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CURAÇÁ VALLEY
COPPER PROJECT
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In the Curaçá Valley two groups of proper lithological-structural-tectonic nature and of different ages were identified: Caraíba and Canudos' Groups. The Caraíba Group (inferior Pre-Cambrian) is constituded of three litho-stratigraphical sequences. The River Curaçá (basal) Sequence is characterized by metamorphic rocks predominantly of granulite facies and transitional amphibolite-granulite, intensely granitized, where charnockitic gneisses, diverse granulites, granulitic migmatites, migmatics gneiss biotite, etc.

The mafic-ultramafic bodies, to which copper mineralizations are associated, are of varied constitution being classified in four categories, in function of lithological predominance; serpentinical bodies, amphibological bodies, noritic-pyroxenitic bodies and gabbic-dioritic bodies. They present, in general, a lenticular prolongated tabular form, with an extension going till 5 kilometres and thickness varying to the 30m maximum, fitting in accordingly in the River Curaçá and Tanque Novo Sequences.

The serpentinical bodies are not mineralized in copper although they show relatively elevated values of chrome and nickel, compatible with their ultrabasic nature and with a possible magmatic origin.

The amphibolitic bodies occur, mainly, in the Tanqüe Novo Sequence and are of meta-sedimentary origin. At times they present a weak sulphide dissemination (pyrite and chalcopyrite) of singenetic origin. They associate, in the field, to chalc-silicated rocks that, eventually, also show a weak sulphide dissemination (pyrite, chalcopyrite) and graphite. These mineralizations are not economical.

The gabbric-dioritic and noritic-pyroxenitic bodies are of doubtful origin, although presenting petrographical and notably chemical characteristics more compatible with a basic volcanic origin. The noritic-pyroxenite bodies are the ones which present greater concentrations of copper and iron sulphides and form the Curaçá Valley Cupriferous

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deposits. The gabbric-dioritic bodies show,eventually, a weak sulphide dissemination but, normally, they do not constitute mineralized bodies.

The sulphide mineralization is composed of the following minerals listed in an abundance decreasing order in the ore bodies: calcopyrite, pyrite, bornite,pyrrhotite and chalcocite; the latter being found only in the Surubim body constituting a supergenic origin sulphide. It normally presents itself disseminated the occurrence of microlenses and sulphide venules filling up together fissures and following the foliation of host rocks. Under massive rock, it may occur in the pyroxenite (hiperstenite) rock or in fractured and hydrothermally alterated zones.

In ore bodies, the vertical horizontal sections present tabular and/or lenticular shaper. In certain deposits they may show more irregular shapes (" amas ") resultant from the sulphides remobilization. The copper purports variation is remarkable in ore bodies and also resultant of mineralization re-mobilizations.

The local controls of copper mineralization are: the nature of mafic-ultramafic rock (more concentration in the hypersthenites and melanorites,regular dissemination in the norites and subordinate dissemination in the diorites); the metamorphic structure of 'host' rocks (more concentration in the isotropic rocks than in its foliate equivalents);granitization (sulphide concentration in the periphery of more granitized parts or in the mafic-ultramafic segregations and the dispersal of sulphides notably pyrite, in the intensely granitized parts); doubling (mineralization concentration in the axis of tight isoclinal folds and crenulated perilcinal terminations); hydrothermalism and metasomatism (sulphide concentrations in hydrothermally and metasomally alterated zones, as the biotitic rocks and equivalents, and sulphide concentrations in fractured zones, associated with mobilized hydrothermals).

The noritic-pyroxenitic bodies with a high sulphide concentrations only occur in the River Curaçá Sequence and keep in its spatial distribution by district a regular distance from chalc-silicated rocks and ferriferous quartzites which constitute the basis of the Tanque Novo' Sequence. This geological fact has been interpreted by authors as substratigraphic regional control of cypriferous mineralization, based in which a series of potential areas for prospecting is being proposed.

Countless small occurrences of copper oxidates are distributed in the Curaçá Valley District, presenting, on the whole, an insignificant reserve, inferior to a 1,000 metallic copper tons. These occurrences resulted from the oxidation of sulphidic ore small bodies formed by the remobilization of a low purport copper mineralization and a re-concentration in fault zones. These concentrations sometimes take place in fractured breccia and shearing zones of acid rocks, beyond the mafic-ultramafic rocks domain, sources of copper primary mineralization.

The estimated reserve of oxidate copper ore, including the mineralized bodies and known occurrences contain, approximately, 60,000 tons of metallic copper which 80% are concentrated in the Caraîba depositing, that makes its economical exploitation feasible.

At present there are seven mineralized bodies confirmed in the Curaçá Valley: Caraîba, Baraûna, Imburana, Surubim, Lagoa da Mina, Cercado Velho, Pirulito and Santa Fé bodies: the latter four were studied by the project. They make, on the whole, a 998,786 tons of metallic copper reservation contained in ore with a medium purport of 1.05% Cu, having been admitted in the calculation, a section purport of 0.20% Cu. Together with copper and possibly profitable as by-products, gold and silver were also found present. The existence of platinum is also suspected because of the petrographic, mineralogical and chemical nature of the paragenesys of copper ore. Based on the correlation of copper and gold purports it was estimated, for the district, a 26.420, 249kg gold reserve, of which 74% are concentrated on the Caraíba depositing.

Of copper reserves, the Caraíba deposit (the Caraíba and Baraúna-Imburana bodies) participates with 70% of sulphidic ore and 80% of the district oxidated ore, in ways that the other small and medium mineralized bodies will possibly constitute 'satellite deposits' around a mining complex centralized in the Caraíba field area.

In relation to the copper mineralized fields, inventoried in the world, the Caraíba deposit fits in that of a medium type, being its copper reserve a little superior to the deposit average exploited in the world, while the other fieds are, normally, small.

The integrated global planning of the Curaçá Valley research, as it thought based on present elements, must be subdivided into three programs: (1) a detailed research of the Caraíba deposit viewing the more economical viability studies of the mining phases, benefitting and metallurgy, for the implantation, at a short notice, of the mining-metallurgic project; (2) the studies of other mineralized fields, viewing their detailed quantification to the recommended level by economical viability studies of the exploitation of copper contained in the area; and (3) the research of even more prospectable areas, defined in function of mineralization controls or selected through indirect prospecting methods, based on conclusions about economical viability of the exploitation of these small bodies, already established with the conclusion of the 2nd program.

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4. RESEARCH METHODOLOGY

4.1. Geological Mapping

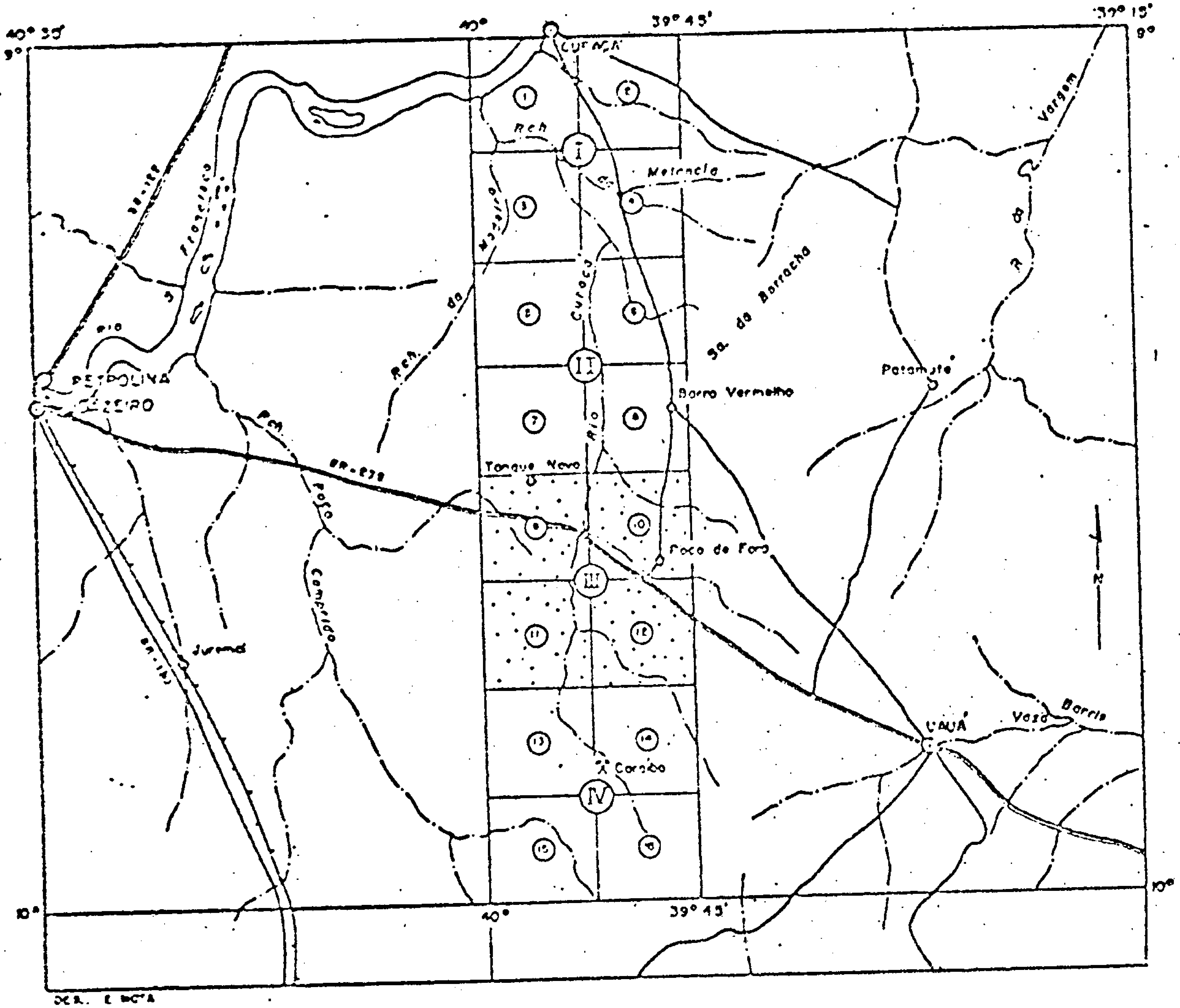
The prospecting program for the Curaçá Valley foresaw the geological surveying of the Copper Project's whole area. The systematic plan for the geological surveying comprises sixteen sheets of 7'30" edge (side) to be mapped in a 1:25,000 scale (Ill. 2). When choosing the mapping scale it was mainly taken into account the reduced dimensions of mafic-ultramafic bodies potentially carriers of cupriferous mineralization. The scale chosen allowed a good representation of great part of these bodies, and made the mapping of certain lithological and structural details which later on showed to be valuable to the orientation of detailed prospecting works and to the geological understanding of the area as a whole.

To each sheet, initially, a preliminary photogeological interpretation was done, in the 1:25,000 scale, produced by Cruzeiro do Sul Aerophotogrammetric Service - S.A.C.S., between 1956 and 1957.

The photo-interpretation data (hydrographic system, topographical and photogeological features), obtained through a stereoscopic exam, were registered in "overlays", which helped to orientate the field works.

During the field compaign, beyond the observations and analyses inherent to the geological mapping service, special emphasis was given to a careful visual exam, viewing the identification of copper minerals, specially in the fragments and rare outcrops of mafic-ultramafic rocks. Because of its association with the cupriferous mineralizations, the mafic-ultramafic bodies, identified on the field by the dark grey soil, "massapê," and by the autochthonous fragments of mafic-ultramafic rocks, have always been the object of most accurate geological investigations.

As the field works went on, the preliminary photo--interpretation was modified because of the collected elements in



——— Project area limitation

——— Sheets limits

Mapped sheets by CPRM

Mapped sheets by Geosol

LEGEND

Code and name of the sheets - 1:20,000

1	SC.24-V-D-II-1-NO	FAZENDA VENEZA
2	SC.24-V-D-II-1-NE	PIRAJÁ
3	SC.24-V-D-II-1-SO	RIACHO DA MADEIRA
4	SC.24-V-D-II-1-SE	RIACHO DA MELANCIA
5	SC.24-V-D-II-3-NO	VERMELHOS
6	SC.24-V-D-II-3-NE	QUIXABA
7	SC.24-V-D-II-3-SO	JARAMATAIA
8	SC.24-V-D-II-3-SE	BARRO VERMELHO
9	SC.24-V-D-V-1-NO	TANQUE NOVO
10	SC.24-V-D-V-1-NE	POÇO DE FORA
11	SC.24-V-D-V-1-SO	LAJES
12	SC.24-V-D-V-1-SE	ESFOMEADO
13	SC.24-V-D-V-3-NO	ARAPUÁ
14	SC.24-V-D-V-3-NE	CARAÍBA-POÇO DA VACA
15	SC.24-V-D-V-3-SO	BOM DESPACHO
16	SC.24-V-D-V-3-SE	SANTOS ARES

Code and name of the sheets - 1:50,000

I	SC.24-V-D-II-1	CURAÇÁ
II	SC.24-V-D-II-3	BARRO VERMELHO
III	SC.24-V-D-V-1	POÇO DE FORA
IV	SC.24-V-D-V-3	CARAÍBA

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Illustration 2 - Place - Code and name of mapped geological crevices

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UNIT was characterized by mineralogic and structures of lithologies similarities by the predominance of one or more lithological types and by metamorphic facies.

It is known that to situate these units stratigraphi cally consisted in a very difficult task due to the notorious difficulties of elaborating the stratigraphical column of highly metamorphical Pre-Cambrian regions, having in mind mainly the 1:25,000 scale and the small extension of the mapped area.

In the Curaçá Valley, these difficulties gravitated around a high level of metamorphism of generalized granitization, of the complicated structural-tectonic picture and the deeply destructive erosion level.

In spite of all the difficulties we managed to group the highly metamorphic rocks of the Caraíba Group, in two litho--stratigraphical sequencies: Curaçá and Tanque Novo Sequencies.

This litho-stratigraphical subdivision was exclusively based on field data starting from the judicious lithological-structur al-stratigraphical analysis of key-places (sites) as the Serrote Preto mountain range, and of key-sections, as the Poço de Pinhões profile along BR-235, in which the stratigraphic positioning of the two sequences may be characterized. A field campaign was accomplished later on with the carry out of various geological sections in the area's diverse quadrants which served to test and confirm the effectiveness of the proposed subdivision.

4.2. Geochemistry

Under this heading summary considerations will be made on the methodology utilized in geochemistry prospection and orientative studies started.

4.2.1. Geochemistry of current sediments

The geochemical prospecting of active sediments was discouraged, in the beginning, by Lewis Jr et Santos (1966) due to the outcrops studied.

When the field investigations were over a transference of all the registered data in the "overlays" to the planimetric maps, in the 1:25,000 scale. The utilized maps were made by PROSPEC S.A., in 1968, using the above mentioned photographs, through the "Slotted templates" radial triangulation and the help of telluro-metrical polygonization. Next we re-interpreted the collected data and carried out a fast, complementary field campaign. Later on, already in the possession of some petrographic studies a preliminary geological map was prepared as well as a brief text for each sheet. After that, having in hand all the petrographic studies ordered, all the necessary changes were made.

