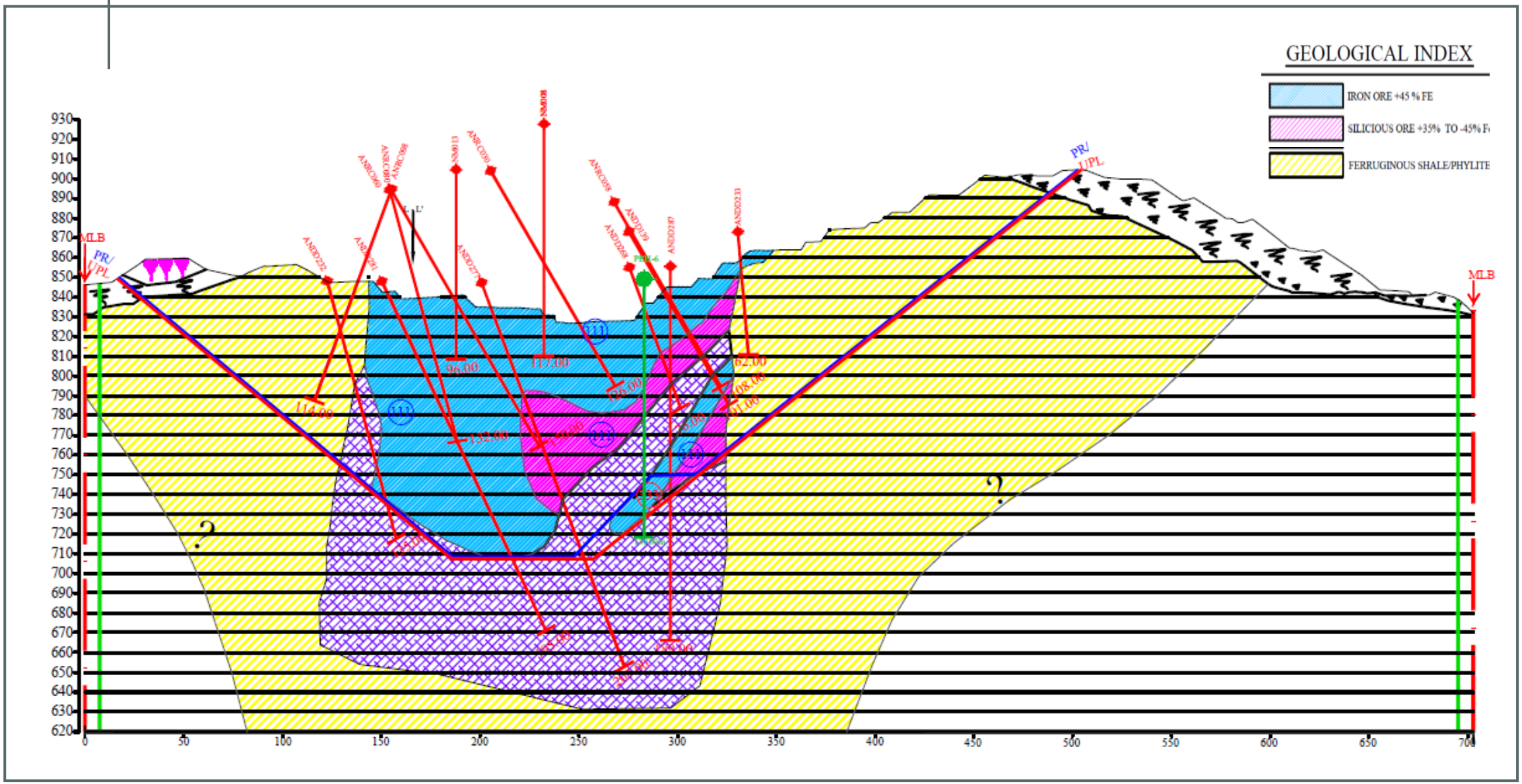
  G3 stage: 400m or closer for regular habit and 200m or closer for irregular habit
- Grid spacing are indicative, however, closer spacing may be necessary depending upon the geological complexity of the deposit
- Planned boreholes to be fixed on ground by GPS and after drilling accurate location may be taken from DGPS

