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FINAL TECHNICAL REPORT ON THE EXPLORATION WORK CARRIED OUT IN JOBAT–BETWASA RP BLOCK, JHABUA & DHAR DISTRICT, MADHYA PRADESH

1. INTRODUCTION

Premier Nickel Mines Pvt. Ltd. (PNMPL) is involved in exploration and development of Ni-Cu-PGE projects in India. Based on significant "in house" research efforts, the company has identified several potential areas for Ni-Cu-PGE mineralization in India. As a part of that the area in and around Jobat Ultramafic-Mafic Complex has been targeted for detailed exploration and has been applied for Reconnaissance Permit (RP). Government of Madhya Pradesh granted 592 sq km, Jobat-Betwasa RP block in Jhabua to PNMPL. The Company executed RP deed on 7.9.2007.

2. LOCATION

Jobat-Betwasa RP block is located about 40 km south of Jhabua, the district headquarter and about 230 km east of Vadodara (earlier known as Baroda in Gujarat) ***(Fig.1)***. The area falls in parts of toposheet Nos.45 J/6, 45 J/7, 45 J/10, 45 J/11 and J/12. During the RP period the company has carried out detailed exploration and succeeded in discovering a potential Ni-Cu-PGE zone in the basal part of the ultramafic-mafic complex. Details of the work carried out during the RP period are presented in this report.

3. REGIONAL GEOLOGY

The Jobat – Betwasa area forms part of Aravalli craton of western India. The rocks exposed in and around Jobat RP block belong to early Proterozoic Aravalli Supergroup and Cretaceous Deccan Traps and associated sediments. Aravalli Supergroup, in general, is made up of thick pile of Paleoproterozoic sediments and basic volcanics overlying the Banded Gneissic Complex. These sediments have undergone low grade metamorphism and several phases of deformation. The average trend of Aravalli Supergroup of the rocks vary from NW-SE to NE-SW. Rocks of Aravalli Supergroup contains a lower quartzite-pellite-carbonates-basic volcanic sequence and a upper graywacke-argillite (turbidites) sequence. These two lithounits are separated from each other by the NNW-SSE to NW-SE trending Rikhavdev lineament which extends for an about 300 kms from Nathdwara in Rajasthan to Barwani in Madhya pradesh ***(Fig.2)***. Several ultramafics and mafic bodies are emplaced along this lineament, among them Jobat complex is one. A curvilinear gravity high of –10m gal overlies this zone of ultramafics from Rajasthan to M.P. The age of the ultramafic-mafic complex is constrained by an age of 1.8Ga from a granite which intrudes into the Um-M Complex as well as Aravalli Supergroup.

4. PREVIOUS WORK

Geological Survey of India (GSI) has carried out detailed geological mapping of the area and identified four discrete ultamafic-mafic bodies in the Jobat area ***(Fig.3)***. They are : a) Jobat-Pangola complex, b) Bilkheri – Kosduna complex, c) Betwasa complex and d) Ratmalaya – Undari complex. The first three lie in strike continuity, whereas the last one lies towards NE from the Jobat-Pangola complex. The complex at Jobat – Pangola is the largest amongst the four. According to GSI, In the Jobat area the Aravalli Super Group of rocks are represented by quartz-chlorite schists and phyllites, which exhibit well developed NNW-SSE trending tectonic fabric. The ultramafic-mafic complex and granitoids intrude, in that order, along the tectonic fabric of the metasediments. In addition, these rocks are overlain by infratrappean sediments and Deccan trap volcanics along the northern and northwestern margins. Among the four ultramafic – mafic bodies, Jobat-Pangola complex is the largest, covering about 50 sq.km of the area.

supracrustal rocks and h) Geochemical data shows that predotite- gabbro – anorthosite are related by fractional crystallization.

Concept behind the exploration

Magmatic Ni-Cu -PGE sulfide deposits form as a result of the segregation and concentration of droplets of liquid sulfide from mafic or ultramafic magma and the partitioning of chalcophile elements into these from the silicate melt. Thre factors that contribute to the formation of these deposits are: (i) the concentration of sulfides in channels or conduits through which magma has flowed (feeder conduits for intrusions are much more prospective targets for exploration than the base of the intrusions themselves); (ii) the interaction of the source magma with country rocks, either leading to the incorporation of sulfur, or the felsification of the magma in question; and (iii) fractional crystallisation of sulfide liquid giving rise to Cu-rich ores which may be far removed from the 'source ore'. Thus, basal parts and conduits of the smaller mafic-ultramafic intrusions become favourable targets for the Ni-Cu-PGE exploration. With this concept, PNMPL has started exploring Jobat – Betwasa area.