These geological maps, in the 1:25,000 scale, were "a posterion" partially modified and fully detailed, because of new data obtained in the detailed mappings of the selected target-areas for copper-prospection. Other modifications were neessary as we acquired the geological knowledge of adjoining sheets to the mapped one.

With the development of the systematic geological mapping, the geological sheets 1:25,000, as they were being finished, were reduced to a 1:50,000 scale and integrated in a single geological map. This procedure was followed till the conclusion of the last geological mapping sheet.

With the slow integration of 1:25,000 maps, in the 1:50,000 scale, were being progressively improved the knowledge on conditioning geological phenomena of the cupriferous mineralizations and the controls of these mineralizations established.

In the present report the geological maps are presented in the scale 1:25,000 of the twelve sheets mapped by the CPRM and integrated maps covering the Copper-Curaçá's Project whole area: four in the 1:50,000 scale, and one in the 1:100,000 scale.

In the 1:25,000 geological mapping, the Caraíba Group, the rocks which cover almost the whole of Curaçá's Valley, was subdivided in lithological groupings, without stratigraphic connotation which were named as UNIT. The separation of these UNITS was based on structural and lithological criteria, so that each the kind of sample effected at that time, restricted to the aluvial sandy material, in order to preconceive a copper concentration in the shape of residual minerals.

Ladeira et alii (1969) making new sampling tests, this time about the most, clayey alluvial material, disputed Lewis Jr et Santos (op. cit) opinion and suggested the use of this work technique in the geochimical recognition phasis.

Finally, we elaborated a complement to the guiding studies, begun by Ladeira et alii (op. cit.),on new occurences of copper in the region, confirming the technical-economical viability of using this prospecting method for copper in the Curaçá River Cupriferous District.

4.2.1.1. Tests carried out

The guiding studies developed by Ladeira et alii (op. cit.), used the following tests:

1) Sampling type test, including sandy material samples, poor in clay, collected near the surface, and samples of a thinner material from the clayey levels of alluviums, collected at a greater depth (picture 3 and 4); and

2) Spectrochemical analyses for copper, chromium and nickel, in the natural fraction to an inferior sample of 120 meshs.

To complement these guiding studies we improved the following tests:

3) Intending to establish a sampling technique to the minor tributaries (drainage of 3rd, 4th etc. order) that do not represent the clayey levels, normally found only in the 1st and 2nd order alluviums, it was collected more clayey material accumulated under or near the surroundings of blocks of rock which are frequently found, slightly buried, in the main canal of one of these brooks;

4) Beyond total copper and nickel, analyses for the soluble copper were done, a method which is being normally utilized,

successfully, in similar studies developed in other parts of the world (pictures 5 and 6); and

5) Analyses were done on a sample lot for copper and nickel in two granulometrical fractions (one, inferior to 80 meshs and another inferior to 120 meshs) to define which of the two fractions were more convenient from the technical-economical point of view, by the fact that in both the analysed fractions the geochemical results were shown to be significant.

4.2.1.2. Summary of results

The conclusions taken from the guiding studies and satisfactorily confirmed in the prospecting development are summarized, as follows:

1) Confirming the affirmation of Ladeira et alii (op. cit.), the sampling of active sediment functioned perfectly as a geochemical method of recognition for copper in the Curaçá River Valley; to this purpose, the appropriate alluviums level was shown - in this case the clayey level must be normally found on the 1st and 2nd order drainage. To the minor tributaries the sampling was processed on the clayey sediments accumulated close to and beneath the blocks of rocks that are slightly buried in these brooks flow.

2) The total and soluble copper values presented clearly-delineated contrasts near to cupriferous occurrences (tab. V) reaching, for total copper, till fifteen times the background value of Cu. t and, for soluble copper, till seven times the Cu. ex. background value. Having a slight contrast, the soluble copper presented more seattering along the brooks flow, favouring its utilization as a geochemical recognition method with the anomalous values persisting down the river till 700 meters distance from the metal source.

3) Due to the copper distribution along the active

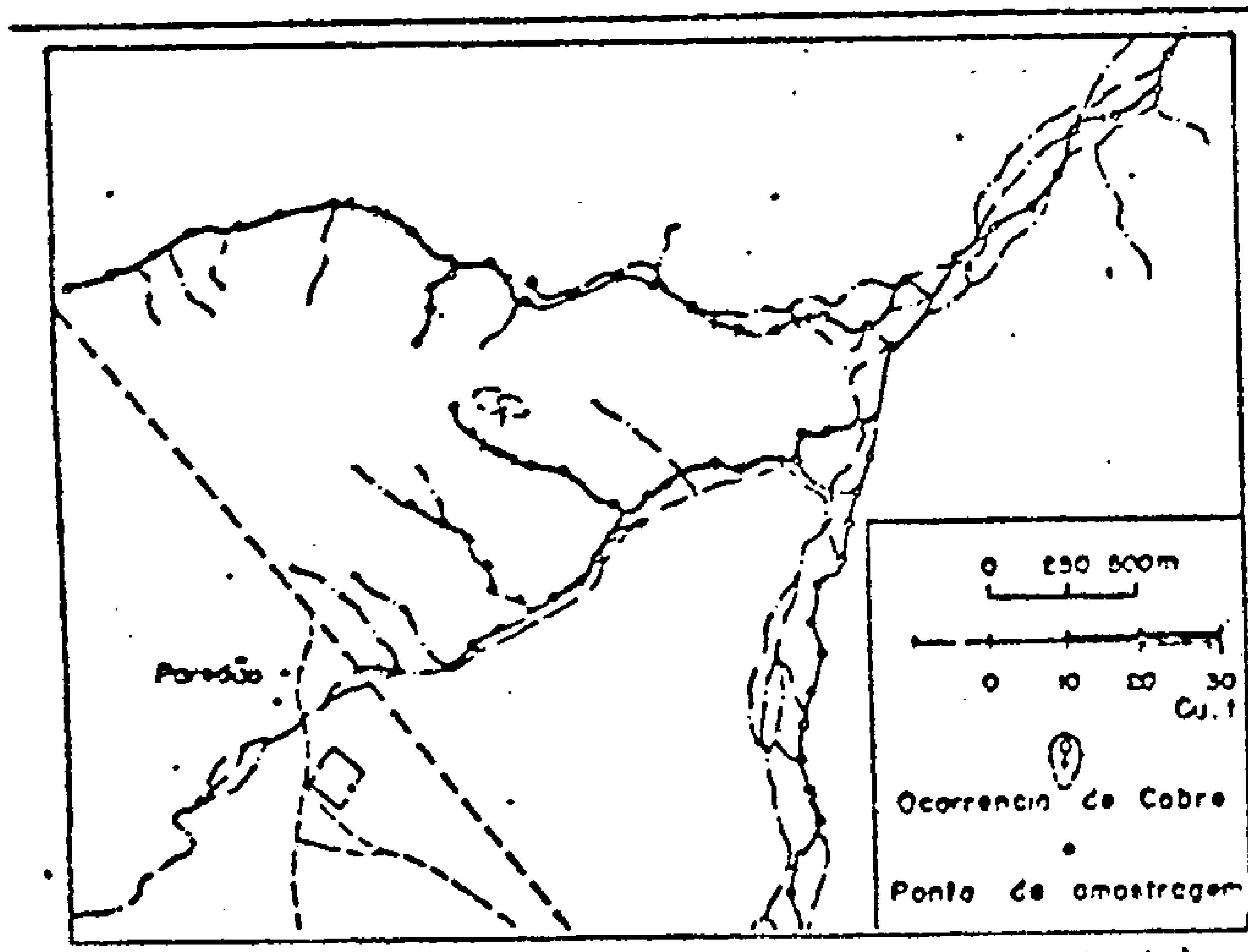


Illustration 3 - Graphic representation of total copper values dosed in sandy samples of flow stream sediments, collected near the surface, in the Paredão cupriferous occurrence area

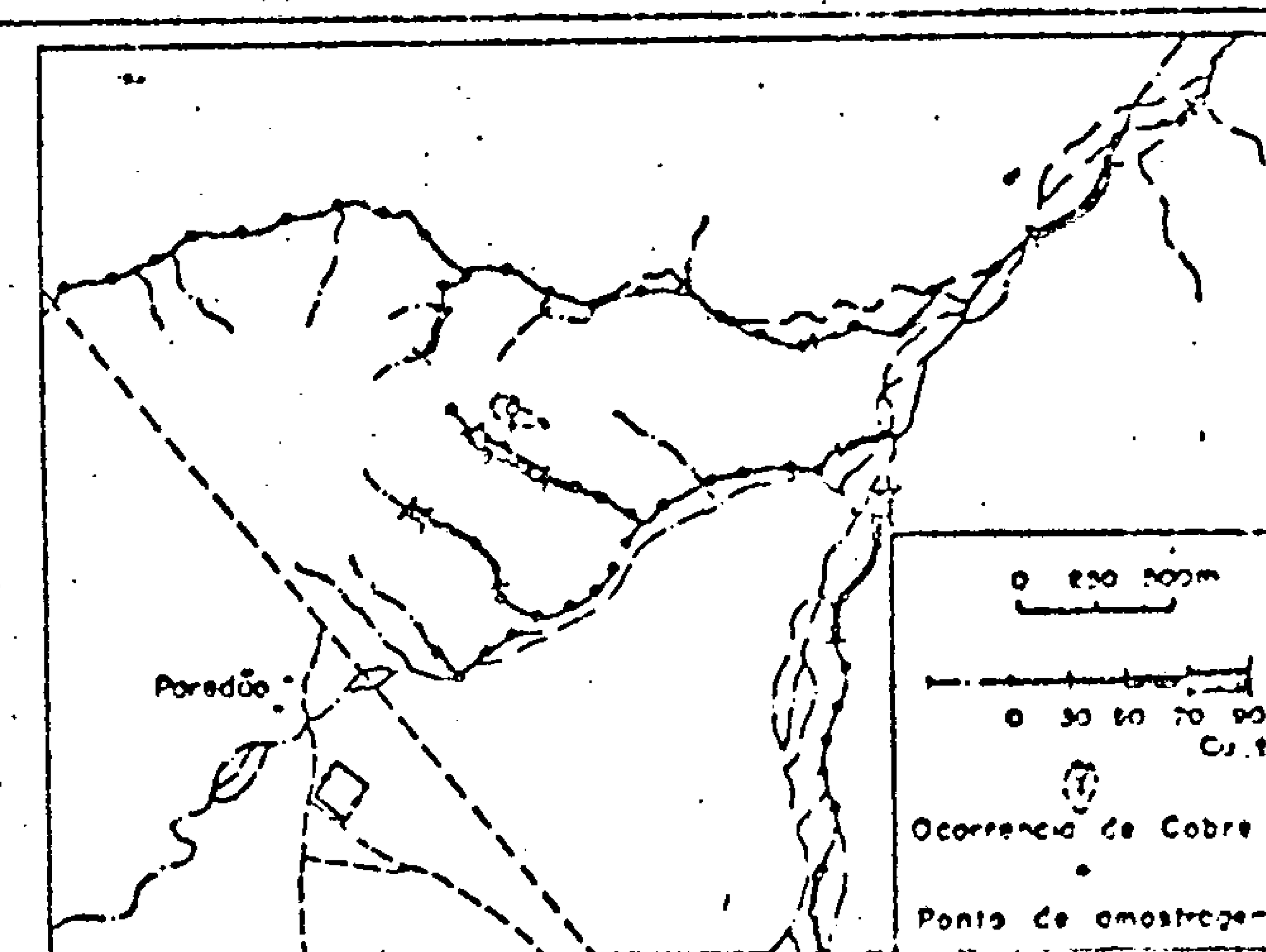


Illustration 4 - Graphic representation of total copper values dosed in clayey samples of flow stream sediments in the Paredão cupriferous occurrence area

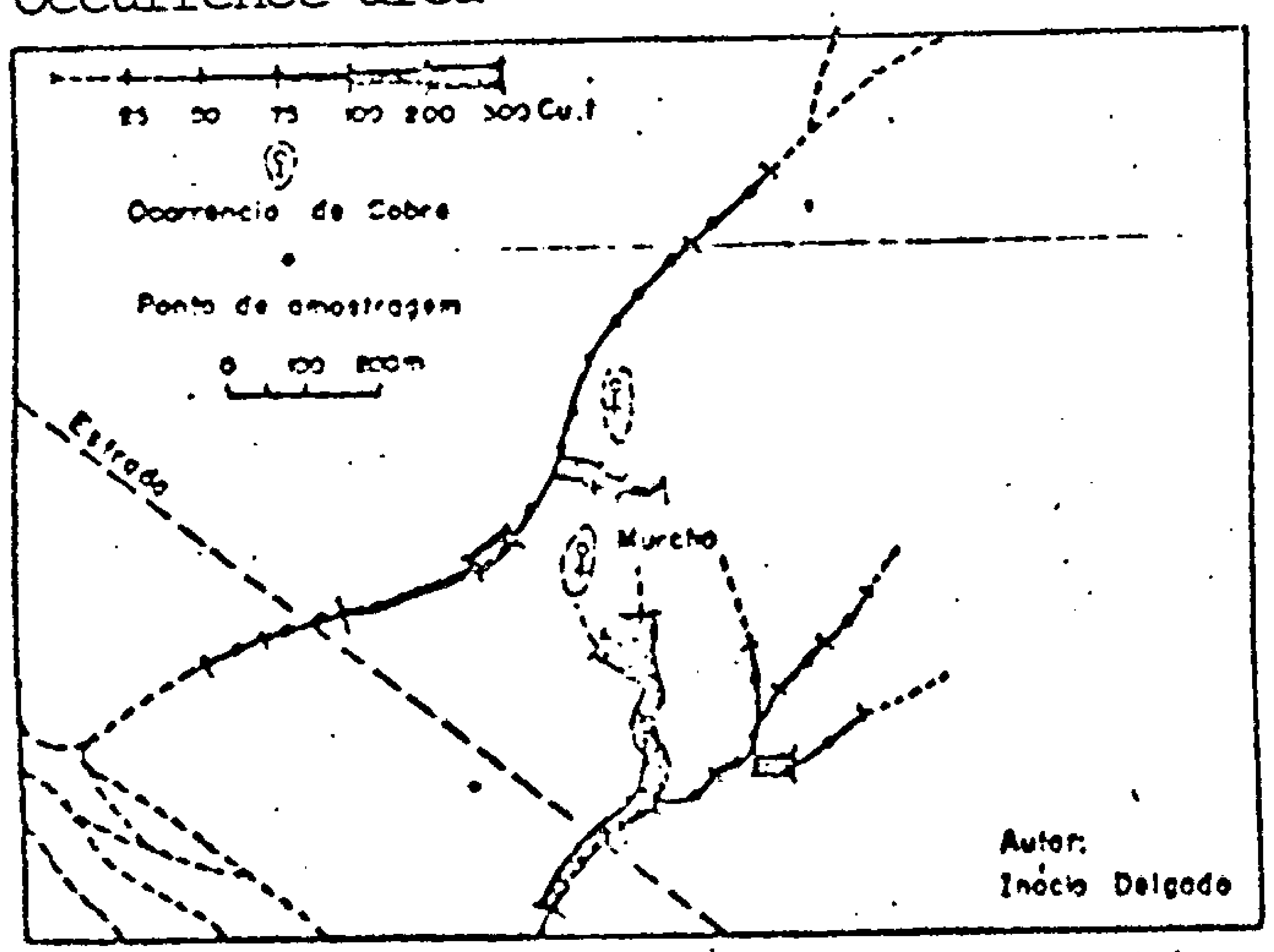
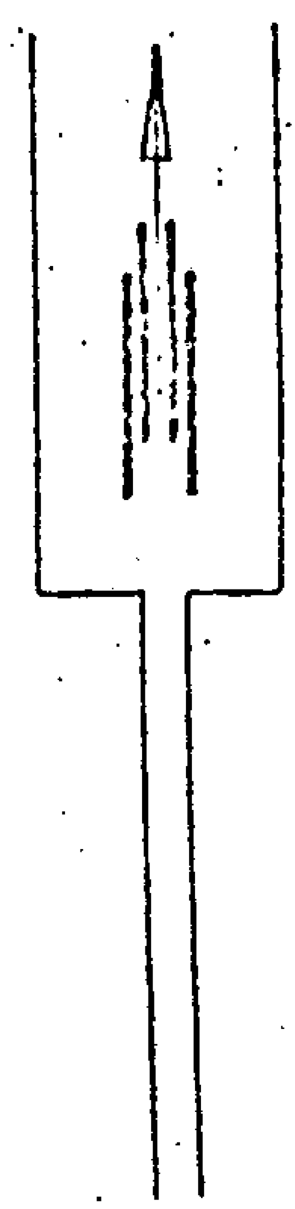