Drill hole planning…

- Effective use of the knowledge of local geology as well as regional geology is critical in fixing the bore holes
- Vertical as well as inclined boreholes are to be judiciously employed considering the strike / dip of ore body and ultimate pit limit
- IBM threshold values for the different ore types are to be kept in mind as it assumes greater importance in conservation of minerals vis-à-vis planning of production program
- Miners usually tend to mine high grade ores only, leaving low grades which will be uneconomic to mine out at later stages

Few good examples of exploration some typical cross sections




GEOLOGICAL INDEX
IRON ORE +45 % FE
SILICIOUS ORE +35% TO -45% F
FERRUGINOUS SHALE/PHYLITE
MLB
PR/
UPL
930
920
910
900
890
880
870
860
850
840
830
820
810
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
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100
150
200
250
300
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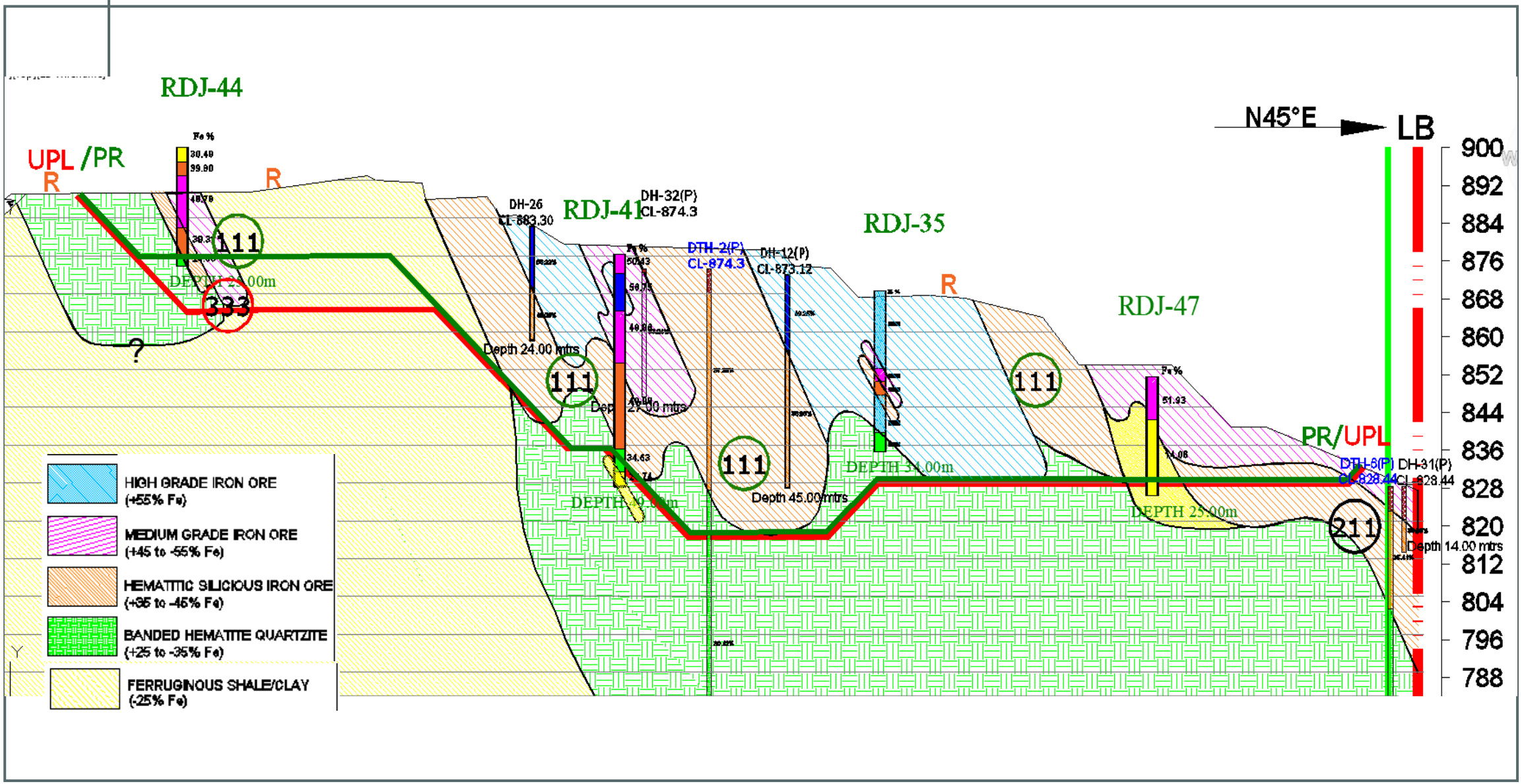
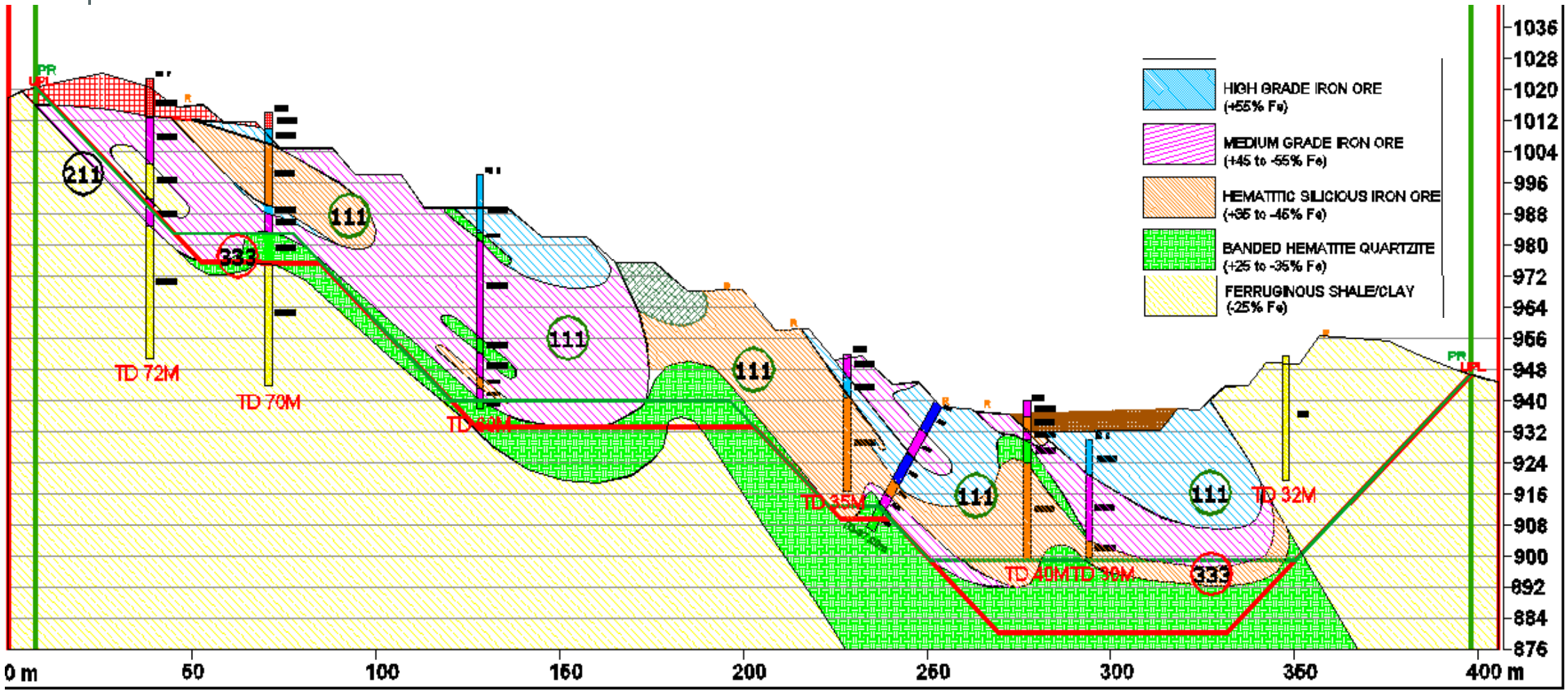
400
450
500
550
600
650
700