5. WORK CARRIED OUT BY PNMPL

PNMPL has carried out the following work during the RP stage of exploration

1) Compilation of existing geological maps and literature
2) Interpretation of Landsat and other remote sensing data to identify lithounits and major lineaments
3) Geological mapping on 1:50,000 and on 1:25,000 in some selected parts
4) Stream, soil, lithogeochemical and channel sampling
5) 570 L.Km of ground magnetic survey
6) Channel sampling
7) Interpretation and defining potential area for the next stage of exploration

SAMPLE STATISTICS						
PX No.	Type of sample					Total No. of Samples
	Rock chip	Stream	Soil (Pit)	Trench/ Channel	RC Drillhole	
0355	36					**36**
0353	17					**17**
0356	13					**13**
0359	7	7				**14**
0309	3			17		**20**
0310	3		79	41		**123**
0311	1			37		**38**
0312	24			10		**34**
TOTAL	104	7	79	105	-	**295**

Ground magnetic survey of 570 l.km to cover 37 Sq.km area

6. LANDSAT IMAGE ANALYSIS

Landsat image of Jobat-Betwasa area shows two major lineaments *(Fig.4).* They are 1) NW-SE trending Rakhabdev lineament and 2) E-W trending Naramada Lineament. The Jobat-Betwasa Ultramafic-Mafic Complex (Um-M) lies along Rakhabdev lineament. The trend of the Jobat-Betwasa Um-M complex is parallel to the major tectonic grain in the host rocks of Aravalli supergroup suggesting that regional tectonic grain has controlled the emplacement of the Um-M Complex. Since the Rakhabdev lineament is a deep seated lineament, it has channeled the melts coming from deep source regions. Such an environment is congenial for the formation of Ni-Cu-PGE deposits.

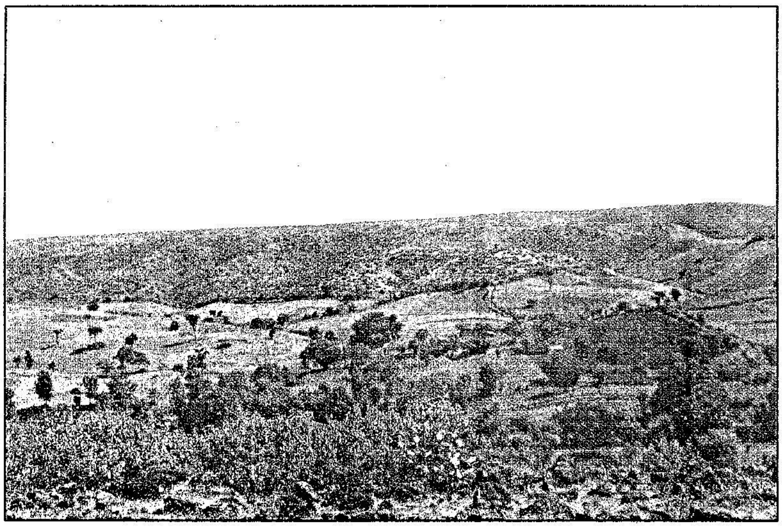

Fig. 15. Panoramic view of the Jobat complex

The serpentinite unit along the western margin, 1 ½ km NW of Jobat, contains rare malachite stains, which has yielded anomalous Ni-Cu-Pt-Pd anomaly. Although the exact contact between the serpentinites and country socks is not noted but boulder and pebbles of the country rocks, viz., bedded carbonates can be observed within serpentinites.

Structure: The planar structural elements present in this area are magmatic layering, schistosity, fracture cleavage, mylonitic foliation and axial planes of mesoscopic folds. The linear structural elements are axes of minor fold, stretching lineation. The dominant structural fabric is S_1 which varies from 300^0 to 330^0 dipping moderately towards west. This fabric has been produced by first phase of regional folding. At some places trace of first phase is seen on S_0 ***(Figs 16 and 17).***

Regional tectonic fabric S_1 is further folded by an axial trace trending 60^0. One set of shear zone is conspicuous in this area trending 300°, which is parallel to the S_1, and it has tightened the geometry of first fold and produced isoclinal F_1fold ***(Fig.18).***

8. GEOCHEMICAL SURVEYS

Systematic geochemical studies have been carried out to understand the magmatic evolution as well as to identify potential Ni-Cu-PGE anomalies in the RP block. Few samples were analysed for their whole rock geochemistry and interpreted in the modern lines to understand the petrogenesis. In addition, number of stream, soil and rock samples were analysed for their Ni, Cu and PGE contents. The chemical analysis tables are provided at the end of the report.

Whole rock geochemical surveys

7 representative samples were collected and analysed for major, trace and RE elements. The MgO content in these rocks vary from 14 to 39%. Al2O3 content in them is very low, except in two samples where it is > 17%. This could be attributed to the effects of lateritization in the area. CaO content is also low in the ultramafic rocks, where as it about 16% in the mafic rocks. Among the trace element, Cr is high in the ultramafic rocks (>1400 ppm).