Illustration 5 - Graphic representation of total copper values dosed in clayey samples of stream sediments in the Murcho cupriferous occurrence area



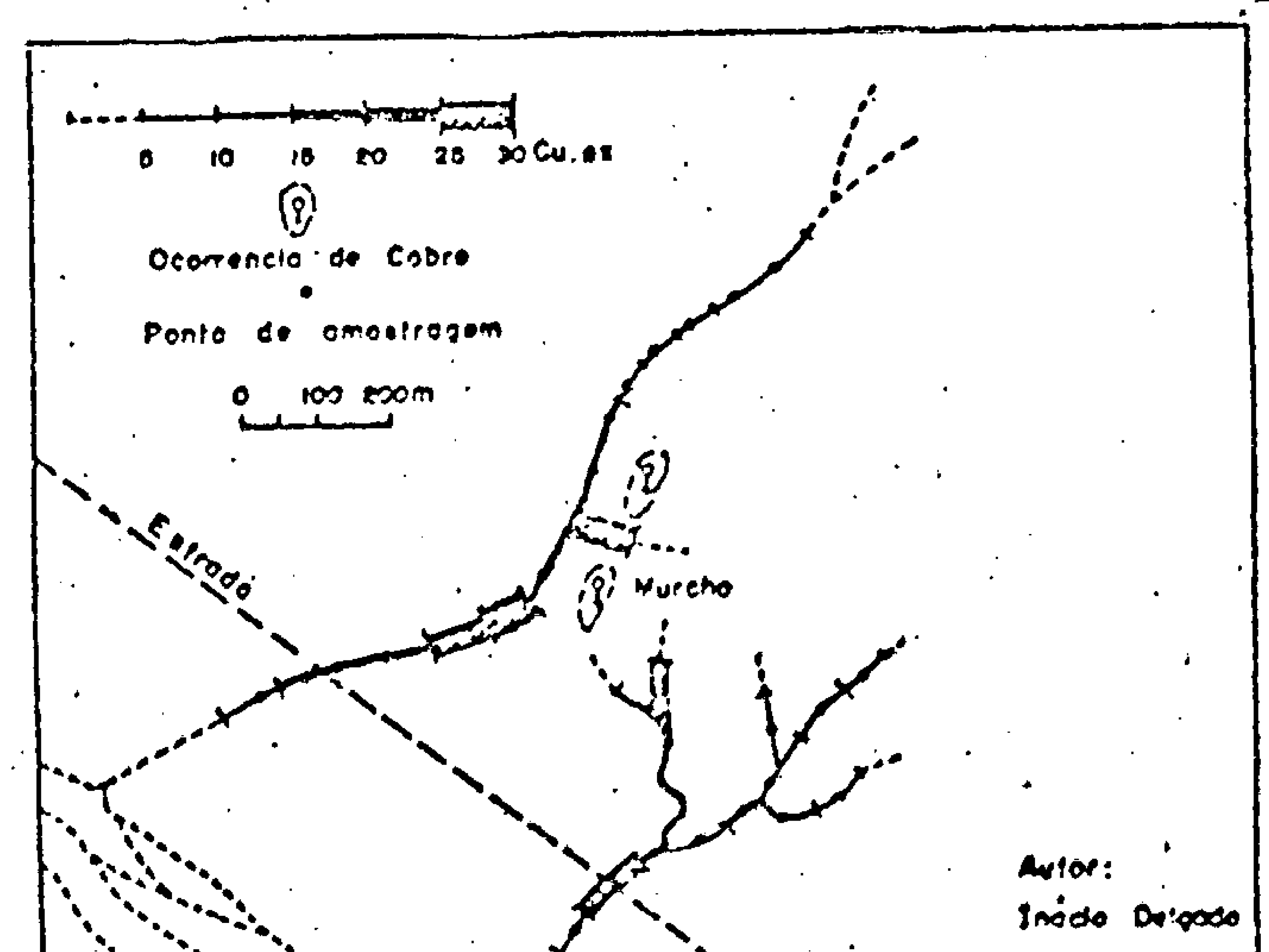


Illustration 6 - Graphic representation of soluble copper values dosed in clayey samples of stream sediments in the Murcho cupriferous occurrence area

Mod. 002

Table V - Copper and nickel concentrations in stream sediments in Murcho's occurrence.

Sediment samples downstream the nuberalized body. (anomalous)	* Cu. t (ppm)	** Cu. ex (ppm)	Cu.ex/Cu.t (%)	Ni (ppm)	Observations
1110-ID-26 near the mineralization	175	30	17	60	Medium brook (2nd order drainage)
27 70m down the river	88	20	22	60	
28 180m down the river	75	18	24	50	
29 250m down the river	62	15	24	45	
65 300m down the river	62	15	24	50	
66 360m down the river	38	12	31	60	
1110-ID-80 near the mineralization	250	20	8	60	Small brook (3rd order drainage)
79 near the mineralization	250	18	7	80	
78 60m down the river	300	15	5	60	
68 210m down the river	150	10	70		
67 240m down the river	150	13	60		
85 300m down the river	175	11	55		
86 360m down the river	12	12	60		
Sediments samples upstream the mineralized body. (Background).					Medium brook (2nd order drainage)
1110-ID-19	25	5	20	60(?)	
1110-ID-20	25	5	20	50(?)	

* Copper delimited through sample opening with $K_2 S_2 O_7$

** Copper delimited through extraction with HCl 1:1

All the delimitations were made at 80 mesh

CPRM

NE 7530.0210.0343

sediments, the sampling interval situated itself around 250 meters, corresponding to two samples per each square kilometre of area. This sampling density allowed that, in the anomalous zones, detected by geochemical recognition, at least two samples presented significant values, lowering in the probability scale the interpretation of anomalies due to sampling or analytical isolated mistakes.

4) We found an evident dilution process of geochemical values when a tributary flows into another, a phenomenon that may lead to the complete vanhishing of a geochemical anomaly, depending on the volume of alluviums of certain brooks that drain the region.

5) Based on guiding works, the following values of background and threshold for the small and medium tributaries were estimated, and later on confirmed in the statistic treatment of geochemical populations:

Analysed element	Background (ppm)	Threshold (ppm)
Total copper	25	60
Soluble copper	5	15

For the major tributaries (1^{st} order drainages), we utilized the 50 ppm threshold for total copper and 10 ppm for soluble copper.

6) Nickel high values, normally superior to 40 ppm, established one of the delimitative characteristics of mafic-ultramafic bodies in the regional geochemical landscape. Owing to the joining of copper mineralization with the bodies referred, the analysis for nickel of the sampled sediments is advisable, viewing a pre-selection of significant copper anomalies, related to "geochemical barriers", of significant anomalies in the proximity of mafic-ultramafic bodies.

7) Having in mind the contrast registered by copper (more significant in an inferior fraction at 80 meshs) and nickel (approximately the same contrast in the inferior fractions at 80

meshs and 120 meshs) and considering the copper population variants tested (0.07 discrepancy between the two fractions) and nickel (less variant in the inferior fraction at 80 meshs), we decided by the adoption of the inferior fraction at 80 meshs for the geochemical analyses processing of the mentioned metals. Adding to the profit pointed out the swiftness of sampling preparation meant an economy of costs.

8) In economical terms, in spite of the high sampling density for the geochemical recognition (conclusion due to guiding studies), the number of sediment samples necessary to cover a 1:25,000 sheet is still five times smaller than if the sampling were processed in an adequate mesh on the residual soil.

4.2.2. Geochemistry of the residual soil

The residual soil geochemical prospecting has been successfully utilized, in the Curaçá River Valley, since the first research programs. References to Lewis Jr et Santos (1966) Ladeira, Brockes Jr et Dutra (1969) and Lewis Jr, Mattoso et Brim (1970) works deserve special emphasis.

Lewis Jr et Santos (op. cit.) tested seven metals (Cu, Pb, Zn, Ni, Co, Cr and Mo) in the soils that cover the main types of rock in the Caraíba deposit and evidenced the following aspects:

1) The soils of the region are essentially residual and reflect the nature of the underlying rock;

2) The presence of 1,000 ppm of Cu in the dark-brown "massapê" soil would probably indicate a mineralized mafic-ultramafic body of rock;

3) High values of Ni, Co, Cr and Zn in the soil only indicate the mafic-ultramafic nature of the underlying rock and not necessarily copper mineralizations;

4) High values of Pb and Mo lack significance at

least as copper or any kind of rock indicators; and

5) The sampling of tree leaves, specially the "catingueira" (Caesalpine pyramidalis) can be of great value in copper prospecting.

Lewis Jr et alii (op. cit.) carried out geochemical studies involving soil prospecting at regional level, semi-regional and detail; from these works resulted the following main conclusions:

1) The regional prospection only for copper did not present a conclusive indication of mafic-ultramafic areas of rocks;

2) The semi-regional prospecting in mesh of (200 x 500)m was not adequate, omitting the characterization of really anomalous zones;

3) In detail level the considered spots (particular places) with 100 ppm or more of copper as of potential interest; with 250 ppm or more of copper as indicative of probable mineralizations and with 1,000 ppm or more of copper as discrimination of a mineralized body presence in the site.

Ladeira et alii (op. cit.) brought innumerable complementary subsidied to former researches having, among others, denying Lewis Jr et Santos's (op. cit.) assertion indicating that the active sediment geochemistry functions perfectly well in the Curaçá Valley. They presented very detailed and reliable informations about the pedological characteristics of mafic-ultramafic zones and characterized the geochemical landscape of the Curaçá valley as "eluvial or autonomous", based on Perel'man's criteria (1967). Among these, other conclusions were emphasized:

1) Inexistence of an optimum level of residual soil sampling, having in mind that the biggest purports in copper occurred erratically im all levels;

2) Due to the danger of the A_{00} - A_1 horizon sampling frequently re-covered by a screen of transported sand that might distort the results, it was suggested that the sampling should be done at about 45cm, because at this depth the "massapê" soil would always be collected, as well as the clayey, montmorilonithic soils, copper retainer;

3) They determined the value of 250 ppm as the most acceptable for the copper threshold ; and

4) They considered the copper secondary residual halos, in the researched places, possessing as much mechanical nature as salic (chemical), being the former ones probably more important.

Whereas the necessity of complementing the information referring to the geochemical dispersal patterns in secondary ambient, Target L-2 for new tests was selected, because it surrounds mafic bodies with purpots significantly anomalous of copper. The research was additionally complemented, by means of a detailed prospecting in residual soil of mafic-ultramafic body, norithic-piroxenithic mineralized, called Pirulito.

Among others, the research had as objectives, the following:

1) Test of the ideal horizon for soil sampling, of an even more doubtful definition by the former researches;

2) Characterization of the geochemical ambient in terms of pH and Eh;

3) A study of the convenience of testing other metals in subsequent campaigns;

4) Determining the geochemical dispersal patterns in the area, with special emphasis in Cu, Cr, Ni and Co elements; and

5) To apply the information obtained to the planning of a more efficient and economical exploitation program in the

same regional geochemical landscape.

4.2.2.1. Pedological profile

The residual soil typical profile of the Pirulito mafic-ultramafic body, may be described according to the characteristics specified next:

A_{00}(0-3)cm Horizon - Level with semi-putrefied organic fragments and many small fragments of weathered residual rock. This horizon is common on mafic rocks.

A (3-20)cm Horizon - Normally underdeveloped owing to partly to the weak pluviometrical precipitance, and the high-rate of superficial drainage. It is comonly a dark-grey horizon, humic, clayey, with small fragments of mafic rocks. Prismatic structure, with brilliant surfaces. All the horizon is crossed normally by almost vertical retraction crevasses, that bestows them a prismatic superstructure. Plastic, with a good density (compactness). The pH measured in laboratory, with a METROHM HERISAU - E 520, is neuter or slightly acid.

B_2(20-50)cm Horizon - Level normally well-developed, dominant clay--sandy texture, with good compactness, much plastic, dark-grey tone. Poliedric structure with brilliant soared faces. Prismatic super-structure. Moderate to high humic purport. Crossed by roots. The pH is normally neuter to slightly alkaline. At times this level contains calcium carbonate modules.

C (+ than 50 cm) Horizon - Matrix rock highly decayed, very friable. Composition mainly amphibolitic-pyroxenitic and fragments of quartz-feldspar-biotitic composition. It is common the preservation of the matrix rock structure. Illustration 7 schematically shows the pedological profile developed on mafic-ultramafic rock of the River Curaçá Valley.