RDJ-44
UPL /PR
R
R
111
333
?
DEPTH 25.00m
DH-26
CL-883.30
Depth 24.00 mtrs
RDJ-41
DH-32(P)
CL-874.3
DTH-2(P)
CL-874.3
DH-12(P)
CL-873.12
RDJ-35
R
RDJ-47
111
111
111
Depth 27.00 mtrs
DEPTH 34.00m
Depth 45.00mtrs
DEPTH 25.00m
PR/UPL
211
DTH-5(P) DH-31(P)
CL-828.44 CL-828.44
Depth 14.00 mtrs
N45°E
LB
900
892
884
876
868
860
852
844
836
828
820
812
804
796
788
HIGH GRADE IRON ORE
(+55% Fe)
MEDIUM GRADE IRON ORE
(+45 to -55% Fe)
HEMATITIC SILICIOUS IRON ORE
(+35 to -45% Fe)
BANDED HEMATITE QUARTZITE
(+25 to -35% Fe)
FERRUGINOUS SHALE/CLAY
(-25% Fe)


HIGH GRADE IRON ORE
(+55% Fe)
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(+45 to -55% Fe)
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(+35 to -45% Fe)
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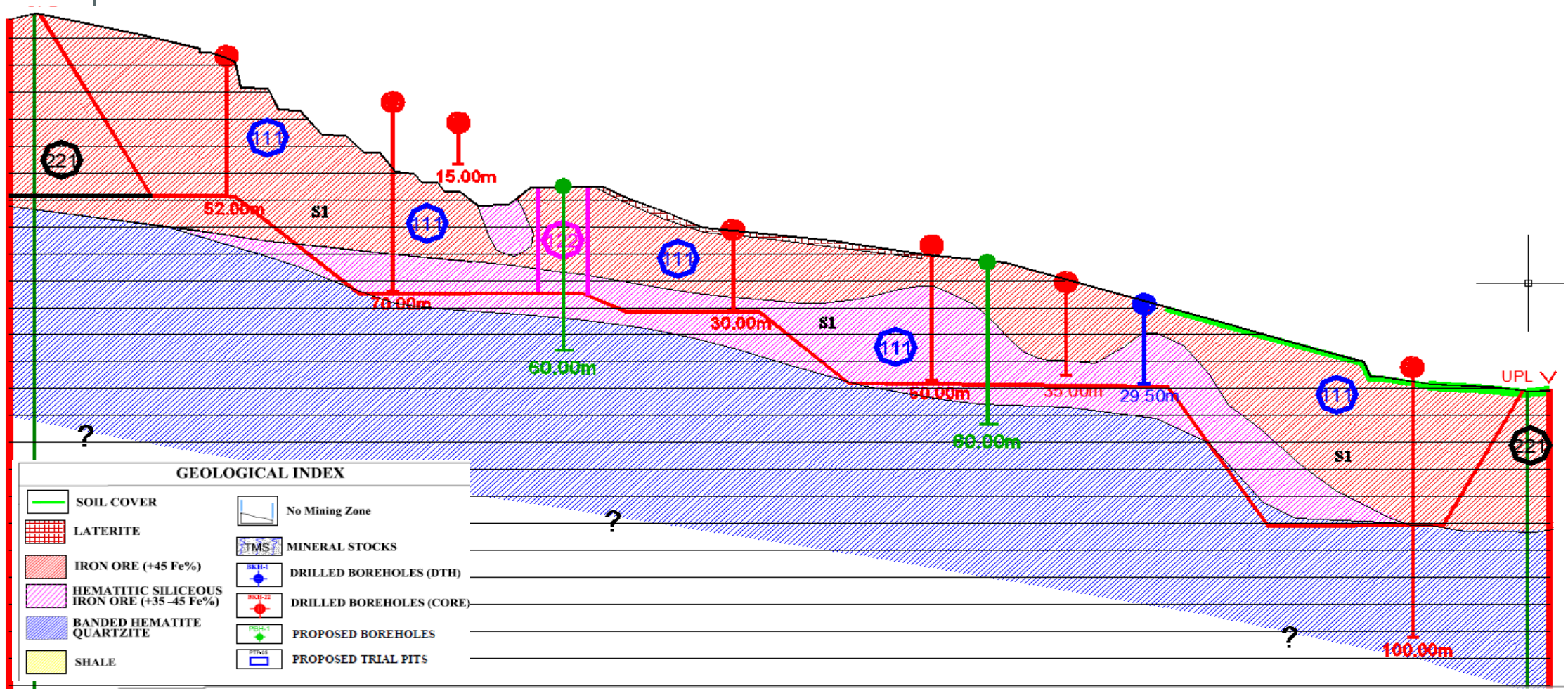
(+25 to -35% Fe)
FERRUGINOUS SHALE/CLAY
(-25% Fe)
211
111
333
TD 72M
TD 78M
TD 35M
TD 40M
TD 36M
TD 32M
PR
UFL
1036
1028
1020
1012
1004
996
988
980
972
964
956
948
940
932
924
916
908
900
892
884
876
0 m
50
100
150
200
250
300
350
400 m