Petrogenesis: On AFM diagram all samples plot along F-M tie line indicating tholeiitic affinity ***(Fig.20).*** On Jensen plot these samples scatter between komatiitic basalt and high Fe-tholeiitic basalt fields ***(Fig.19).*** From these two diagrams it can be inferred that the source magma was generated through high degree partial melting of the mantle. Serpentinites show slight LREE enrichment and flat- to slight HREE-depleted patterns ***(Fig.21).*** This suggests a normal to slightly enriched mantle source for the parent magma. Also, it indicates absence of garnet in the residue during mantle melting. On the other hand, pyroxenites from the Jobat Complex show flat LREE and steep HREE pattern ***(Fig.22).*** Total REE in these samples is about 50 x chondrite. This clearly shows that pyroxenites were derived from evolved melt. It is interesting to note that pyroxenites show HREE depletion, which can be attributed either to a) melting of a shallow mantle source with garnet in the residue or b) crustal contamination and consequent stabilization of HREE-bearing accessory phases, such as ilmenite, pervoskite etc.,. On chondrite-normalized spidergrams both serpentinites and pyroxenites of the Jobat intrusion show distinct negative peaks at Nb-Ta-Ti-P-Sr ***(Figs.23 & 24).*** These negative peaks clearly indicate crustal contamination, which has been observed in many rift-related magmas. Depletion of these elements is generally attributed to the contamination of the magma with either fluid or melt phase derived from the crustal sources and formation of accessory phases which retain Nb, Ta, Ti, P and Sr. Thus, it is evident that parental magma of the Jobat Complex was contaminated by the continental crustal material. This contention is further supported by the presence of crustal xenoliths, mainly metasedimentary, in the serpentinites from the western margin of the Jobat Body.

Petrological and geochemical data strongly suggest that parental magma for the formation of Jobat body was derived through high degree partial melting of the mantle source. During its ascent the magma assimilated the metasedimentary rocks of the Aravalli Group, which possibly contributed to sulfur to the magma. This might have led to early sulfur saturation and formation of Ni-Cu-PGE mineralization. Aravalli group of rocks near the margins of the Um-M complex are made up of carbonates-carbonaceous phyllite – sulphide bearing assemblage. These rocks, once assimilated, are ideal to cause Ni-Cu-PGE mineralization in the M-Um complexes.

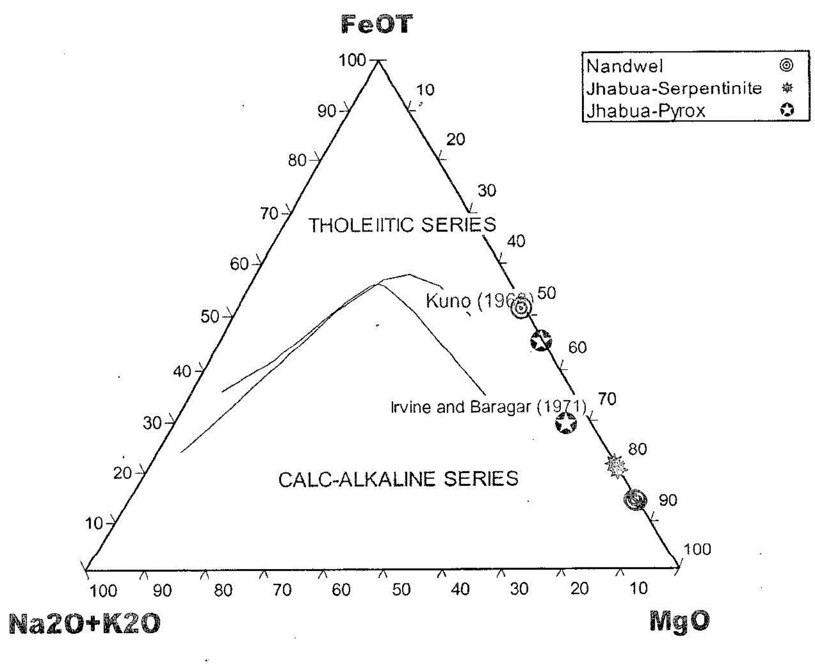

Fig. 19 Jensen plot showing the distribution of Um and M rocks

Sulfide Mineralization

As mentioned above, malachite stains were noticed on the ultramafic rocks along the western margin of the Jobat intrusion. Here these ultramafic rocks intrude carbonaceous phyllite and carbonates. Xenoliths of these sediments are found in serpentinites. To assess the nature of the mineralization detailed geochemical sampling has been taken up. Stream, soil and rock chip samples were collected to define the mineralized zone. The geochemical data for various samples is tabulated at the end of the report.