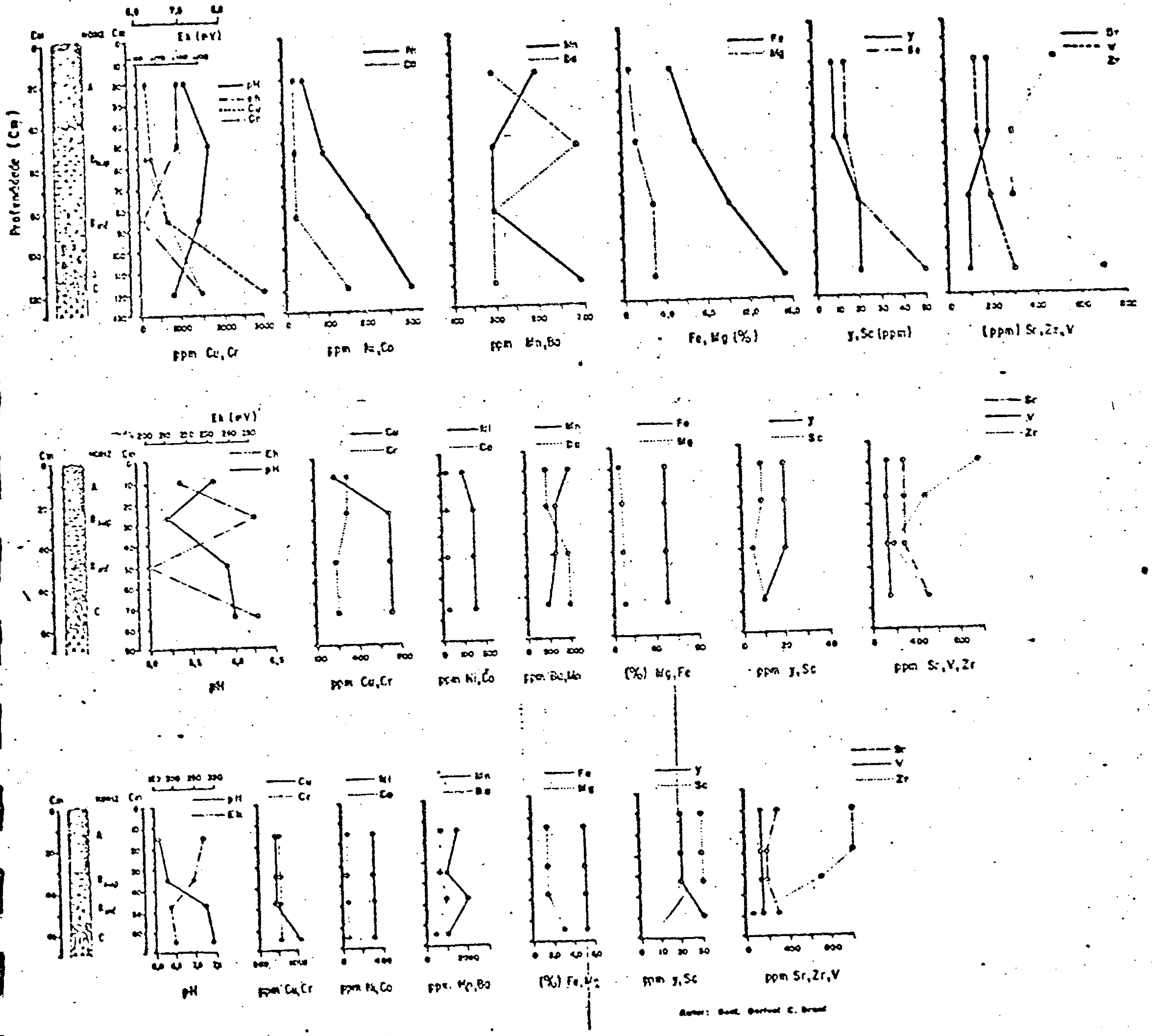


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Illustration 7 - Vertical geochemical profiles developed on soils derived from mafic-ultramafic rocks from Pirulito test area.

In the edges of the mafic-ultramafic body and progressivel as it distances itself, predominates the sandy-clayey texture soil becoming sandy and showing from a cream to dusky ochre, colour tone normally of small thickness (less than 30 cm), with an incipient A horizont, weakly developed reflecting the residual covering of migmatic biotite-gnaisse that inserts the body.

According to researches previous to Ladeira et alii's (op. cit.) the "massapê" soil is made of phylosilicates, especially the montmorilonite and in a lesser scale, vermiculite, illite and chlorite. Montmorilonite-clorite-vermiculite interstratificated are registered and also montmorilonite-illite and montmorilonite-chlorite-vermiculite. Caolinite occurs subordinately.

It is a advisable to notice that the profile pedological characteristics here described can be considered as a whole as peculiar to derived soils of mafic-ultramafic complexes, in the River Curaçá Cupriferous District, according to observations registered in the Copper Project scope complemented by Lewis Jr et Santos' (1966) and Ladeira et alii (1969) former researches.

4.2.2.2. Guiding study in the Pirulito body

4.2.2.2.1. - Routine sampling and analytical techniques

A recognition prospecting was preliminarily done in the Sertãozinho farm area (Target L-2), according to a 300m (N-S) x 100m (E-W) mesh, comprising the collection of samples at B horizon level. At this stage, colour-metrical determinations semi-quantitative for copper, in granulometrical fraction inferior to 100 meshs, according to the technique described in the USGS-1152 Bulletin.

In the Pirulito target test 76 sampling wells were opened, according to a 50m (N-S) x 25m (E-W) mesh, so as to totally include the mafic noritic-pyroxenitic mineralized body with the approximate dimensions of 70m (E-W) x 300m (N-S).

The samples were collected in four levels including the A, B and C horizons (subdivided into two equidimensional parts). In three profiles, strategically located, thirty elements were additionally tested.

The metals were tested by semi-quantitative spectography according to a technique described by Grimes et Marranzino (1968) in the 591-USGS Circular. The visual comparison process utilizes concentration patterns of 1 - 2 - 5 - 10 - 20 - 50 - 100 - 200 - 500 - 1000 - 2000 - 5000 ppm, and visual interpolations among these values are always given as 1,5 - 3 - 7 - 15 - 30 - 70 - 150 - 300 - 700 - 1500 ppm etc.

The precision (reproductibility) of a registered value is approximately, of more (+) or less (-) a concentration interval in a 68% trust limit, or two concentration intervals in a 95% trust limit.

4.2.2.2.2. Statistical techniques utilized

The analytical results for copper, chromium nickel and cobalt were preliminarily submitted to a conventional statistic treatment following the procedures established by Tennant et White (1959) and Lepeltier (1969).

Data were satisfactorily adequate to a distribution according to the lognormal law. Copper however, showed a bimodal distribution probably conditioned by the sudden variation of the lithological controls (mafic-ultramafic and gnaisse migmatitic), in the detailed scale done. The histograms for the non-transformed data showed positively unsymmetrical distribution, which indicates a lognormal distribution among others. Cumulative frequency curves to Cu, Cr, Ni and Co allowed a better characterization of the two population involved by the Pirulito target-test.

At times, the other metals tested detected by the method sensibility level, adequated themselves to a distribution according to the normal law. Additional programming through the computer was developed by simple lineal correlation tests and multiple sequential lineal regression. The lineal correlation was applied viewing, specially, to define eventual metal associations in the target-test, particularly concerning copper. Correlation lineal equations for copper were obtained according to the general equation:

$$Cu = a_o + a_1 Y, \text{ being:}$$

Cu, the dependent variable;
Y, the independent variable (another metal);
a_o, the intersection; and
a_1, the straight line declivity; where:

$$a_1 = \frac{\text{Covariance between Cu and Y}}{\text{Y Variance}}; \text{ and}$$

$$a_o = C\bar{u} - a_1 \bar{Y} \text{ ; being:}$$

$C\bar{u}$ and $\bar{Y}$ the copper and the second metal rates.

Concerning copper the following metal correlations were registered: Cr (0.91), Ni (0.90), Sc (0.72), Mg (0.70), V (0.66), Co (0.66), La (-0.52), Fe (0.40) and Sr (-0.40), strong correlations admitted. However, weak correlations were registered with the following elements: Ti (o.29), Y (0.17), Pb (0.11), Zr (-0.99), Ca (0.90) and Ba (0.08).

A study of the multiple sequential lineal regression made possible the characterization of some geochemical point-of-view critical associations. Copper was accepted as a dependent variable, having as independent variables the following,metals: Ni, Cr, Fe and Y, common association to mafic-ultramafic bodies.

It was proved that for the A, B and C horizons, after the entrance of two dependent variables we do not have much explained variance (accounted for),i.e., we do not possess more quantity of motivated informations.

4.2.2.2.3. Geochemical ambience in pH and Eh terms

Adopting Hansuld (1966) established criteria, two practical considerations were developed, approaching: (1) the primary sulphide oxidation to the ambient of mineralized suboutcropping and (2) the movement of metals in a secondary dispersion (soil) enviroument.

The pH measured oscilated from 5.00 to 8.00 while the Eh varied from + 90 to + 330 m V, in the residual soil of the researched target-test.

This is a particularly favourable ambience to copper precipitation under the Cu (OH) form and also to the formation of metal oxidates.

The pH dominanting conditions, neutral to slightly alkaline, favoured the migration of metals Cu, Ni and Co very little what would explain the narrow halos, close to the suboutcroppingly mineralized body, as the configuration of the metal geochemical distribution in the four testes levels has shown. It was also vertically registered a sudden lowering in metal concentrations right from the mineralized rock, proving the difficulty in mobilizing metals in a secondary ambient.

The main characterized zone through copper oxidades saturation is defined by pH band between 7.0 and 8.0 with Eh varying from + 100 to + 250 m V, which is well delineated in the four levels tested.

4.2.2.2.4. The distribution of metals in residual soil

The copper regional "background" in residual soil, in the Sertãozinho farm area is located in the 40 ppm band. However, in the regional mafic soils of rocks conspicuously mineralized the medium purport was of Cu 130 ppm order, concentration which contrasts of 5 times in relation to the estimated media for the other populations in residual soils of different lithologies.

An increase in the Cu purports with depth was registered, while the variance showed only slight discrepancies in the four levels, which "a priori" could define an equivalence of them in terms of geochemical representativeness.

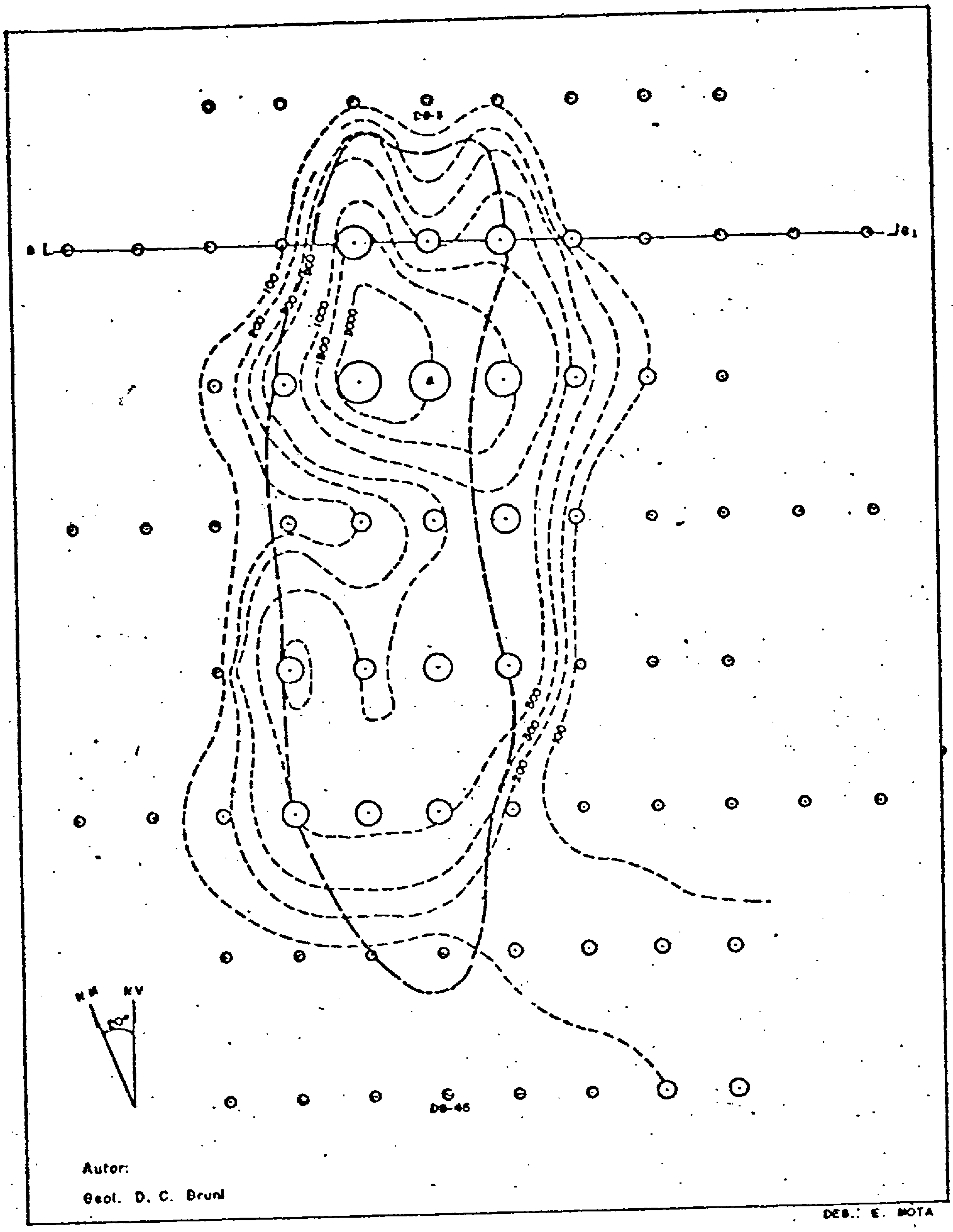
The 100 ppm isopleth for copper in the A, B and C horizons constituted a good geometry delineation of a mafic--ultramafic body, mainly to a decayed rock level (picture 8).

In the clayey bands as much as in the sandy ones, the more intense and better defined anomalies were obtained by sampling in the B and C horizons, making possible a more effective characterization of mineralized suboutcroppings. Table VI presents a summary of statistics pertinent to the metals tested in four residual soil levels.

The declivity of the ground to SW, starting from the mineralized level, reflected in the copper migration in the soil overthrusting zone, affecting mainly the A horizon. On the other hand, this level showed itself in the detailed prospecting scale, considerably de-characterized due to the "canibalism" process (Lewis et Santos, 1966). Furthermore, the presence of humic substances conditioned a certain copper absorption in this level.

The strong copper correlation with Cr (correlation coefficient r = 0.91), Ni (0.90), Sc (0.72), Mg (0.70) and Co (0.66) was kept in the four tested levels (picture 9). Cobalt, however, exhibited a greater a real dispersion when compared with the Cu, Cr and Ni distribution starting from the mineralized mafic body. Such correlations emphasized the strait paragenetic correlation mantained between Cu and Ni in the primary ambient, secondarily confirmed by the strong correlation kept between then in the residual soil.

The significant Cu correlation with Cr, Ni, Sc, Mg and V, proved that the migration of these elements was very restricted to the residual covering of the mineralized mafic body.



< 100 ppm Cu
(100 - 200) ppm Cu
(200 - 300) " "
(300 - 500) " "
(500 - 1000) " "
(1000 - 1500) " "
(1500 - 3000) " "
≥ 3000 " "

Curve of isoteor (ppm Cu)
Soil sampling point
Geochemical profile
Anchorage picket
Mark CPRM-DNPM nº 3
Mafic-body contour

SCALE

COPPER - CURAÇÁ PROJECT

Illustration 8 - Copper geochemical distribution map in the C horizon of the residual soil in the Pirulito test-area.

