Geological re-interpretation and resources estimation of "Zona A Oeste" ore deposit

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Abstract: The objective of the investigation is to complete the geological interpretation and re-estimation of the resources contained in Zona A Oeste. The origin of the weathering crust apparently on ultramafic rocks only was determined. The areas most likely to have deposits of nickel plus cobalt were identified; that is, the areas with higher potential Lb concentrations. The re-estimation of the resources was developed; obtaining a total of 609 790 t with Ni = 1,19 %, Co = 0,088 % and Fe = 39,52 %.

Key words: Zona A Oeste, geological reinterpretation, estimation of resources.

Reinterpretación geológica y recálculo de recursos del sector Zona A Oeste

Resumen: Se realiza la interpretación geológica y recálculo de recursos del sector Zona A Oeste. Como resultado de los trabajos se determinó la génesis de la corteza de intemperismo generada, al parecer, únicamente sobre basamento ultramáfico. Se definieron las zonas más perspectivas para la localización de acumulaciones útiles de Ni + Co, es decir, las zonas con mayores potencias de Lb y se calcularon los recursos del sector obteniéndose 609 790 t con Ni = 1,19 %, Co = 0,088 % y Fe = 39,52 %, respectivamente.

Palabras clave: Zona A Oeste; reinterpretación geológica; cálculo de recursos.

Introduction

This work was conducted out of a need of re-interpretation of the geological information of Zona A Oeste and the re-estimation of resources for industrial exploitation. This work was requested by the Geology Department of the "Comandante Pedro Sotto Alba" Mining Subdirection.

A detailed investigation on the existing weathering crusts was carried out based on the information contained in the documentation of drill holes completed in a displaced grid of 33,33 x 33,33 m and 33,33 x 33,33. Thorough exploration works conducted uninterruptedly by the Empresa Geominera Oriente on the Zona A ore body during 1987 through 1995, exploration reports on measured resources of Zona A Oeste issued by Moa Nickel Mine Subdirection in addition to site visits completed by a group of fourth-year Geology students were referenced in order to complete the reinterpretation of the geological information of the sector as well as the re-estimation of its resources.

Geological characteristics of the region

The geological evolution of the territory of Moa began at the end of the uppermost Campanian Maestrichtian after the extinction of the Cretaceous Volcanic Arc and the beginning of south to north compression; which resulted in emplacement of the

ophiolitic massifs, according to the system of sliding scales, from the obduction of the Cuban Western Block above the passive edge of the Bahamas platform (Lewis & Draper, 1990; Morris et al., 1990; Pindell & Barret, 1990).

Compression forces decrease at the beginning of the Middle Eocene through the Medium Miocene as indicated by the slip faults according to direction, fold and local thrusts. Vertical movements play an important role in regional morphotectonic characterization. The regional increase process starts during the Middle Miocene (Rodríguez, 1999).

The continental units are not represented in Moa-Baracoa ophiolitic massif while oceanic units consist of northern ophiolitic rocks, the arc rocks of the Cretaceous volcanic islands, the sequence of Late Campanian Danian *piggy back* basin, the Paleogene volcanic arc and the *piggy back* from the Middle Eocene to the Oligocene (Iturralde, 1997).

Ophiolitic massif rocks are predominantly serpentinized piroxenite ultramafic rocks, dunites, harzburgites, lherzolites and piroxenites upon which intense meteorization processes have occurred, forming thick ferronickel crusts which are associated with nickel and cobalt ore bodies.

Two well defined geo-morphological zones have been identified in the territory: of prairies and of mountains which are most widely spread out. It has been classified into four subtypes, prevailing the lower flattened mountain type slightly dissected for being associated with largest ferronickel ore bodies. Weathering processes are predominant and are conditioned not only by the cracking degree of rocks upon which they occur but also by the surface dynamics based on the hypsometric curve, land slope and regional stepped structure. The highest values of current soil survey evidenced by cliffs, scarps and carsic forms have been determined for this zone (Rodríguez, 1999).

Methodology Applied in the Investigation

This investigation was developed in three basic stages: preliminary, field and office work.

The preliminary stage involves gathering and processing existing available information. Field works directed towards obtaining basic geological information were completed during short campaigns. This included geological reconnaissance visits, documentation and sampling of weathering crust outcrops of Zona A Oeste.

Weathering crust outcrops were documented, photographed and sampled.

Sample taking was undertaken timely and the samples were collected directly from the various outcrops using a geologist pick. These samples were numbered and described. Plastic bags and field back bags were used for sample preservation and transportation.

Re-interpretation of Geology of Zona Oeste A

Zona A Oeste is characterized by a relatively soft relief gradually rising without abrupt changes from north towards the south. The hydrographic network is oriented south-north, with intermittent creeks with waters flowing to the Cabaña River. La Vieja creek originating from the reject pond spillway, is located on the west end. Zona A and Zona Central orebodies are demarcated by this creek.