Stream Sediment sampling: 7 stream sediment samples were collected from the first order streams originating from the malachite stained ultramafic unit in the western part of the Jobat intrusion *(Fig.25).* These stream sediments were panned and heavies were concentrated. These heavies were analysed for Ni, Cu, Cr, Pt and Pd **(See Annexure-1).**

Fig. - 25

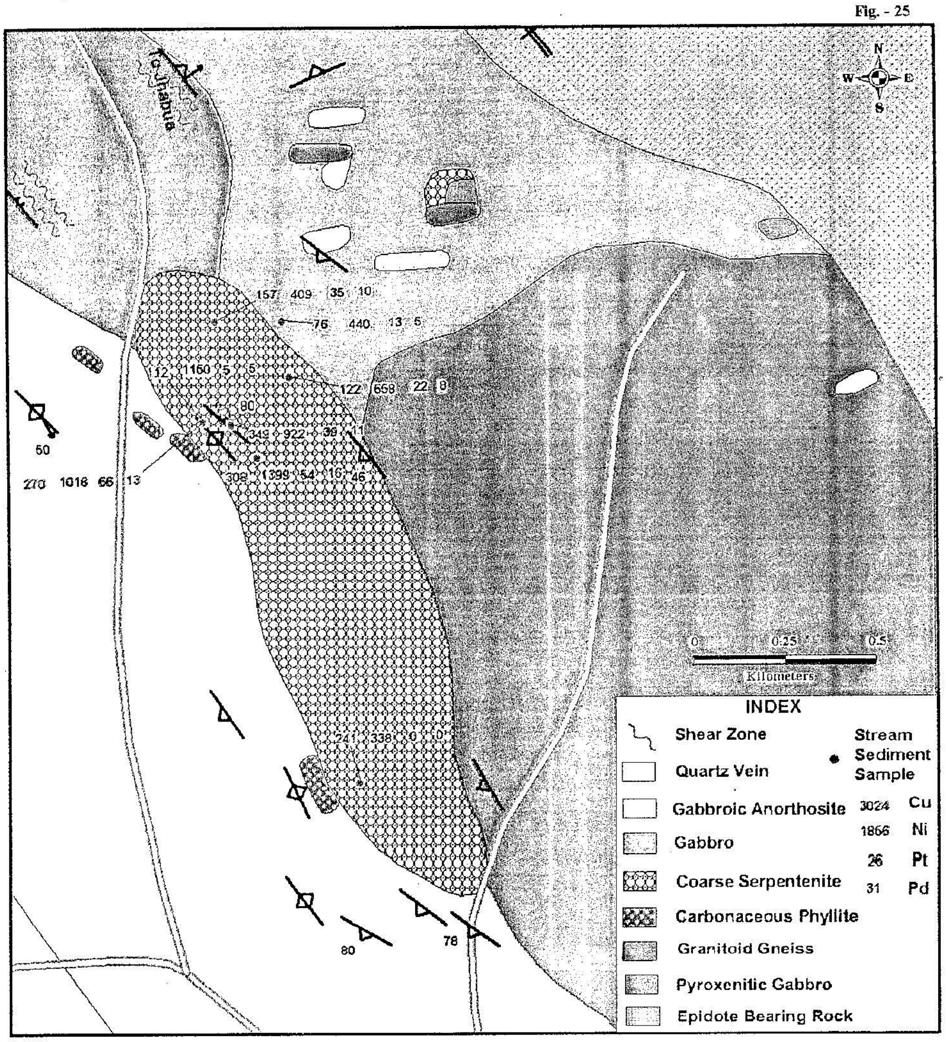

Fig.25. Geological map of western part of the Jobat intrusion showing stream sediments samples

This is done with a purpose to delineate the mineralized zone as well to understand the controls on the mineralization. All the samples exhibit high concentration of Cr (1561 ppm to 15918 ppm), Ni (409 ppm to 1018 ppm) and Pt (13 ppb to 77 ppb). Elevated Cu contents are seen in 3 samples in which the concentration varies from 270 to 349 ppm. On Cr vs Pt diagram a positive correlation is noted between Cr and Pt ***(Fig.26).*** This may indicates control of chromite in the formation of Pt. On the Cu-Pd diagram a strong positive correlation is noted between the two elements, which points towards the presence of sulphide in the system.