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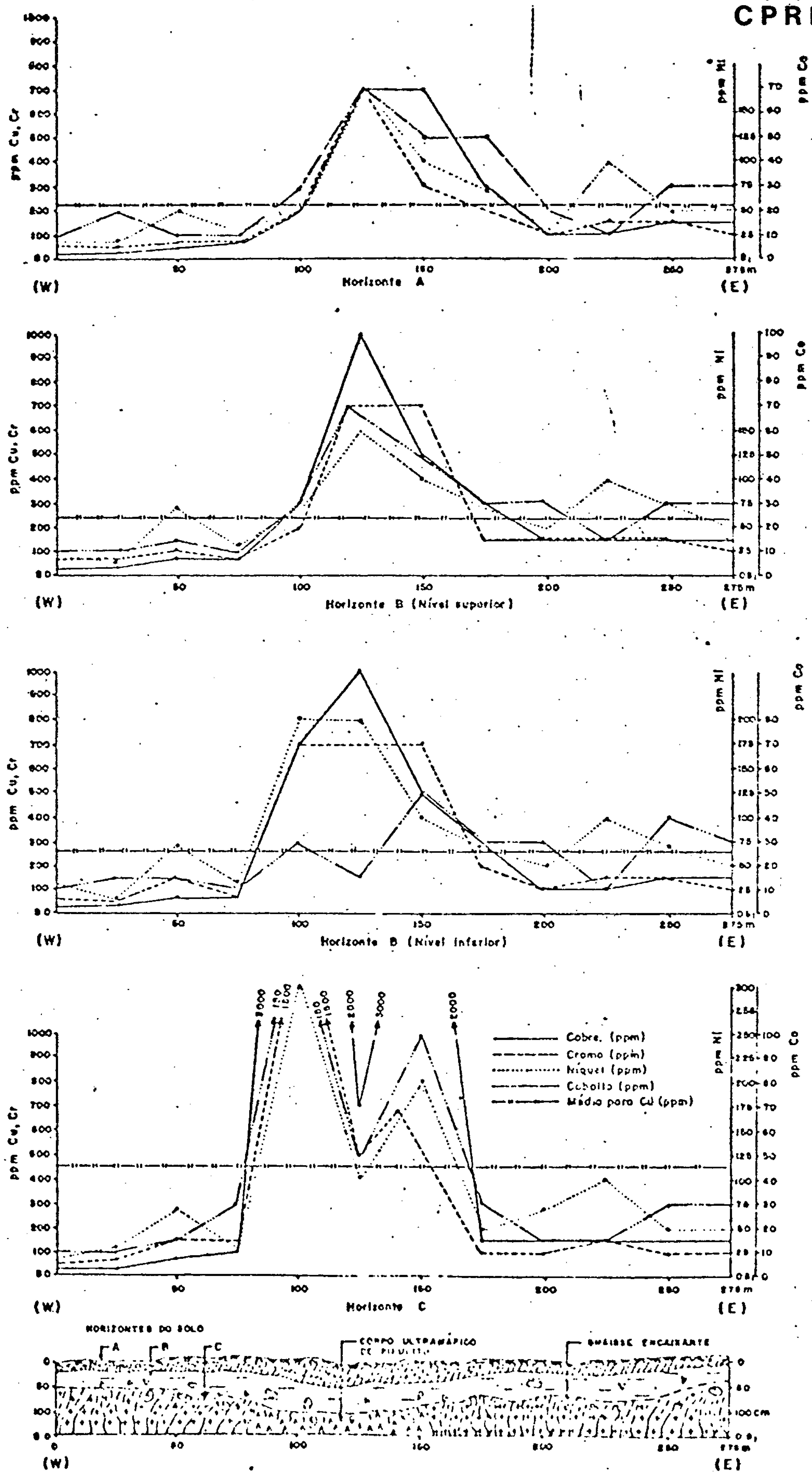

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Illustration 9 - Geochemical profiles of copper, chrome, nickel and cobalt in the different pedological horizons (Profile $B-B_1$)

Table VI - Statistics partial summary for the target-test populations according to the four levels tested

Metal	Horizon A		Horizon B (superior)		Horizon B (inferior)		Horizon C		Averages Vinogradov (1959) Krauskopf (1967) Hawkes e Webb (1962) Coted		
									Rock		Soil
	X̄ average	Amplitude Population	X̄ average	Amplitude Population	X̄ average	Amplitude Population	X̄ Average	Amplitude Population	Mafic	Ultramafic	Residual
Fe	4,36	8,5	5,24	13,5	5,49	13,0	5,97	13,0	8,56	9,85	1,4-4,0
Mg	0,84	1,80	0,95	2,70	1,03	2,70	1,28	3,50	4,5	25,9	-
Ca	1,17	0,80	1,17	1,30	1,23	2,30	1,61	11,30	6,7	0,7	0,40
Ti	0,69	1,00	0,66	0,50	0,58	0,70	0,51	0,80	0,90	0,30	0,46
Mn	700	1200	610	1350	660	1350	750	4800	2200	1300	850
Ba	550	800	590	1300	670	1400	1000	5200	270	15	500
Co	25	60	24	60	27	145	30	145	45	200	8
Ni	65	270	89	280	99	290	114	290	160	1200	40
Cr	23	980	240	980	270	980	310	1480	300	2000	200
Cu	225	980	235	980	265	980	455	2980	140	80	20
La	105	480	100	280	86	180	91	480	27	-	40
Y	18	20	19	20	19	20	21	40	33	-	-
Pb	14	25	16	25	16	25	17	45	12	-	10
Sr	290	600	270	600	270	600	310	600	140	27	350
V	115	150	120	150	125	150	130	230	200	140	100
Zr	710	800	630	800	470	800	370	950	100	30	300
Sc	14	25	16	25	16	25	17	45	24	5	-

NOTE: 1) Fe, Mg, Ca and Ti rates are expressed in percentage (%). The other elements in parts per million (ppm).

2) The table values refer to the raw data (non-transformed)

Through the multiple sequencial lineal regression study (table VII) it was registered in all cases, to the A, B and C horizons that, after the entrance of two variables we do not have too much variance of copper explained (accounted for), i.e., we do not have more quantity of motivated informations. Then, it become viable to establish a hypothesis that the Cu is following the Ni, Cr and Co metals in a strait correlation in the primary and secondary means.

The Ni-Co, Ni-Fe and Ni-Cr associations behaved in a similar way, independently of the lasted horizon, being that the Ni-Co association explained the Cu variability better, reaching the significant reduction rate of 89.69%.

A much stronger correlation between Ni and Cr, Ni and Co, and Co and Cr was respectively pointed out as 0.91, 0.61, and 0.65.

4.2.2.3. Summary of results

1) The variance calculated for the tested elements, mainly Cu, Ni, Cr and Co, show small discrepancies among the 4 levels shown (A, B superior, B inferior and C), and the study of the multiple sequential lineal regression proves only slight variations in the behaviour of several associations of metals that motivated (accounted for) the variability of copper in the levels of the mafic body residual covering.

All the horizons reveal significant anomalies and a strong geochemical contrast.

"A priori", we could therefore recommend the sampling to the A horizon level, considering the factors that imply a certain swiftness in collecting samples and in its low cost. This procedure to start with, is valid and acceptable.

Considering however that the A horizon in the detail scale is susceptible to a constant de-characterization process brought about by the "cannibalism" phenomenon (Lewis Jr et Santos, 1966), with the filling up of mud crocks

REGRESSION VARIABLES	(%) REDUCTION HORIZON A	HORIZON B (higher)	HORIZON B (lower)	HORIZON C
Ni-Co-Cr-Fe-Mn-V	88,69	79,72	87,85	94,39
Ni-Co-Cr-Fe-Mn	88,25	79,43	87,83	94,32
Ni-Co-Cr-Fe-V	87,30	79,60	87,31	92,30
Ni-Co-Cr-Mn-V	86,06	79,17	87,82	92,39
Ni-Co-Fe-Mn-V	88,49	79,60	87,78	94,30
Ni-Cr-Fe-Mn-V	88,08	76,50	84,67	84,76
Co-Cr-Fe-Mn-V	81,75	77,42	79,62	89,58
Ni-Co-Cr-Fe	86,85	79,23	87,17	92,29
Ni-Co-Cr-Mn	88,01	79,14	87,81	92,15
Ni-Co-Cr-V	86,63	79,03	87,26	90,75
Ni-Co-Fe-Mn	88,21	79,11	87,73	94,24
Ni-Co-Fe-V	86,97	79,42	87,20	92,62
Ni-Co-Mn-V	87,97	78,79	87,74	92,04
Ni-Cr-Fe-Mn	87,18	76,50	86,67	84,70
Ni-Cr-Fe-V	85,77	76,44	84,16	85,60
Ni-Cr-Mn-V	82,83	75,98	83,69	82,30
Ni-Fe-Mn-V	87,72	73,05	84,27	81,08
Co-Cr-Fe-Mn	81,34	76,57	78,34	89,53
Co-Cr-Fe-V	81,74	76,58	78,91	89,22
Co-Cr-Mn-V	81,70	76,05	78,70	87,21
Co-Fe-Mn-V	69,67	75,69	70,17	79,98
Cr-Fe-Mn-V	79,76	73,69	74,72	81,69
Ni-Co-Cr	76,57	78,97	87,17	90,73
Ni-Co-Fe	86,74	78,68	86,98	91,56
Ni-Co-Mn	87,95	78,68	87,72	91,53
Ni-Co-V	86,41	78,49	87,15	89,59
Ni-Cr-Fe	85,89	76,44	84,14	84,59
Ni-Cr-Mn	82,65	75,91	83,41	81,23
Ni-Cr-V	81,57	75,55	83,25	83,32
Ni-Fe-Mn	87,11	72,94	84,27	80,74
Ni-Fe-V	86,25	72,57	83,68	80,65
Ni-Mn-V	82,47	71,87	83,12	76,34
Co-Cr-Fe	81,33	75,76	77,85	89,11
Co-Cr-Mn	81,30	75,90	78,07	87,21
Co-Cr-V	81,70	74,72	77,78	87,00
Co-Fe-Mn	66,70	71,34	57,07	77,49
Co-Fe-V	67,13	74,17	64,86	79,56
Co-Mn-V	67,55	70,32	66,73	71,17
Cr-Fe-Mn	78,44	73,59	73,77	81,31
Cr-Fe-V	79,64	72,15	73,56	81,49
Cr-Mn-V	75,23	73,61	74,63	80,51
Fe-Mn-V	55,34	53,00	55,87	52,22
Ni-Co	86,41	78,26	86,98	89,69
Ni-Cr	81,38	75,86	82,71	81,22
Ni-Fe	85,73	72,30	83,58	80,11
Ni-Mn	81,85	70,89	82,54	72,16
Ni-V	81,05	71,50	82,60	76,34
Co-Cr	81,29	74,66	77,40	80,99
Co-Fe	61,12	69,00	48,81	76,56
Co-Mn	66,07	67,69	56,67	68,63
Co-V	61,49	65,13	58,55	71,15
Cr-Fe	78,27	72,11	72,86	81,17
Cr-Mn	75,22	73,41	73,02	79,12
Cr-V	75,13	72,13	73,50	80,05
Fe-Mn	52,36	40,97	34,84	33,10
Fe-V	38,41	32,68	42,06	49,33
Mn-V	52,21	52,98	55,86	49,62
Ni	80,33	70,10	81,51	72,05
Co	58,54	62,37	47,17	68,44
Cr	75,13	72,04	72,32	78,74
Fe	25,31	4,36	10,2[illegible]	30,33
Mn	38,69	37,20	25,42	9,58
V	36,35	32,43	41,94	45,37

Table VII - Multiple sequential lineal regression summary for the target-test.

Dependent variable: Cu
Independent variables: Ni, Co, Cr, Fe, Mn, V

by materials carried on the surface by the torrents of torrential rains, provoking in this way a constant revolting of this level, we can based on these evidences, suggest as perfectly viable the convenience of sampling to the B horizon level, for the geochemical prospecting, in a detailed scale, in residual coverings of similar mafic-ultramafic bodies, in the same geochemical panorama.

Nevertheless it is worth noting taking the above considerations into account that the A horizon constitutes a reasonably good reflex of the anomalous dispersal halo, in which is favored, as a matter of fact, by its own clayey texture (montmorilonithic) that tends to promote the concentration of metals in this clay that shows a high change capacity attracting and wrapping the metalic cations by surface adsorption. The "cannibalism" effect would be therefore of a very local and restricted scope, the A horizon being useful for recognition geochemical surveys, or even semi-detailed, in geologically similar areas.

2) Having in mind the main characteristic of copper mineralizations, of great ubiquity in the River Curaçá Cupriferous District as several former works carried out in regional confirm and considering the evidence obtained in the target-test, where, among the 30 researched metals, only copper showed, effectively, significant anomalous concentrations in the residual soil of mafic rock, the other metals relapsing preferentially, in the background value level quoted by the geochemical literature we may suggest to start with, that the systematic carrying out of additional tests for other metals might raise the costs of a detailed geochemical prospecting sensibly.

The copper analytical determinations, in its own, would supply effective subsidies for the geochemical characterization of fortuites mineralized strips considering the strong correlation pointed out for Cr, Ni, Sc, Mg, V, Co, La, Fe and Mn.

3) The metals secondary dispersal in the target--test is mainly conditioned clastic patterns, and hydromorphic of epigenetic dispersal. The biogenic dispersal patterns also appeared reasonably characterized, specially in the superficial levels (A horizon), where a certain fraction of mineral matter liberated by the organic decay appears retained in the soil at times, causing an increase in the concentrations of some metals as copper, for example.

4) The soluble cations mobilization, specially Cu, Ni and Co, is only partial and very restricted in the residual soil of target-test, what would be, "a priori", an effect of the pH particularly unfavourable conditions, neuter to slightly alkaline, considerably inhibiting the migration of metals. The sudden vertical decrease in the concentration of metals in A, B and C horizons, right from the mineralized rock, makes this conditioning very clear.

The mountmorilonytic clays (A and B horizons) great capacity of exchange (swap) make possible an effective adsorption of cations by the adsorbent complexes, contributing for the diffusion through ascendional capilarity process that mainly occurs in a limited band adjoining and immediately overlay to the mineralized mafic body.

Concerning copper, hydromorphic dispersal patterns sum very limited in terms of sandy spreading being that concerning nickel and mainly, cobalt, such kind of dispersal is wider and more significant, attesting the subtle variations in the physic--chemical behaviour of the metals mentioned.

5) In the target-test, of the 30 researched elements concentration of 17 metals were detected to the method sensibility level. Excluding the anomalous copper concentrations, the other metals fall in the background band mentioned by the geochemical literature for mafic bodies.

6) The background and threshold regionally estimated, fall respectively in the Cu's 40 and 270 ppm bands.

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In relation to such value bands, the purports registered in the Pirulito target-area take, statistically, a significant anomalous character, proving, naturally the associated mineralization. In practice, the Cu's 100 ppm isopleth allows a reasonable delineation of the mafic-ultramafic body of the target-test while the 50 ppm contour gives the configuration of potentially mineralized levels.