221
111
52.00m
S1
15.00m
111
70.00m
123
60.00m
111
30.00m
S1
111
50.00m
60.00m
35.00m
29.50m
111
S1
UPL
221
100.00m
?
?
?
GEOLOGICAL INDEX
SOIL COVER
LATERITE
IRON ORE (+45 Fe%)
HEMATITIC SILICEOUS IRON ORE (+35 -45 Fe%)
BANDED HEMATITE QUARTZITE
SHALE
No Mining Zone
MINERAL STOCKS
DRILLED BOREHOLES (DTH)
DRILLED BOREHOLES (CORE)
PROPOSED BOREHOLES
PROPOSED TRIAL PITS

Data collection and reporting…

Typical field data collection format (Field Log Sheet)

Field Logging Sheet

Drill Hole ID:		Latitude	
Start date of BH		Longitude	
End Date ofBH		Elevation(mRL)	
Logged by		Azimuth & Inclination of BH	

Detailed Core Logging

Depth Interval in mtrs			Geotechnical Parameters in %			Lithology	Color	Mineralogy	Structure	Remarks
From	To	Run length	TCR	SCR	RQD					

Core photography…

All solid and complete cores are to be examined in both dry and wet states during core logging and photographed for later reference

DRY

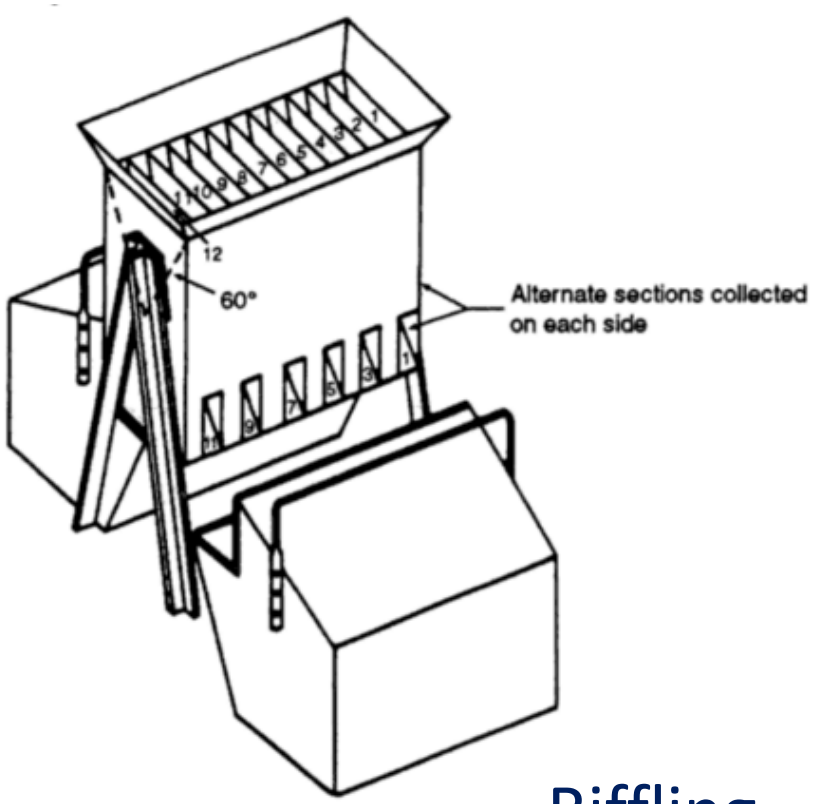
WET

Sampling…

- Sampling of the drill cores or chips is a key step for good representative sampling
- The drill core is to be split into two halves along the length along predetermined marking using a hydraulic core splitter
- For chips of RC drilling, the meter wise samples are to be properly mixed and sample to be reduced using standard coning & quartering method or using a riffler

Core Splitting

Coning and quartering



Riffling

Analysis…

- Meter wise as well as composite samples to be analysed. Few samples for 100% analysis
- Laboratory chemical analysis program should be planned such way that the radicals should help assessing distribution of ore, subgrade, waste, etc.
- The laboratory should include quality control procedures like standards, blanks, duplicates, internal and external checks, accuracy, and precision analysis etc.
- As per the rules about 10% of the total samples to be analysed as check samples in NABL accredited laboratory.