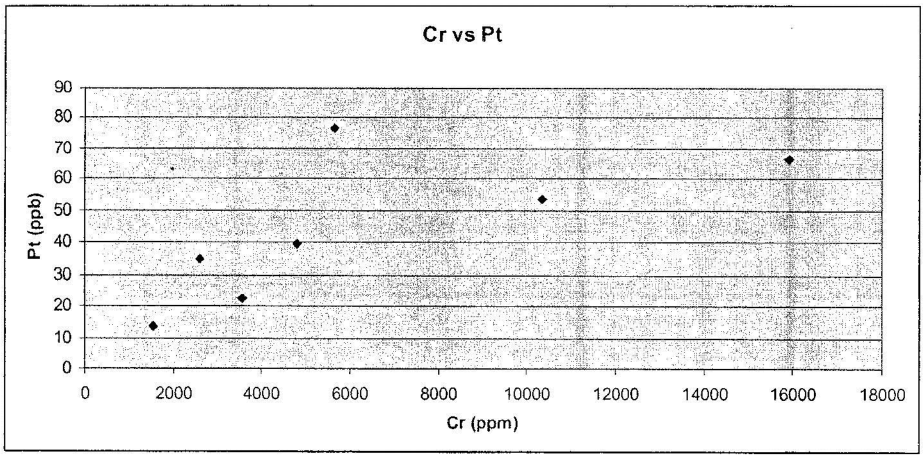

Fig. 26. Cr vs Pt diagram for the stream sediment samples

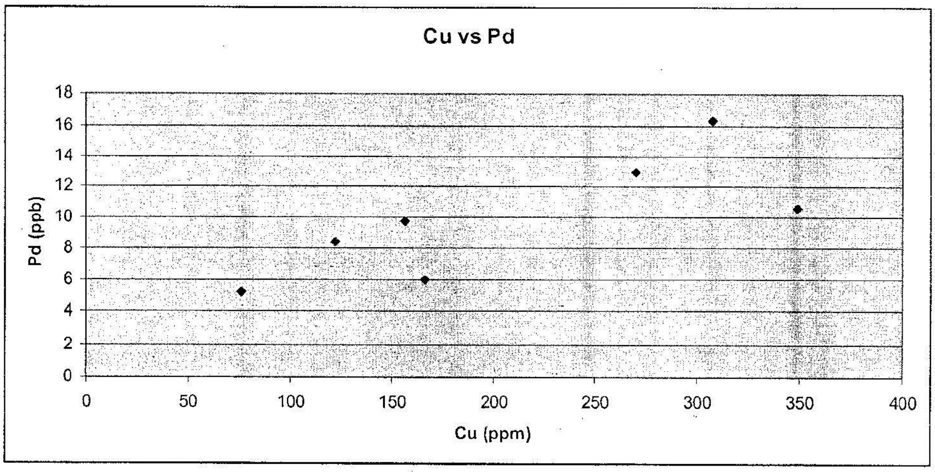

Fig. 27. Cu vs Pd diagram for the stream sediment samples

Lithogeochemical sampling : About 104 rock chip samples have been collected ***(Fig.28)*** and analyzed for Cu, Ni, MgO, Pt and Pd **(See Annexure-2).** The analyses show that in the samples Cu ranges from<5ppm to 2,46,534 ppm; Ni from 18 to 5041. Pt and Pd reach up to 300 to 400 ppb. Geochemical anomaly defined by the rock chip sampling extends for about 1 ½ km along the strike.

Ni	Cu	Pt	Pd
2494	3403	42	49
5041	3756	243	285
3587	6668	305	176
2899	2462	272	218
2661	2786	125	59
1380	4895	32	33
2778	5637	227	188
1871	7631	117	52
2401	3131	240	89

Some of the important anomalies are listed in the table above. In many of the samples coinciding Ni, Cu, Pt and Pd anomalies are found, which indicates sulphide controlled mineralization in the area. It is also to be noted that Pt/Pd ratio is more than 1.

Soil sampling: Potential area defined by stream and lithogeochemical sampling has been further studied by using soil sampling. 79 soil samples were collected on 100m grid and analysed for Ni and Cu **(See Annexure-3).** This work is done to further refine the geochemical anomalies and also to identify sulphide mineralization in the area. A contour diagram is prepared for Ni and Cu values. Cu values in the samples vary from 38 to 482 ppm and the Ni values vary from 93 to 1501 ppm. On the binary diagram a strong correlation is noted between Ni and Cu, which again indicates the presence of sulphide mineralization in the area ***(Fig.29).***

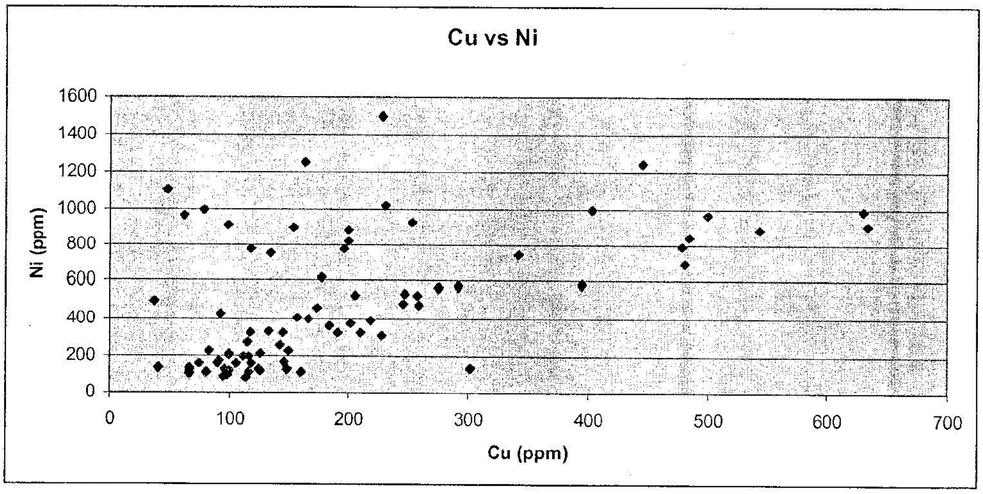

Fig. 29. Ni vs Cu diagram for the soil samples

On the contour diagram ***(Fig.29 a)*** coinciding Ni-Cu contours are noted. Two such coinciding Ni-Cu axes can be identified, which are trend WNW-ESE direction. A only –Ni anomaly is found to the west of the Ni-Cu anomaly, which can be attributed to silicate association of Ni.