7) The clastic configuration of secondary dispersal patterns appears in the target-test clearly delineated. Therefore, even if copper which is a good mobility metal (in pH acid ambient) in the local physic-chemical conditions, seems less mobile, favouring the formation of anomalous concentrations of clastic origin in the mafic residual soil, fact evidenced by granules of oxidated minerals (malachite, azurite, etc.) in the anomalous halos of target soils. The ample lateral variation also, starting from the mineralized centres, showing (sudden) rash contrasts within the small spacings seem to confirm this supposition. As to low mobility metals specially chrome naturally predominates the dispersal clastic and residual character, favouring the formation of discreet concentrations starting from the liberation of background purpots of matrix-rock.

8) A high correlation of Cu with Cr, Ni, Sc, Mg, V, Co and La in the total population of the residual soil is verified (A + B + C horizon). This makes us admit a close association of them in the primary and secondary environments at any rate, a lowering of reduction percentage going from C horizon to the B horizon inferior and superior levels, forming a separation evidence of trace elements therefore avoiding the correlation removal.

It is worth noticing that the montmorilonite resultant of such bodies weathering retains a high purpot of soluble cations, to the A horizon level, presenting a relative increase of reduction percentage in relation with B horizon (superior level).

9) The multiple sequential lineal regression,

taking copper as a dependent variable and other six metals as independent variables, suggests that we do not obtain many more motivated (accounted for) informations after more than two independent variables entrance.

The Ni-Co association is the one which presents better reduction percentage in the four levels tested.

Therefore, it is unnecessary the envolvement of other independent variables, by way of research costs economy.

10) The application of the media-mobile technique to the study of detail in Pirulito, did not present any effective contribution in terms of geochemical interpretation. It only made possible, to the C horizon level to set in a distribution map with reasonable precision, the mafic body smooth contour giving a configuration of the population envolved. Then, to the level of detailing done, the media-mobile technique shows itself unnecessary.

However, this technique has proved to be really effective in regional geochemical recognition in the dispersal halos characterization, which was effectively substantiated in the Target L-2 area, including the Pirulito mafic-ultramafic body. In practical terms, the adoption of a 400m (E-W) mesh per 800m (N-S), with 50% lateral re-coverings made possible good delineation of the anomalous trend regionally detected.

The envolvement of a great number of data, according to the adopted mesh, making the lateral variations of anomalous halos smoother, conditions a better positioning, geographically, the main admitted bands, as potentially favourable to mineralization.

11) The sampling mesh adopted in the Target L-2 semi-detailed prospecting, Sertãozinho Farm, according to a 300m (N-S) per 100m (E-W) net showed effective in defining the anomalous band reflected by the mineralized noritic-pyroxenitic bodies. Characterized, secondarily by copper oxidades impregnation (cuprite, malachite etc.) in Pirulito site.

In more economical terms, however, a 400m (N-S) x 200m (E-W) meshs, would "a priori" be, susceptible to the characterization of eventual anomalous dispersal halos in secondary ambiént, as attested by a research developed in the target--test.

12) The strategic sampling' criterium successfully applied in recoginition and semi-detail geochemical surveys in the River Curaçá Valley showed itself to be of a special efficiency in the target-test survey.

Considering that the systematization of a sampling mesh implus, many times, in an inadequate positioning of the sampling stations in relation with certain mafic bodies sparcely distributed, it became necessary, in function of a visual inspection in situ, to promote an additional sampling, in a very limited character, corresponding to the referred bands. In this case, the population tested acquired an effective geochemical representativeness in qualitative and quantitative terms. Such experience was a well-succeeded one in the Target L-2 geochemical recognition, including the Pirulito deposit, where the strategical sampling supplied very useful subsidies in the anomalous bands definition.

13) The establishing of ideal horizons for the geochemical sampling in soil (A horizon, in regional scale and B horizon, in detail scale) and the analyses reduction to, preferentially, a single metal (total copper) are data that may be utilized in the development of future prospecting campaigns, maintaining the method efficiency and a high economy of costs.

14) It was evident once more, that in residual soil areas of mafic-ultramafic covering an evaluation through geochemical prospecting provides very precise and efficient informations about the suboutcropping, making the method indispensable to copper prospecting within the regional geochemical landscape.

4.3. Geophysics

In this chapter a concise comment on the geophysical methods utilized and/or tested in the Curaçá Valley, is presented. From the orientative studies performed and the systematic employment of these methods, conclusions were drawn on the "modus operandi" and the interpretation techniques, that were minutely reported in another volume of this report.

4.3.1. Induced Polarization

The induced polarization electrical method is the only geophysical method, among those investigated, applied for the conducting bodies characterization, related to the River Curaçá Valley. For this reason, the method must be utilized since the semi-detailed phase, mainly if the Targets selected for the research are geologically located in areas of great prospective interest, defined in function of mineralization controls.

Within this context, the method was routinally utilized in the Copper Project, since 1972, after the feasibility pioneer tests, performed by Hales et Chamon in 1971. Such tests were performed in the Lagoa da Mina, Surubim and Senhor de Lisboa bodies. Due to the concordance presence in the bodies studied, the authors concluded by the technical-economical feasibility of the method application.

Through the IP continuous utilization, the Copper Project team was gradually becoming familiar with the results obtained and through experiences with different arrangements and spacing managed to rationalize the operational costs through a productivity increase.

4.3.1.1. Instrumentation and operational technique

The equipment employed was from the Geoscience Cambridge Mass., manufactured by the Electro-Technical Labs (ETL), composed of a T-2800 model transmitting unit and a GEOMITE (TM) R 401/S receiving unit.

The frequency band varies from 0,05 to 10 cps. It was selected in the routine, the 0,3 and 3,0 cps frequency pair, as the best for operations.

The IP team, independent of arrangement, was constituted of a geophysicist, a medium-level technician and field auxiliaries being five for the polo-dipolo and Schlumberger arrangements and three for the dipolo-dipolo arrangement. Normally, the geophysicist operated the receiver and the medium level technician operated the transmitter.

The more used current electrodes were those of vion and those of potential, type "porous pot" preferably; however, the geoelectrical conditions of the River Curaçá Valley, allowed the utilization of stainless steel electrodes without harming the readings.

The experiences with the spacings and different arrangements showed that, because the semi-detail phase envolves relatively extensive areas, the IP must be employed according the polo-dipolo device, which affers advantages over the dipolo-dipolo arrangement concerning a faster operation and consequent reduction of research costs, and presents more precise technical information than the Schlumberger assymmetrical arrangement. In this phase the method must be employed according to a (300 x 50)m or (150 x 50)m mesh in four investigation levels, that reach a 112,5m depth approximately, in the 4^{th} level.

Illustration 10 (*) shows the polo-dipolo arrangement device, which consists in fixing the current electrode theorically in the infinite and move another one along the profile (outline) surveyed.

In the detail phase the dipolo-dipolo arrangement presents more detailed technical information, suggesting its use according to a (75 x 25)m mesh in six levels of investigation reaching, approximately 87.5m of depth in the 6^{th} level.

Illustrations 12 and 13 illustrate the dipolo-dipolo arrangement.

(*) For illustrations 10, 11, 12 and 13 see annexed page $\underline{a}_1$ and $\underline{a}_2$

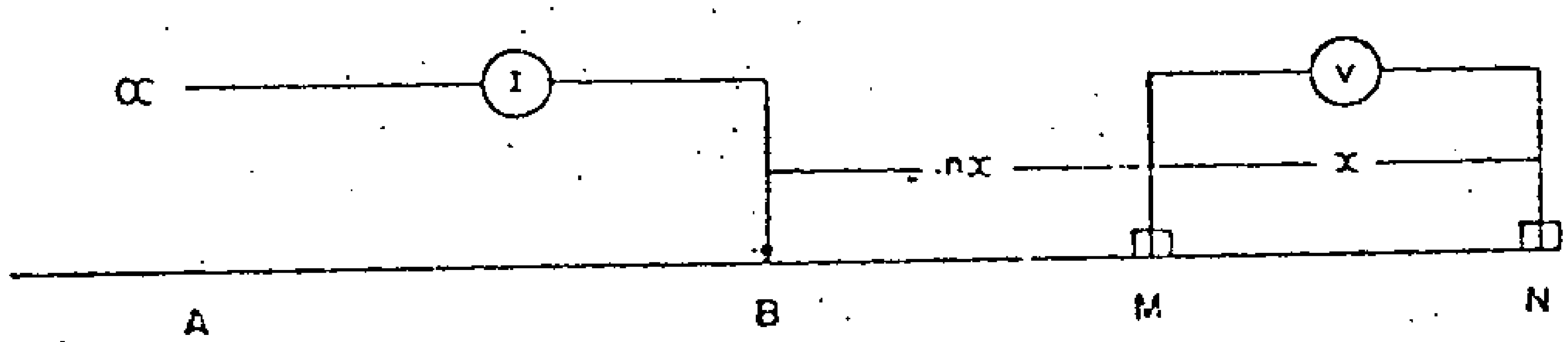
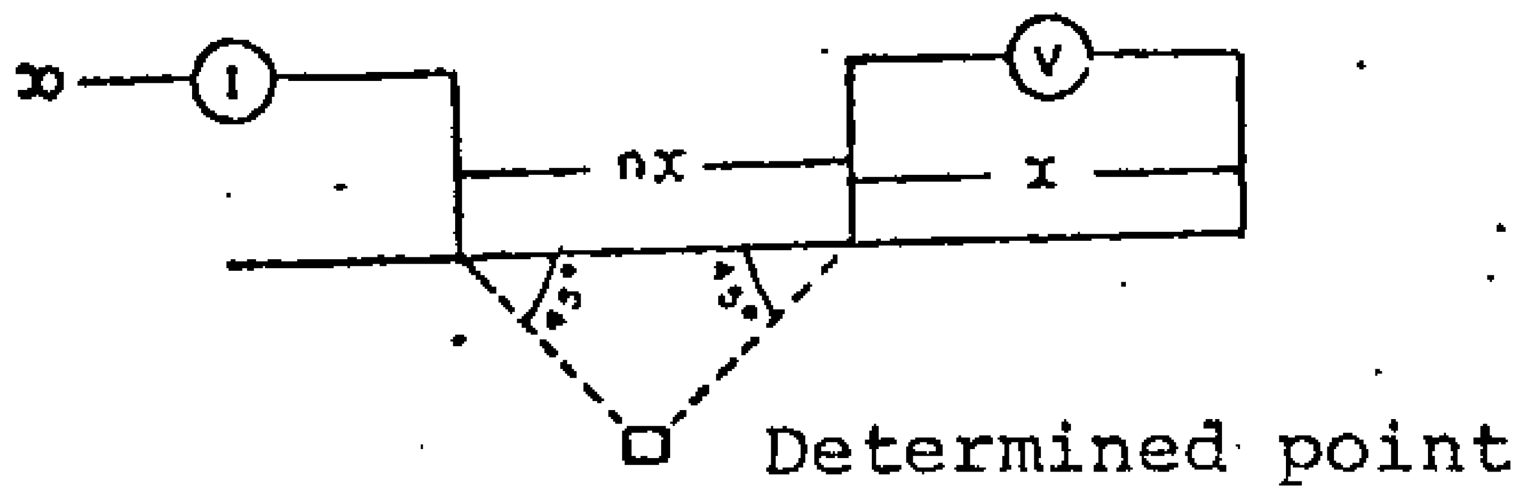


Illustration 10 - Illustration of the polo-dipolo arrangement device



Geometrical factor formula

$$Kn = 2\pi xn\ (n + 1)$$

Illustration 11 - Data plotting scheme of polo-dipolo arrangement utilized in the Copper Project

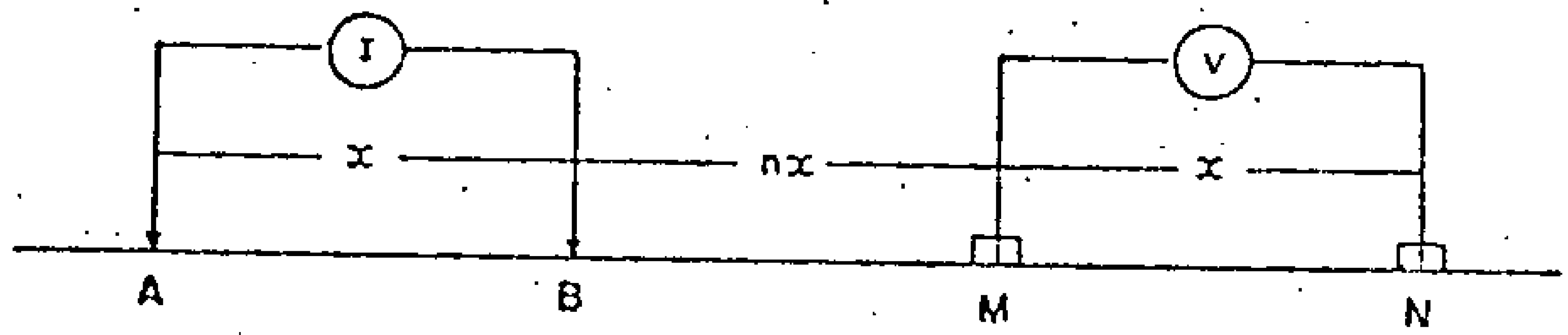
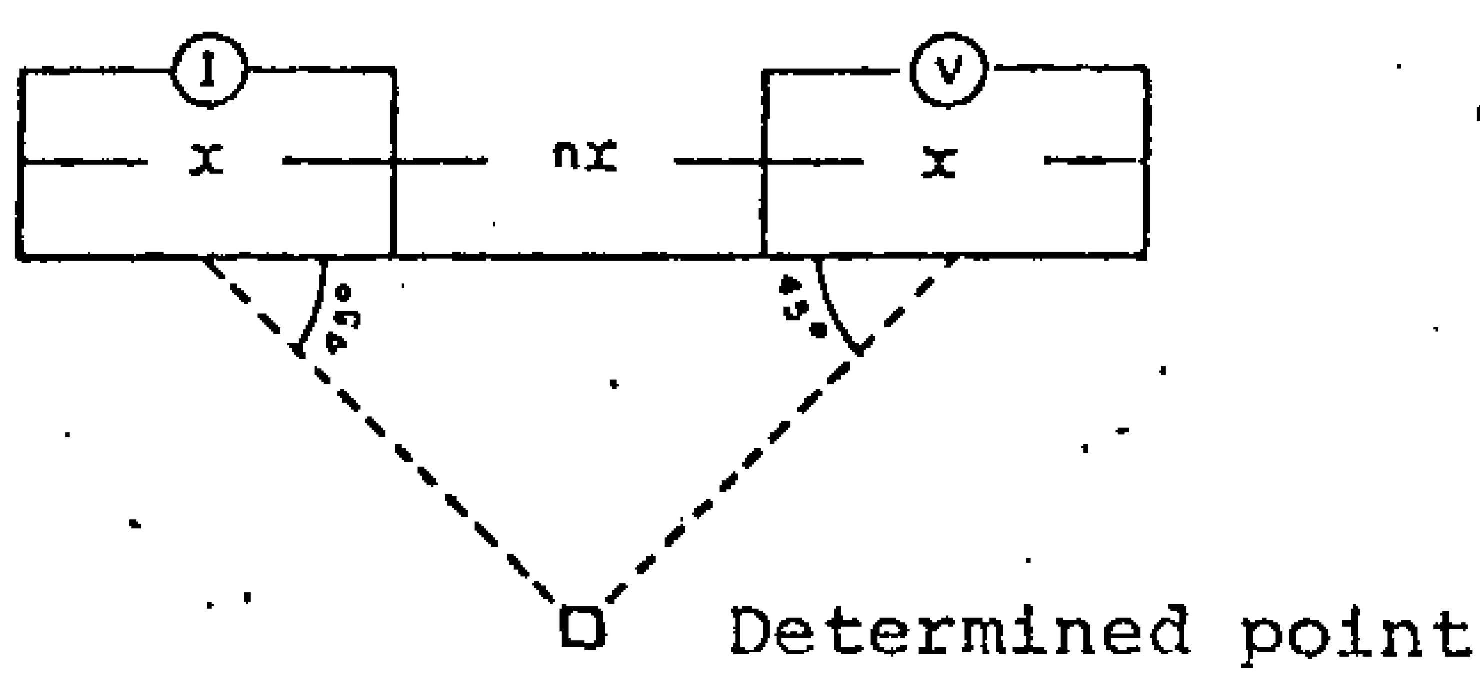


Illustration 12 - Illustration of dipolo-dipolo arrangement device



Geometrical factor formula

$$Kn = \pi\ nx\ (n + 1)\ (n + 2)$$

Illustration 13 - Data plotting scheme of dipolo-dipolo arrangement utilized in the Copper Project.