Table format– Core Sampling and Analysis

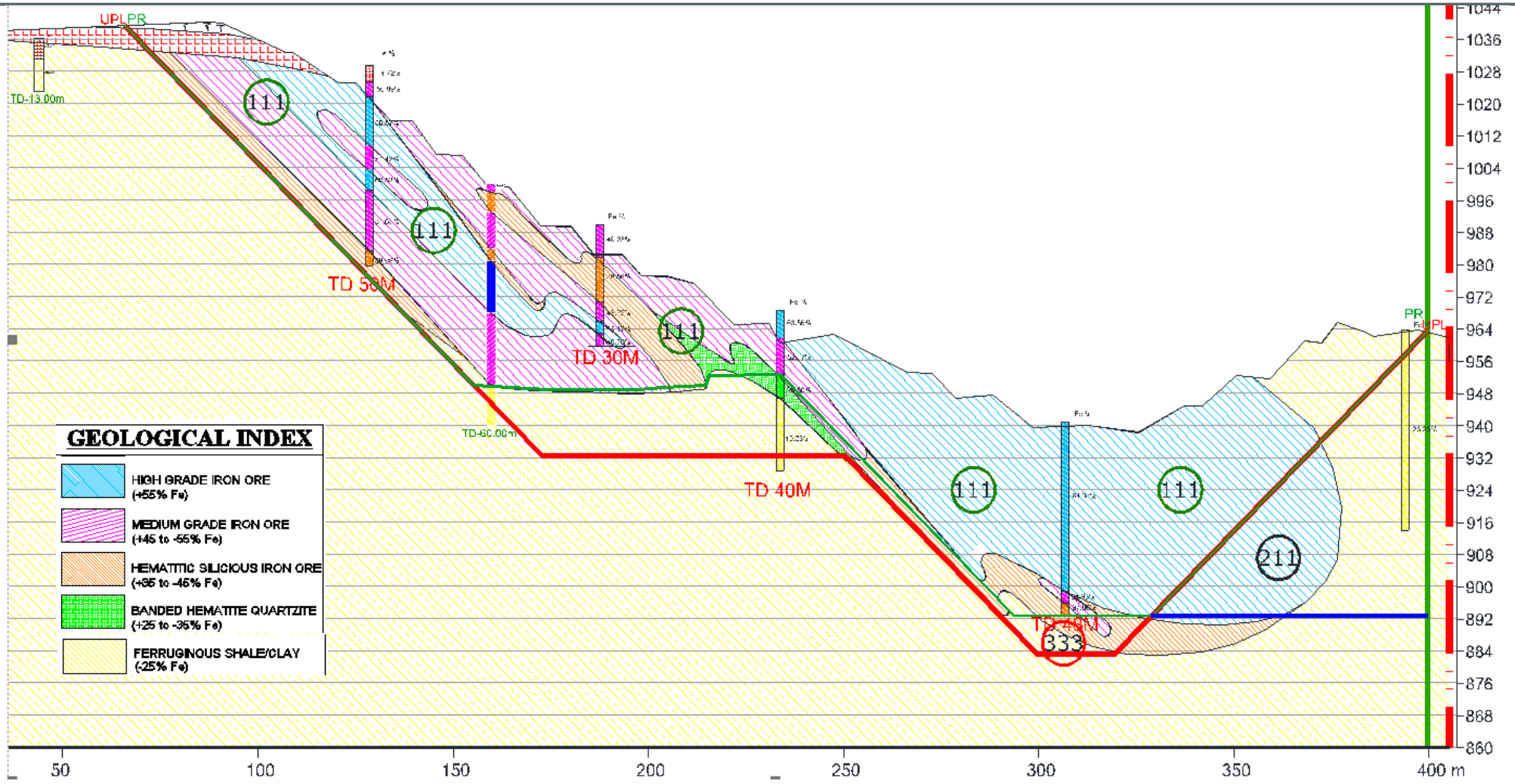
From	To	Actual sample length	Sample no.	Lithology	Fe%	SiO_2%	Al_2O_3%	P%	S%	Mn%	Remarks