Fig. 29a. Ni and Cu contour diagram based on the soil sampling

Channel Sampling: 12 channels were made across the mineralized zone at 100m interval ***(Fig.30).*** Length of the channel varies from 10m to 30m. 1m composite samples were collected along each channel and analyzed **(See Annexure-4).** Results of the channel samples were provided at the end of the report. Ni and Cu values in these samples vary from 121 ppm to 2397 ppm and 8 ppm to 29999 ppm, respectively. Pt and Pd values in these samples vary from <5 ppb to 352 ppb and <5 ppb to 142 ppb, respectively. 1m composite samples define the following mineralized zones *a) 7m @ 0.14% Ni, 0.13% Cu and 0.14 gm/t Pt+Pd, b) 4m @ 0.14% Ni, 0.28% Cu and 0.21 gm/t Pt+Pd and c) 2m @ 0.40 gm/t Pt+Pd.*

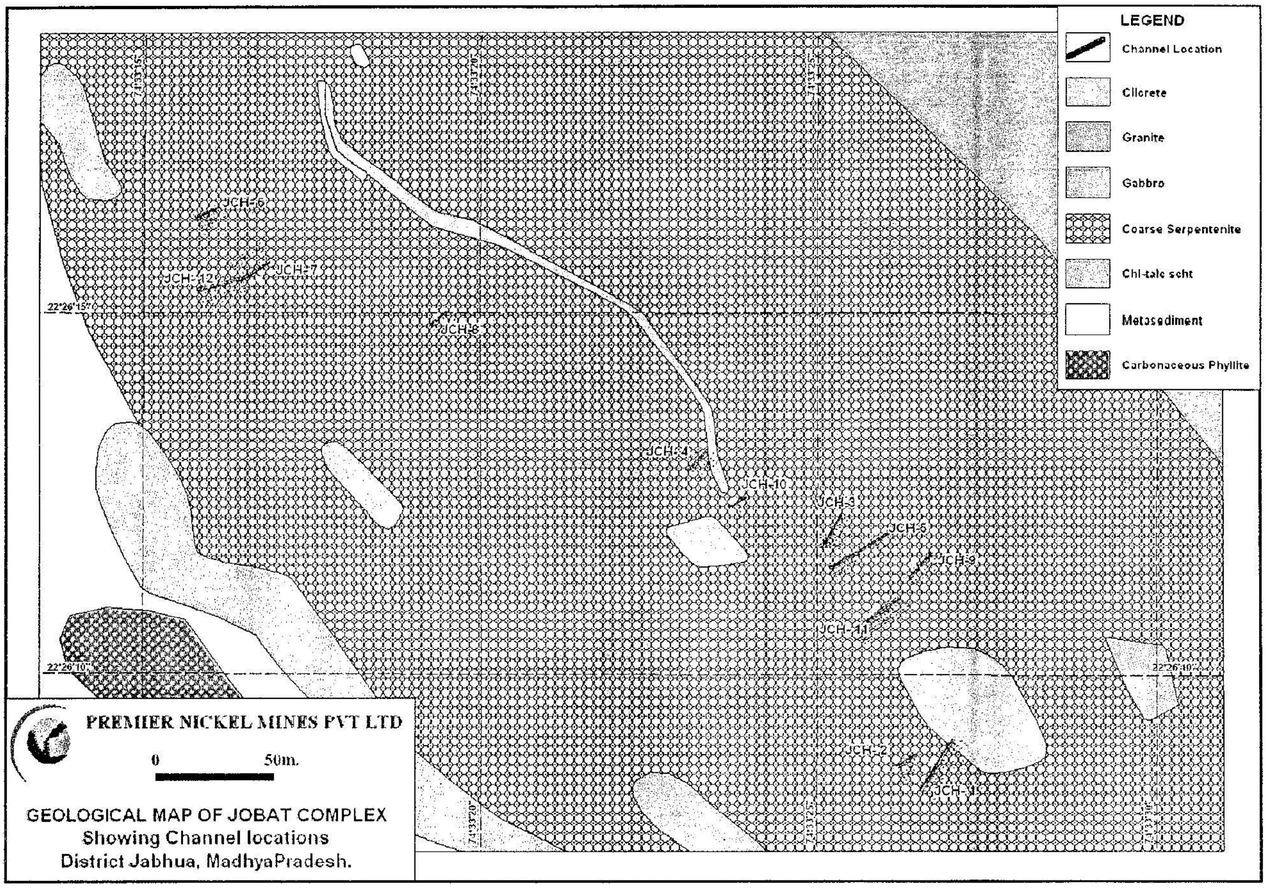

Fig.30. Geological map of Jobat Complex showing channel locations

Interpretation of Geochemical data

Ni, Cu, Pt, Pd and MgO values have been plotted on various binary diagrams to understand their relationship. On MgO – Ni diagram a positive correlation is noted between the two, which suggest silicate controlled fractionation ***(Fig.30a).*** However, at high MgO levels (>20%), it deviates from a calculated silicate fractionation curve, which can be attributed the precipitation of sulphide phase. On MgO – Cu diagram a similar relationship is noted ***(Fig.31).*** Ideally Cu shows inverse relationship with MgO during magmatic crystallization. However, the positive correlation between these two elements could be due to silicate-sulphide fractionation during the early stages of magmatic evolution. On Ni-Cu binary diagram a strong positive correlation is noted, particularly in >500 ppm Ni and >150 ppm Cu range ***(Fig.32).*** Similarly, on Cu-Pd binary diagram a positive correlation is observed ***(Fig.33).*** From these two diagrams it can be inferred that Ni-Cu-Pd concentrations were controlled by the sulphide precipitation in the magma. On Ni-Pt binary diagram a positive correlation is observed, which corroborates sulphide fractionation from the magma ***(Fig.34)***.

The relationship between MgO and Pt is not very clear ***(Fig.35)***. On Cu/Pd vs Pd diagram majority of the samples plot in depleted field ***(Fig.36)***. However, some of the samples plot close to the mantle field and further show fractionation parallel to R=1000. This clearly indicates sulphide fractionation (<10%), particularly very early in the magmatic evolution. This would also explain the reason for number of samples plotted in the depleted field, which again indicates separation of sulphide phase early in the magmatic evolution and precipitation of the same at depth.