According to previous investigation results, the geological characteristics of the sector are quite peculiar; which make it different from neighboring sectors. Given its characteristics this sector was separated from Zona A orebody to be studied separately. Some peculiarities include: the presence of shell blocks of up to 2 m in diameter along the entire sector; the appearance of crusts from basic rocks mixed with rocks having ultrabasic origin; outcrops of silica blocks (quartz, chalcedony, opal) in the central and northern areas of the sector and the possible existence of a fault from north towards the south; to which basic rock outcrops are associated.

The reinterpretation of the geology of the sector was carried out to confirm or rule out that these phenomena occurred. In order to meet the objectives, a reconnaissance visit and some itineraries to the areas with higher probabilities of occurrence of the abovementioned phenomena were completed to describe the outcrops and interpret geological phenomena present in the sector.

After completing the proposed geological itineraries, the results were as follows:

- Abundant shell blocks of Fe are present in the entire sector. Diameters range from 0,5 – 1 m, but not exceeding 2 m.

- No crusts developed on basic rocks were found or gabbro outcrops to which these crusts are associated.

- Silica blocks are mainly found along the creek shores and in the central area; however, these blocks are observed in the entire sector but in smaller dimension.

Drill Hole Data Interpretation

Based on the EGMO data base and drill holes of 33,33 x 33,33 m and 33,33 x 33,33 m some maps were created for the different technological mines; thereby facilitating the interpretation of data obtained on drill holes.

The average LB thickness in Zona A Oeste is 3,93 m. The areas with thickness between 0 and 4 m prevail. The areas with higher thickness are located to the southeast, north and northeast of the area (always higher than 4m). The thickness can exceed 10 m. 7 areas with a higher potential for mining have been identified. It was also indicated that the surrounding areas to the selected areas will not be excluded from the mining plan. The LB thickness for the selected areas is over 4 m; especially in the central and towards northeast areas where the highest LB thicknesses are found. The impact caused by the creeks flowing into the sector towards different areas with high LB thickness was analyzed. This is the reason why some areas can not be mined.

The average cobalt content for LB in the Zona A Oeste is 0.088%. The areas with cobalt content between 0,080 and 0.13 % predominate. The areas having the lowest cobalt content (between 0,03 and 0,08 %) are located on the southeastern part of the sector. The areas with highest values between 0,13 and 0,23 % mainly, reaching up to 0,28 % are to the north. Of the identified areas, the first four have low cobalt content, reaching up to 0,15% in small sectors. The cobalt content is generally lower than 0,13%. The first area has the lowest content values (between 0,03 % and 0,08 %). The last three areas have the highest cobalt contents (between 0,13 and 0,28 %); especially area V with average contents ranging from 0,18 and 0,23 %.

The average iron content for LB in Zona A Oeste is 38,81 %. There are two areas of the sector which are clearly different based on iron content: the southern area with predominant contents between 38% and 41 % and also having areas with iron content below 38 %; the northern part with areas having iron contents between 41% and 47 % and above 47 % occasionally. The first two areas are located to the southern part. They have the lowest iron content (ranging from 35 and 41 %); however, iron contents in the remaining areas are 41 % to 50 %.

The average nickel content for LB in Zona A Oeste is 1,13 %. Similar to the iron content, the sector is divided into two different areas with relation to nickel content

but in other directions: the lowest nickel contents for LB are mainly between 0,95 and 1,25 % all along the south and the west of the area. The highest ncikel contents (from 1,25 to 1,75 % and above) are present in the northern and northeastern areas. The highest nickel concentrations (always above 1,45 %) within the LB are observed in two areas: one to the north-northeast and the other one to the northeast. Apart from area IV, the first two areas have again the lowest nickel contents (between 1,05 and 1,35 %); Ni is more concentrated (between 1,25 and 1,75 %, mainly) in the remaining selected areas.

Overburden is highly developed in Zona A Oeste. The average overburden thickness is 7,56 m. The lowest overburden thickness is between 1 and 7 m towards the southeast, north and east of the sector. Apart from the northeastern and northwestern areas, the highest thickness is found in the central region; always above 10 m and occasionally reaching 22 m. Of the selected areas, areas I, II and VII have the lowest overburden thickness (between 1 and 7 m, mainly).

A map was created to analyze the relationship between the overburden and the LB thicknesses. The acceptable overburden/ore ratio for mining is variable depending on Ni and Co prices in the international market but it generally ranges from 3:1 and 5:1. The predominant ratio in the sector is 3:1; that is, 3 meters of overburden per 1 meter of useful ore. This ratio increases in the central part of the sector but in very small areas. The ratio in all of the selected areas is mainly 3:1; however, it has to be pointed out that the overburden/ore ratio significantly increases up to 12:1 in small areas within zones III, IV and V.

When combining the interpretations based on soil survey data on the Zona A Oeste, the following results were as follows:

The southern area of the sector, which also coincides with the most elevated zones, has poor mining prospect. Mining activities can only be developed in the selected areas I and II.

-The northern area of the sector occupying the lowest point has the areas most suitable for mining, especially zones III, IV, V, VI and VII.