Mineral Estimation…

- Data to be plotted on the sections prepared from the detailed geological map.
- Geological cross-sections to be prepared at suitable interval (say 100 or 50m) based on drill hole data density.
- The section line should be plotted in such a way that maximum boreholes should be covered on the section line.
- Boreholes not falling on section lines are to be projected on to nearby section line along the strike direction.
- Graphic lithologs generated from exploration data are to be plotted on the particular section lines.

Mineral Estimation…

- Knowledge of local as well as regional geology needs to be referred for finalising the ore body shape/size and structure and dimension of ore body.
- The various ore bands with clear markings of different grade cut-offs as well as different UNFC categories (G_1 G_2 G_3) should be marked on sections with different colour coding.
- Bulk density tests for different ore categories to be conducted accounting for void spaces-if any in the ore zone.
- Bulk density data is necessary for mineral estimation as tonnage factor
- Software like AutoCAD, Surpac, Datamine can be employed for this process.



Using the borehole data for interpreting the structure of the deposit in line with regional structure

Mineral Estimation…

- Estimation of reserves / resources should be made in such way that the data should be a ready reckoner for all types of queries.
- Better to conduct estimation of reserves/resources block wise, section wise, level wise, grade wise, so that the data will be helpful in flexible planning of excavation program as per the requirements of the end user.

CATEGORY	Iron Ore (+55%Fe)	Avg Grade	Iron Ore (55-45%Fe)	Avg Grade	HSIO (45-35%Fe)	Avg Grade	Total
PROVED (111)							
PROBABLE (122)							
Total Minable							
FEASIBILITY (211)							
INFERRED (333)							
TOTAL							

Report preparation…

- Report should be a detailed account of,

  why of exploration,

  how it was conducted and

  what is the outcome.

- Hence, the report should also be planned, organised with data types/evaluation, and finally summarised properly.

Standard format of Report…

The standard format of the report should contain, but not limited to;

- Introduction with intent and scope of the study undertaken
- Summary of literature survey
- Defining the geologic setting made up of lithological units and its characteristics
- Detailed tables of exploration activity, photographs, etc
- Maps/drawings and Illustrations used in interpretation, few photographs
- Details of sampling and chemical analysis reports, detailed lithologs and data analysis reports
- Estimations of reserves and resources as per UNFC system
- Conclusions and Recommendations that are specifically needed in the planning, design, and execution of the proposed project

Role of Geologist…

Following wise words of one great Geologist should be the guiding philosophy for all the exploration activities:

A proper appreciation of mineral resources may be the greatest service we as geologists can perform for our society and our country!

Role of Geologist…

- The Geologist-in-charge having good knowledge and experience of local geology as well as regional geology should embark with the project with above attitude.
- The Geologist should plan the exploration to completely unravel the shape, size, and structure of the ore body with respect to different cut-offs in line with latest IBM threshold values.
- A good exploration data will help in efficient and economic exploitation of the deposit keeping mineral conservation point of view.
- The Geologist working in tandem with the Mining Engineer should ensure economic mining operation meeting the quality and quantity requirements/targets in short term as well as in long term.
- A judicious blending program of low grade with better grades is necessary to achieve the above goal.

Conclusions…

- A good understanding of all the unit operations of the exploratory program is very critical. Optimisation in each stage of planning and development needs a solid base of geological data which can be generated by a good exploration program
- Proper excavation scheduling based on this data helps in blending the low-grade ores which or neglected otherwise in the pressures of operating economics. This will eventually enhance the reserve base and extend the life of the mine
- Focussing on low grade ores especially BHQ/BHJ is an important aspect for assessing the same as future ores
- Following the regulatory guidelines in letter and spirit
- Hence, exploration to be treated as an essential activity in mining and in optimising the mine operation by adopting good practices of exploration to achieve the overall goals of efficiency, economics as well as conservation of mineral resources.

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