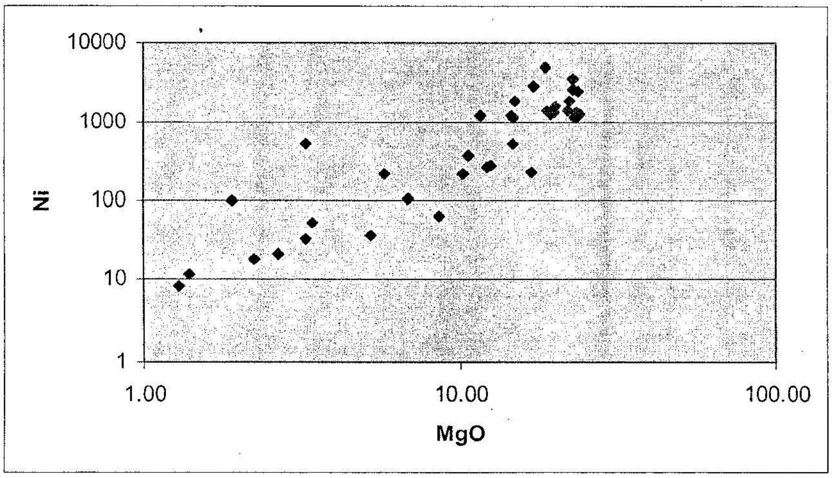

Fig. 30a. MgO vs Ni diagram

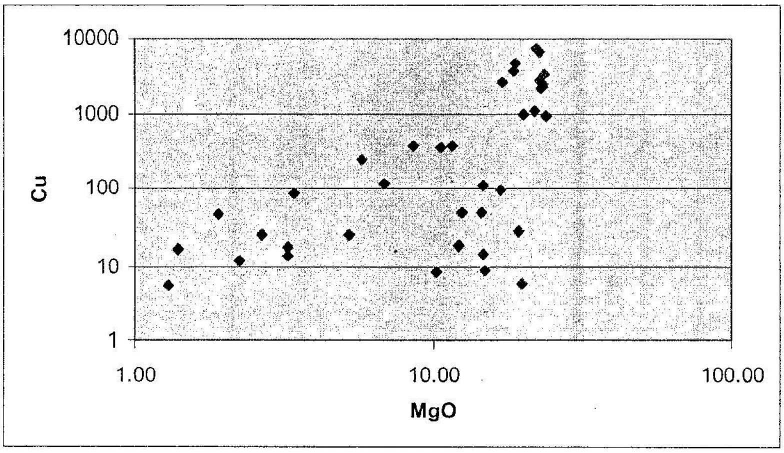

Fig. 31. MgO vs Cu diagram

Fig. 41. Cu-Pd vs stratigraphic height from the channel 5

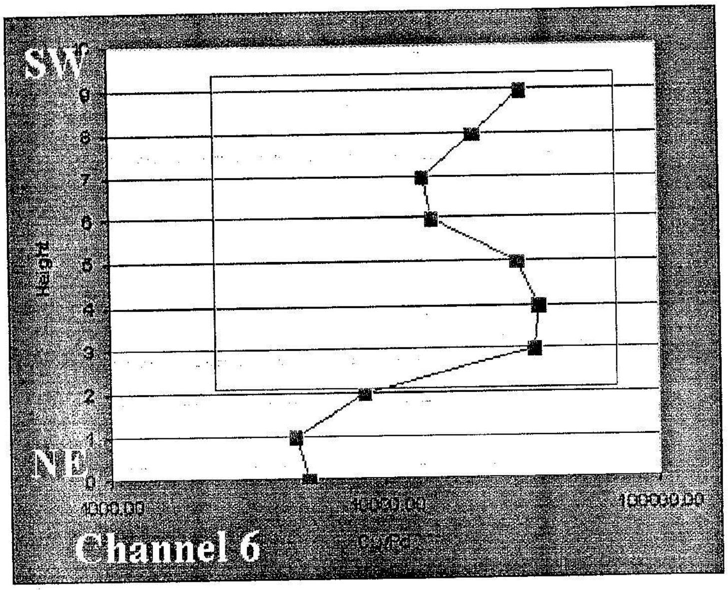

Fig. 42. Cu-Pd vs stratigraphic height from the channel 6

9. GROUND MAGNETIC SURVEY

From the geochemical surveys presence of sulphide mineralization is identified along the western margin of the Jobat intrusion. To assess the geophysical signature of the mineralized zone, as well as to trace its continuities, ground magnetic survey has been taken up. About 37 sq. km area has been surveyed by using the in-house Proton Precision Magnetometer (Gem systems), GSM-19W model which has an accuracy of .01nT. A similar equipment was used at the Base station for diurnal correction. The frequency of data collection was kept at one second. This normally generates one data at every 2m ground distance. The area was covered along E-W traverse, separated at 100m ground interval. A total of 570 l. km survey has been carried out to cover 37 sq.km area. Total Magnetic Intensity (TMI) map was prepared using Geosoft software ***(Fig. 43).