- The creeks flowing through the sector significantly impact on the areas with a higher mining potential as the areas close to the creeks can not be mined; resulting in a loss of resources.

- Of 428 drill holes in a displaced grid 33,33 m X 33,33 m and 33,33, 115 had no

minerals and 313 were found to have laterite ore.

- Mining planning and designing for this sector will be highly complex and problems will arise at the time of building drill banks of 8 x 8 x 3. The reason is that the areas with a higher mining potential are found in flatter areas while the areas with less mining potential are in areas of high elevation in addition to the LB low thickness.

Re-estimation of resources and reserves contained in Zona A Oeste

The estimation of the resources contained in the investigated sector is based on the data base on drill holes in a displaced grid of 33,33 x 33,33 m and 33,33 x 33,33 m. *Cutoff* for Ni and Co was >=1 and >=35; respectively.

The estimation of resources was developed by using the method of areas of influence and considering as Lb mines the lithologies with Ni >=1 and Fe >=35; as Lf for Ni <1 and Fe >=35; as Sb for Ni >=1 and Fe <35.

The resources of the areas having a Lb thickness > 4 m were estimated. The areas having lower thicknesses are then part of the group of resources of the sector.

Seven areas were selected to have high mining potential. The reserves of the selected areas were estimated and the following values were obtained:

Table 1. Areas for the selected zones and reserves contained in each of them

Areas (m^2)	Thickness/	Ni (%)	Co (%)	Fe (%)	Ton (t)
I 37916,884342645	5,33	1,13	0,080	38,68	17598,06
II 15701,049671988	5,77	1,04	0,067	37,88	28828,05
III 28053,696431374	5,56	1,26	0,087	38,95	127319,96
IV 13502,896062909	5,56	1,12	41,19	0,085	72830,70
V 42928,704652661	5,51	1,23	0,094	39,38	197806,50
VI 41561,990515577	5,49	1,21	0,096	40,84	110875,80
VII 3685,480703078	6,21	1,22	0,083	37,38	24209,96

The following table shows the total of resources present in the seven areas:

Table 2. Resources contained in the selected areas

Thickness	Ni (%)	Co (%)	Fe (%)	Ton (t)
5,52	1,19	0,088	39,52	609790,74

The areas having Lb thickness >=1m within the sector are also included as part of

the resources and nickel, iron and cobalt contents were determined. The table below shows the results:

Table 3. Resources contained in Zona A Oeste

Thickness	Ni (%)	Co (%)	Fe (%)	Ton(t)
3,93	1,14	0,082	38,81	1174445,6

The content of different chemicals elements present in the LB laterite mine was determined. The results are as follows:

Table 4. Average content of chemicals elements present in the LB mine

Ni (%)	Co (%)	Fe (%)	Mg (%)	Al (%)	Mn (%)	SiO2 (%)
1,14	0,082	38,81	2,28	3,1	0,58	28,13

Calculations of concentration of these elements in the entire sector were also run. The results are shown below:

Table 5. Average content of these elements in Zona A Oeste

Ni (%)	Co (%)	Fe (%)	Mg (%)	Al (%)	Mn	SiO2 (%)
1,14	0,082	38,74	1,18	4,10	0,75	14,77

Using the method of area of influence and a *cutoff* of >=1 for Ni and >=35 for Fe and LB greater than 4 m, the resources of Zona A Oeste are estimated to be on the order of:

Table 6. Resource Re-estimation Results

Thickness (m)	Ni (%)	Co (%)	Fe (%)	Ton (t)
5,52	1,19	0,088	39,52	609790,74

Geological exploration studies conducted in the area revealed the presence of zones with high overburden thickness and low LB thickness; which explains relatively low values for existing limonitic resources in the area.

Conclusions

Abundant iron shell blocks and ephithermal silica blocks were observed in the entire sector.

No development of weathering crusts on basic rocks was observed.

There was no indication of a possible presence of a disjunctive structure to which basic rock outcrops are associated.

A total of 1 174 445,62 t of LB in the sector were obtained. Ore grade is 1,14 % for Ni; 38,82 % for Fe and 0,082 % for Co.

A 609 790,74 t of resources were obtained from the seven selected areas. Ore grade is 1,19 % for Ni, 39,52 % for Fe and 0,088 % for Co.

The areas with a higher mining potential based on LB thickness are located in the most northern part of the sector where the surface is flatter.

The most elevated areas are less attractive for mining exploitation (with low LB thickness); therefore, it will more complex to undertake mining activities with bank systems of 8 x 8 x 3 m.

Recommendations

To conduct a paleontological survey of the area to determine whether or not the crusts are re-deposited or *in situ*.

The distribution of useful ore is not uniform so it is recommended to perform simultaneous mining in another ore body to proceed with blending and homogenization of the extracted ore to obtain improved quality ore feeds according to specifications in addition to meet Ni/Co ratio and ore volume requirements.

To analyze the impact caused by the existing creeks in Zona A Oeste when completing the final estimation of resources and reserves contained in the sector.

To undertake a feasibility study of the areas having an overburden/ore ratio higher than 3:1.

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