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4.3.1.2. Elements used in the interpretation

With the data obtained in each line three profiles were traced, corresponding, respectively, to (ρa) Apparent Resistivity, (PFE) Frequency Percentage Effect, and (MCF) Metallic Carriage Factor. Based on these profiles, in each prospected area, isovalue maps were made for each of the parameters mentioned, in different depth levels.

In the comparative study of curves, in profiles as in maps, the influences that suggested false anomalies or disguised true anomalies were taken in consideration, emphasizing among these influences the crack zones filled up with conveying material, as graphite, magnitite, saline solutions, etc.

The anomalous values were considered as relative values, for each prospected area, in function of the acquired experience. In the Santa Fé body, for example, owing to the granitization process the PFE anomalous values are low, in an 0.5% order. In the Lagoa da Mina and Pirulito bodies these values are located around 1.0%, while in the Surubim body (picture 14), the PFE anomalous values threshold rises to 2.0% reaching till 5.0%.

In areas in which the graphite presence is striking the PFE values are high, reaching till 10.0%. Joining these values to the graphite low resistivity we have a MCF much above the media found in mineralized bodies with sulphides, which permits the characterization of the anomaly caused by graphite.

In alluvium covered zones, the values are characterized by a low PFE and low resistivity. The low resistivity which is given mainly due to the presence of saline solutions in the alluviums, causes an anomalous value for the MCF characterizing a false anomaly.

In the interpretation of profiles and maps, in the different depth levels, taking the cited interferences and others, of secondary order into account, as soil humidity and conductive covering, we can define the really significant anomalies, associated with mineralized bodied with sulphides.

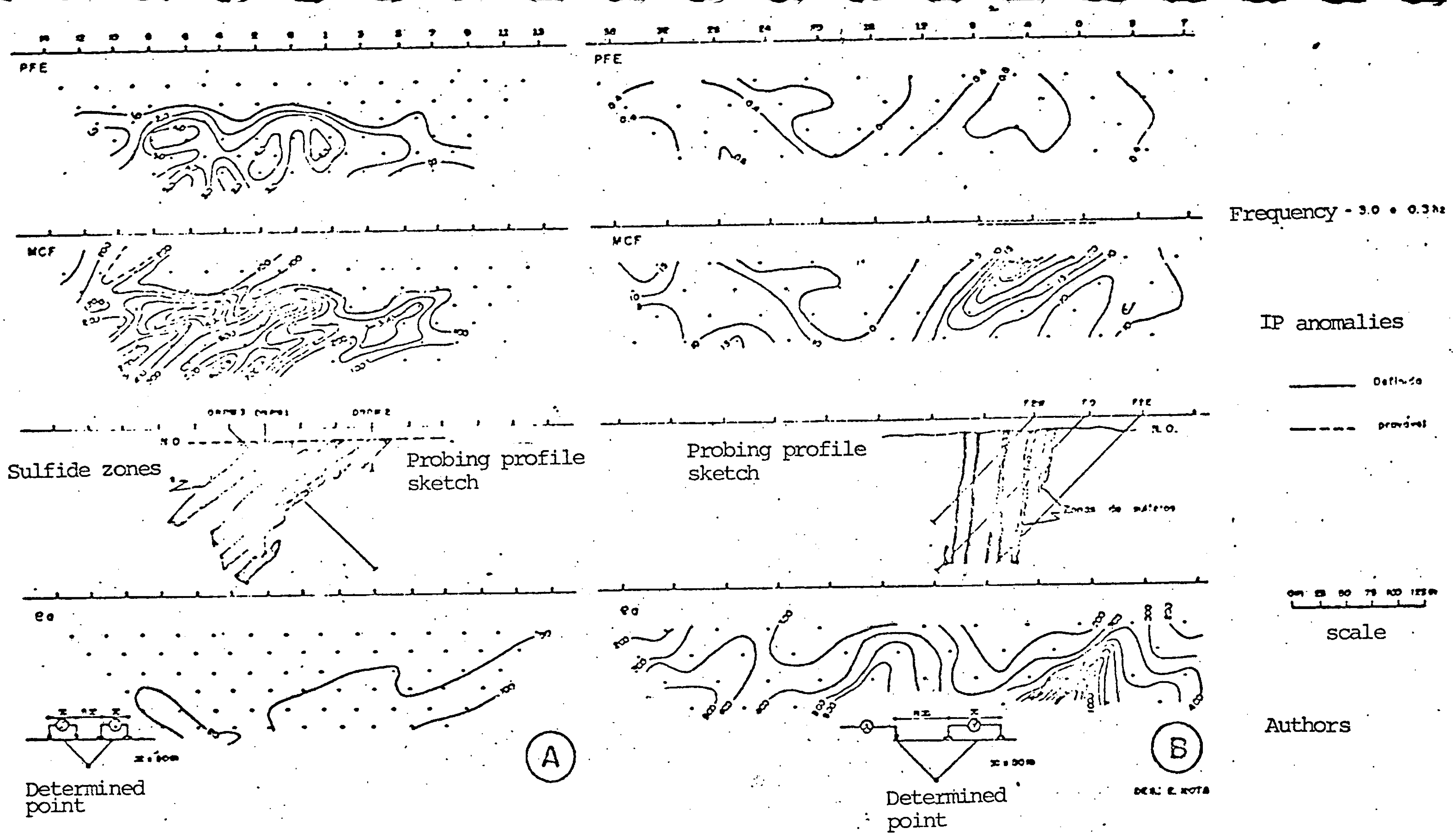

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Illustration 14 - IP experimental profiles with dipolo-dipolo arrangement in the Surubim (A) Body and the polo-dipolo arrengement in the Lagoa da Mina (B) formation.

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4.3.1.3. Limitations and production

The Schlumberger arrangement modified does not give quantitative data on the geological body investigated as depths,dip slopes etc. Notebook calculations are hard and take a long time. In the surface, the interpretation may disguise certain depth effects. For these reasons the polo-dipolo and dipolo-dipolo arrangements are recommended for the routine.

As polo-dipolo limitations, we may mention the fact that they can superficially disguise desired depth effects and demand a numerous team in the field. As to the dipolo-dipolo, it is operationally very slow.

The production is influenced by several factors as: the trail's condition, the equipment operation, the wires, the team's good training level and a good communication between the operators through the use of "Walkie-talkies".

4.3.1.4. Summary of results

The PFE values obtained in profiles carried out on several sulphide deposits testify that 1.0% and 5.0% values indicate the presence of disseminated sulphides in mafic-ultramafic bodies. The low PFE values, around 1%, obtained in the Lagoa da Mina and Pirulito deposits are probably influenced by the Granitization process that occur more intensily, the referred areas. However, in the Surubim deposit, where granitization is less intense, the PFE obtained goes till 5%.

There are other geological phenomena that interfere in the induced polarization surveys and that must be carefully considered in the method interpretation, that is to say, that the values of PFE and MCF are relative, and can never be judged in an absolute way. Therefore, the crackings are normally conductive structures that produce a PFE superior to 5%. The alluvial deposits are characterized by low resistivities and low values of PFE. Graphite, may be identified through high PFE values and isonomaly curves normally complex, when graphite spreads itself

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on the surface.

4.3.2. Magnetometry

Two fundamental objectives motivated the introduction of the magnetometrical technique in the geophysics prospecting of the River Curaçá Valley: (1) to help, on the whole, the geological interpretation specially in the identification of lineaments due to cracks or fracture zones and the delineation of mafic-ultramafic bodies, chiefly those non-outcropping; (2) to eliminate the false anomalies of induced polarization owing to graphite present, fractured zones etc.

The method was first employed (tested) utilizing the vertical component measure with ASKANIA'S Gfz and Gfs equipment, the only one available at that time, in the Angico's farm area, in a pionneer work in the River Curaçá Valley done under the supervision of Frederick Hales, a DNPM's geophysicist, in 1969. However the systematic surveyings were carried out by the Copper Project, with the total component utilization, measured through a Proton's magnetometer.

4.3.2.1. Instrumentation and operational technique

The instrument utilized in the research works was a Proton magnetometer, model G-806, made by Geometrics, with a 1 (one) gamma precision.

Only two people are necessary to operate field works. This fact together with an instrumental portability and the digitalization of readings, grant a low operational cost to the method.

4.3.2.2. Elements used in the interpretation

Form of anomalies - The measurings resultant anomalies on mafic--ultramafic bodies in the River Curaçá Valley, possess typical characters of curves to the proximities of the magnetic equator;

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i.e., they present two flanks of maxima relatives associated to a minimum relative, of normally bigger amplitude. Picture 15 shows the general form of curves, when the theoretical model is a sphere:

(For the illustration see annexed page b)

Corrections - As the instrument has a temperature compensating system, the field measurement were corrected only for the diurnal variation, utilizing the expression:

C = d. t/T, where:

C = correction, i.e., the value to be added or diminished to the registered value, in gammas;

t = calculated time interval between the reading of an X station and the initial station reading, in minutes;

T = total time spent to return to the initial base station, in minutes; and

d = variation in gammas, of reading in the base station, in the beginning and end of a T time interval.

Residual Determination - The basic problem for a geological interpretation of a magnetic isoanomalous map is the distinction between the effects due to great bodies and deeper structures inside the terrestrial crust and denominated REGIONAL effect, effects due to flatter and smaller bodies and structures, which, however, are exactly the objectives of interest for mineral research and called of RESIDUAL effect.

In the project works three residual types were utilized:

1) The center-point method;
2) An analytical method of statistic reduction of values to a reference level equal to zero; and

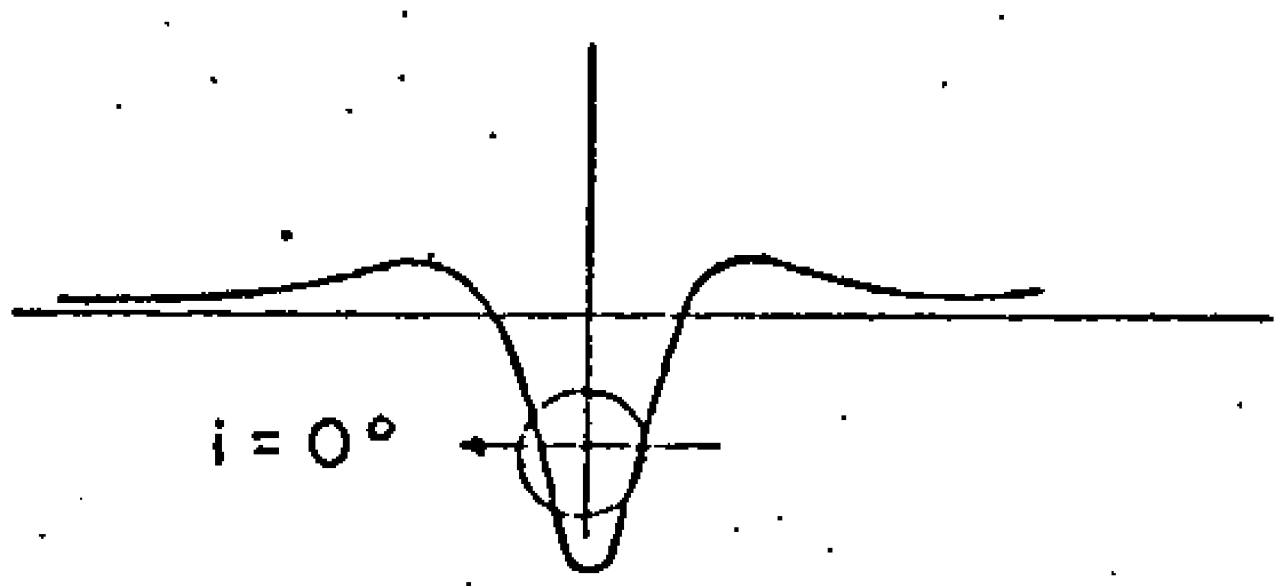

Illustration 15 - Magnetic Anomaly pattern of total intensity, in the magnetic equator proximity, for a sphere theoretical model.

3) A method that utilizes a computer based on polynomials (NST - Numerical Surface Techniques and Contour Map Plotting)

A special study was carried out in S-12 Target, aiming to compare the residuals obtained by the second and third methods.

The main conclusives drawn from this special study were the following:

a) From the geological point of view there are no important differences between the residual maps; the interpreter can utilize any residual among the ones tested;

b) More than two maps per area are unnecessary (Total Intensity and Residual Maps) either being contoured by hand or with the help of a computer; and

c) The contoured maps by computer present the inconvenience of rounding off and dividing anomalies, effects which would be avoided with the manual sketch of curves. This tendency is taken into a account for any 'GRID' that is utilized.

Determination of magnetic susceptibility (K) - 41 samples were utilized for the magnetic susceptibility measures.

Tables VIII and IX show the data obtained and picture 16 summarizes the results, showing through the frequency curve the six different groups in which were divided the region rocks, concerning the magnetic susceptibility.