*** An over lay of ground mag and geochemical anomaly map has been prepared ***(Fig. 44).***

than oxygen fugacity. Such a reduction of the magma through the interaction of carbonates is observed in Jinchuan intrusion of China, which hosts one of the biggest Ni-Cu deposits in the world.

B) The obtained Ni-Cu-PGE geochemical anomalies are not associated with significant S anomaly, which indicates that Ni-Cu-PGE minerals may not be locked in sulphides. Ni-Cu-PGE anomalies without sulphide can occur as oxide phases as is found in PGE deposits of Urals, Russia, where phases like tetraferriplatinum and tetraferripalladium carry PGE, Cu and Ni mineralization. It is possible in the present case such phases were formed once bulk of Ni-Cu-PGE were removed in sulphide phase. Drilling is planned to identify deeply buried massive sulphide bodies.

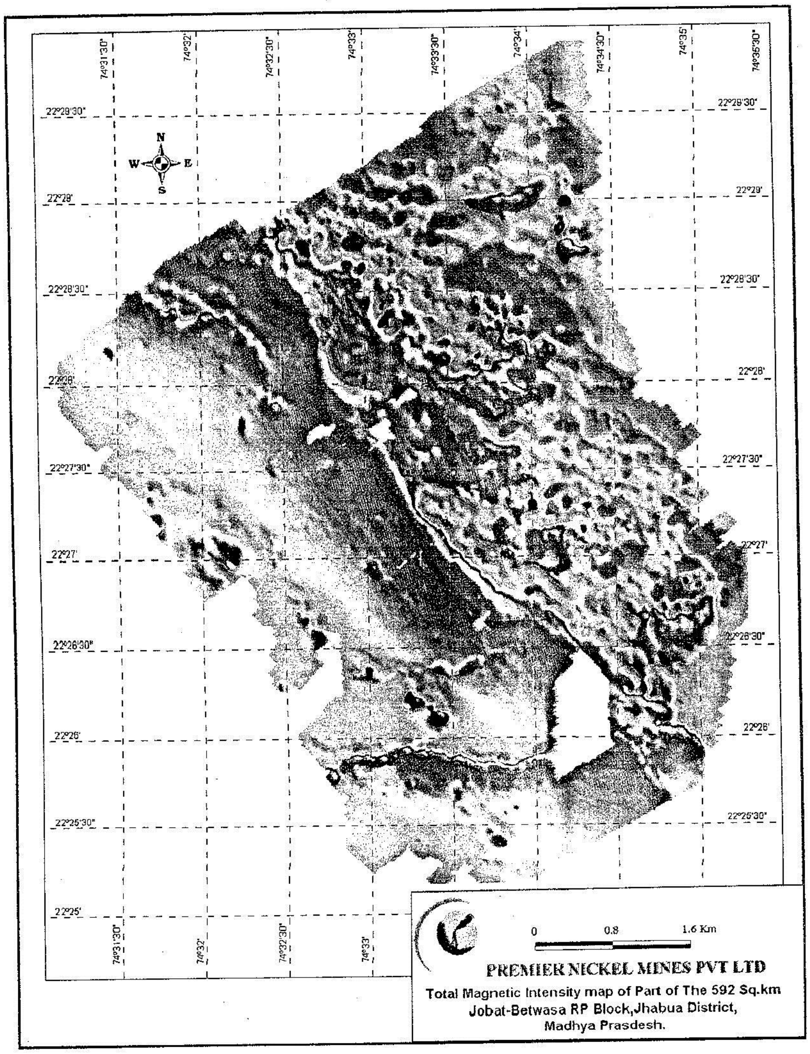

Fig. 43. TMI map of the Jobat intrusion