The more important conclusions were the following:

a) The mineralizations only start to show in the second group, the magnetic susceptibility medium value of which

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Nº	LITHOLOGY	HOLE	Depth (m)	K_s C.G.S.x10^{-6}
1	Diorite	F 2	60	46
2	Mineralized melanorite	F 2	86	2.552
3	Diorite augite	F 2	116	2.527
4	Mineralized norite	F 0	196	1.615
5	gneiss biotite	1JO-1-BA	66	161
6	Gneiss feldspar quartz	1CA-11-BA	121	25
7	Amphibolite	1CA-16-BA	32	122
8	Gneiss biotite	1CA-16-BA	41	0
9	Norite	1CA-19-BA	91	190
10	Mineralized norite	1CA-19-BA	92	755
11	Amphibolite	1CA-19-BA	94	3.145
12	Gneiss biotite	1CA-27-BA	168	0
13	Amphibolite	1CA-33-BA	42	415
14	Gneiss feldspar quartz	1CA-33-BA	43	102
15	Rosy granite	1CA-33-BA	51	36
16	Amphibolite	1CA-33-CA	115	117
17	Pyroxenite biotite	1CA-33-BA	127	7.672
18	Amphibolite	1CA-33-BA	134	5.258
19	Mineralized pyroxenite biotite	1CA-33-BA	149	7.785
20	Rosy granite	1CA-33-BA	245	583
21	Rosy granite	1CA-34-BA	107	0
22	Rosy granite	1CA-34-BA	138	287
23	Amphibolite	1CA-34-BA	140	1.703
24	Gneiss feldspar quartz	1CA-34-BA	163	32
25	Gneiss biotite	1CA-35-BA	63	1.689
26	Mineralized pyroxenite biotite	1CA-35-BA	67	6.528
27	Hornblend gabbro	1CA-37-BA	49	3.174
28	Clinopyroxenic diorite	1CA-37-BA	53	41
29	Orthopyroxenic diorite	1CA-37-BA	82	2.556
30	Orthopyroxenic meladiorite	1CA-37-BA	83	2.556
31	" "	1CA-38-BA	83	2.221
32	Gneiss biotite	1CA-38-BA	116	0
33	Orthopyroxenic diorite	1CA-40-BA	161	2.962
34	Mineralized hornblend pyroxenite biotite	1CA-40-BA	250	5.511
35	Gneiss hornblend biotite	1CA-40-BA	345	0

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Cont.

Nº	LITHOLOGY	HOLE	Depth (m)	K_s C.G.S.x10^{-6}
36	Mineralized pyroxenite biotite	1CA-40-BA	354	4.603
37	Pyroxene diorite	1CA-40-BA	368	4.889
38	Pyroxene leucodiorite	1CA-40-BA	380	946
39	Gneiss biotite	1CA-40-BA	499	769
40	Gneiss feldspar quartz	1CA-45-BA	292	1.121
41	Rosy granite	1CA-45-BA	309	865

Table VIII - Chart of magnetic susceptibility from diferrent lithological types of the Cucurá Valley.

GROUPS	LITHOLOGY	GROUP (%)	MAGNETIC SUSCEPTIBILITY (X 10^{-6} cgs)			
			Samples (numbers)	Minimum value	Maximum value	Medium value
1st	Gneiss Granite Diotite Norite Amphibolite	47 17 11 7 17	17	0	375	125
2nd	Granite Gneiss Pyroxenite Mineralized norite	33,5 33,5 16,5 16,5	6	500	1.000	810
4th	Gneiss Amphibolite Norite Mineralized	33,3 33,3 33,3	3	1.625	1.750	1.690
4th	Orthopyxenite meladiorite Anorite meladiorite Orthopyroxene diorite Hornblend gabbro Amphibolite Mineralized norite	25 12,5 25 12,5 12,5 12,5	8	2.250	4.250	2.750
5th	Mineralized pyroxenite Piroxenite diorite Amphibolite Biotite pyroxenite	25 25 25 25	4	4.500	5.125	5.050
	Mineralized pyroxenite	100	3	-	-	6.500

Table IX - Groups of different magnetic susceptibilities found for the lithological types of the Curaçá Valley

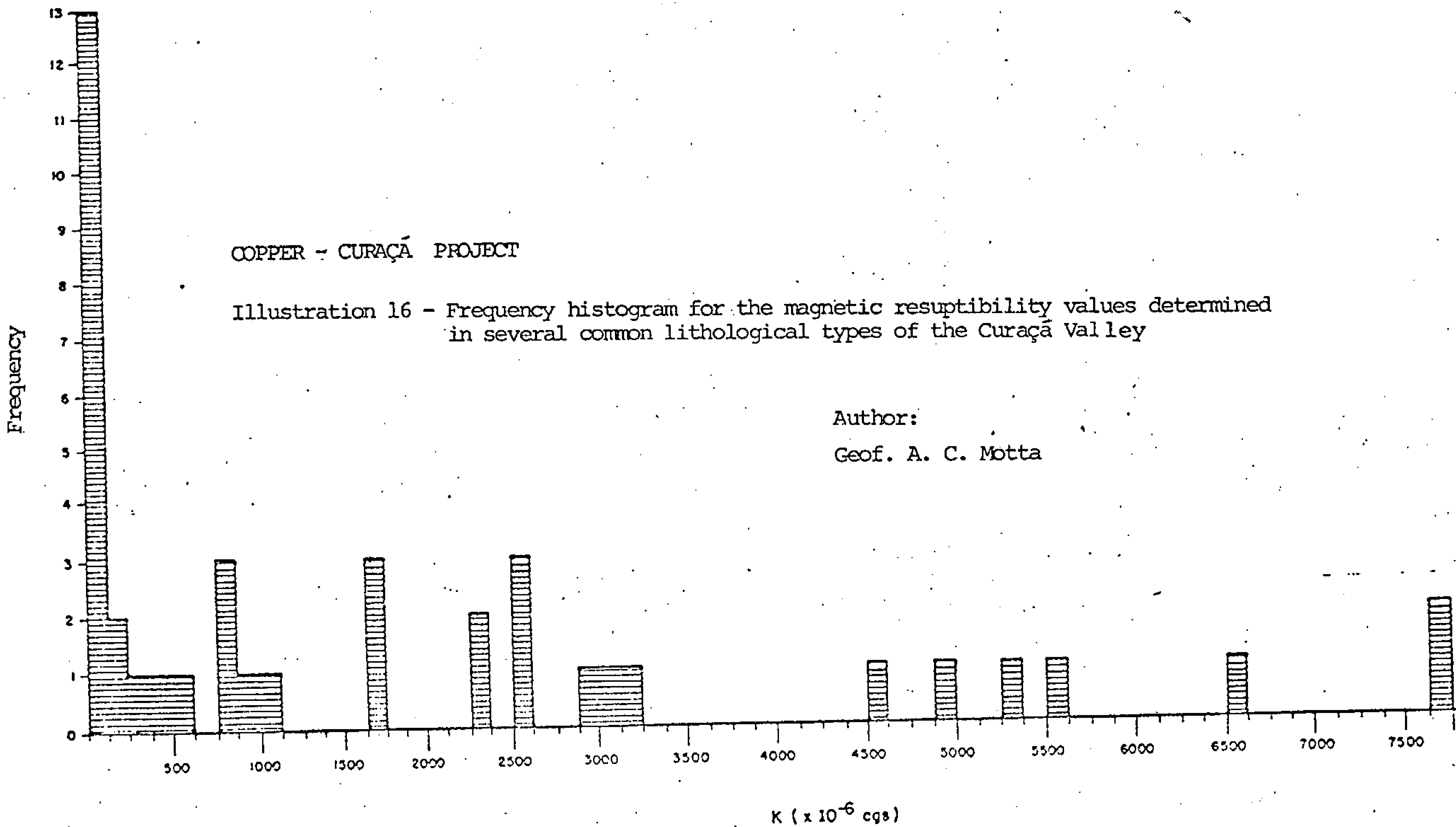

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Illustration 16 - Frequency histogram for the magnetic resuptibility values determined in several common lithological types of the Curaçá Valley

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is of an 810 x 10^{-6} CGS order;

b) The pyroxenites which only appear in the second group too, represent the lithological type where the magnetic susceptibility values are more elevated, chiefly when they are mineralized.

Similar conclusions to the previous two were found by Motta (1974).

c) Althrough it is necessary a statistical study with a great number of samples, and mainly establishing the connection between the sulphides purport and the magnetic susceptibility value, we can affirm that this relation is directly proportional. Such fact, supported by geological observations and witness discription, opens the perspective of utilizing the intensities of magnetic anomalies as an indicative factor of mineralization in the mafic-ultramafic rocks.

4.3.2.3. Limitations and production

The method limitation in the area, common to the other potential methods in any geological situation, is the known ambiguity. This normal fact does not allow accurate quantitative calculations concerning depth, width and diving of bodies.

The daily production in the detail phase is of three to four kilometres order, practically doubling in the semi--detail. Table X shows the production chart for the magnetic method.

(This table is in the following page)

4.3.2.4. Summary of results

The studies performed with magnetometry confirmed the method efficiency in indicating the mafic-ultramafic bodies, in demarcating the cracks and delimiting the contacts of "magnetic

Phases	Profile	Stations Spacing	Number of Stations	Reading time + displacement	Total
Semi - detail	1.000m	50m	20	2 min.	40min.
Detail	500m	25m	20	2 min.	40min.

Table X - Medium production of magnetometry works in the Curaçá Valley.

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unities", information which is utilized to help the geological mapping and the interpretation of other geophysical methods, the IP specially.

On the other hand, the existence of a relation between the increase of sulphide purport in rock and its magnetic susceptibility (K), what foresees the possibility of the method utilization, in the mafic-ultramafic bodies analysis more promising under the sulphides mineralization point of view. Thus, it was seen that the mineralizations frequently appear in a group of rocks the "K" medium value of which is equal or more than 810×10^{-6} CGS. "K"'s greater values are found in the mineralized pyroxenites and are superior to 5.000×10^{-6} CGS.

Facing the great number of technical information that the method provides and the low operational cost, we suggest its utilization in any phase of prospecting.

4.3.3. Gravimetry

The works carried out by means of gravimetric methods aimed check the general performance of such technique and the possibility of using gravimetric methods for copper research.

4.3.3.1. Equipment and operational techniques

A Worden gravimeter, model Projector, manufactured by Atlas Instruments. Precision: ± 0.01 miligal.

The first survey was made in the Angico farm area in the Curaçá Valley. This survey covered an area of 150 hectares. These areas are in flat land and in the direction EAST/WEST the gradient for 1.8Km is 30m.

The area was measured according to the following criteria:

Gravimetry - A polygon with first order points having two readings was established. The lines that form these secondary points start from and come back to these first order points.

The measurement process made with the gravimeter is illustrated in figure 17.

All the measurements, both from first and second orders obeyed a maximum time of 120 minutes for Drift or Lance alterations. 120 minutes was the time interval between the first reading and the last one. The last reading was made only upon returning to the initial stage. The tide correction was not necessary due to the use of the 120 minute interval.

Illustration 18 shows a mapping of the closing, adjustment and distribution of the gravimetric errors obtained at Angico farm.

Altimetry - A precision level was used to level the first and secondary stations. The operational system was very similar to the gravimetric one. The polygons were closed and the errors analysed. The distributions of errors in this case is proportional to the length of the lines. In the gravimetric process, the errors were proportional to the time.

The points of first order were leveled and counterleveled. No readings different than $\pm$ 0.04 meters were permitted.

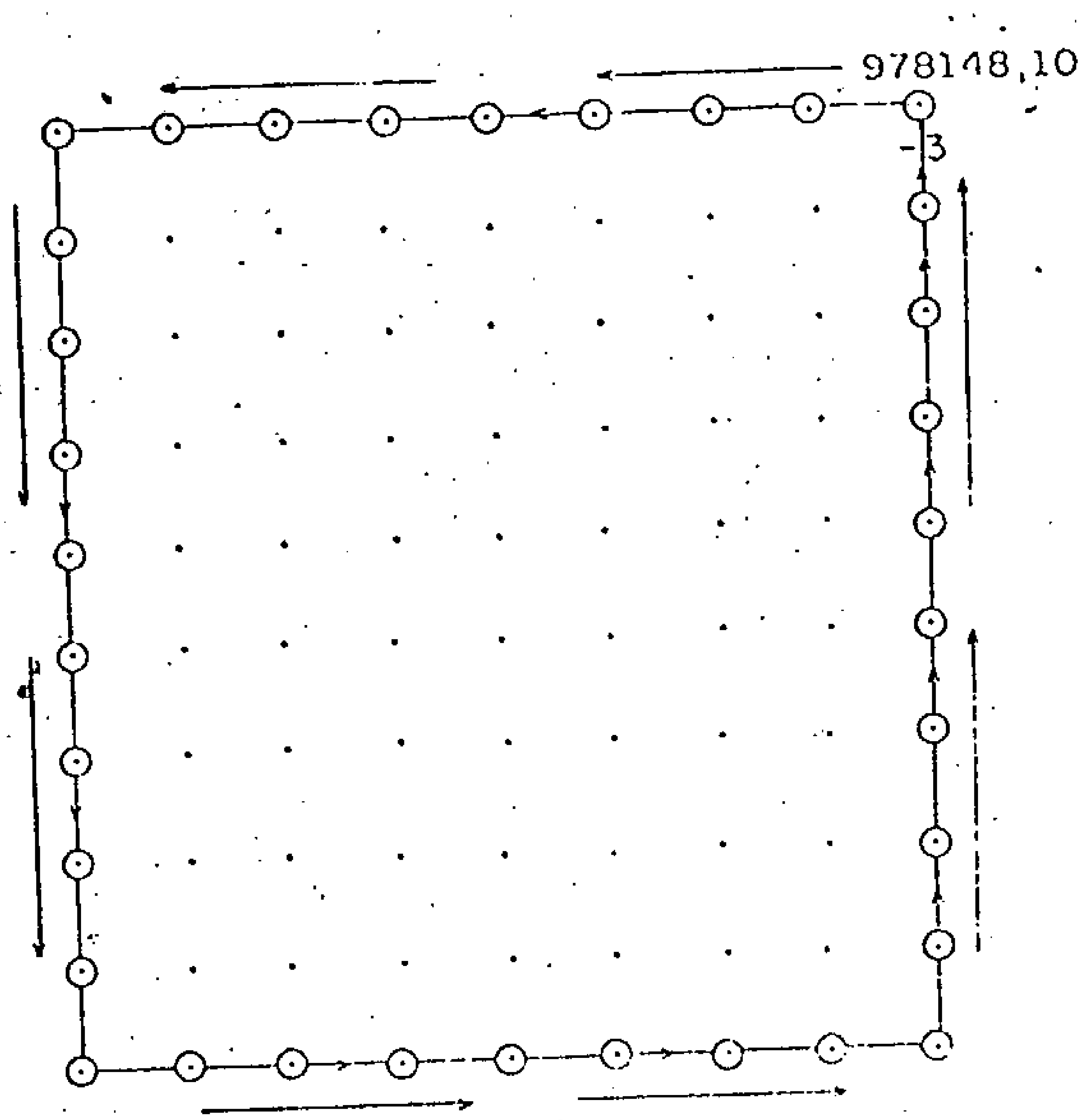
Illustration 19 shows a map of closing, ajustment and distribution of altimetric errors obtained at Angico farm.

Planimetry - Measuring theodolites were used to orientate the directions. The distances between the stations were measured with a tape measure.

4.3.3.2. Elements used in the interpretation

Bouguer results - The calculation used to arrive at Bouguer values were made according to the following formula:

Bouguer anomaly = AB correction + ground correction (considered non existent) + measured gravity - theoretic gravity



LEGEND

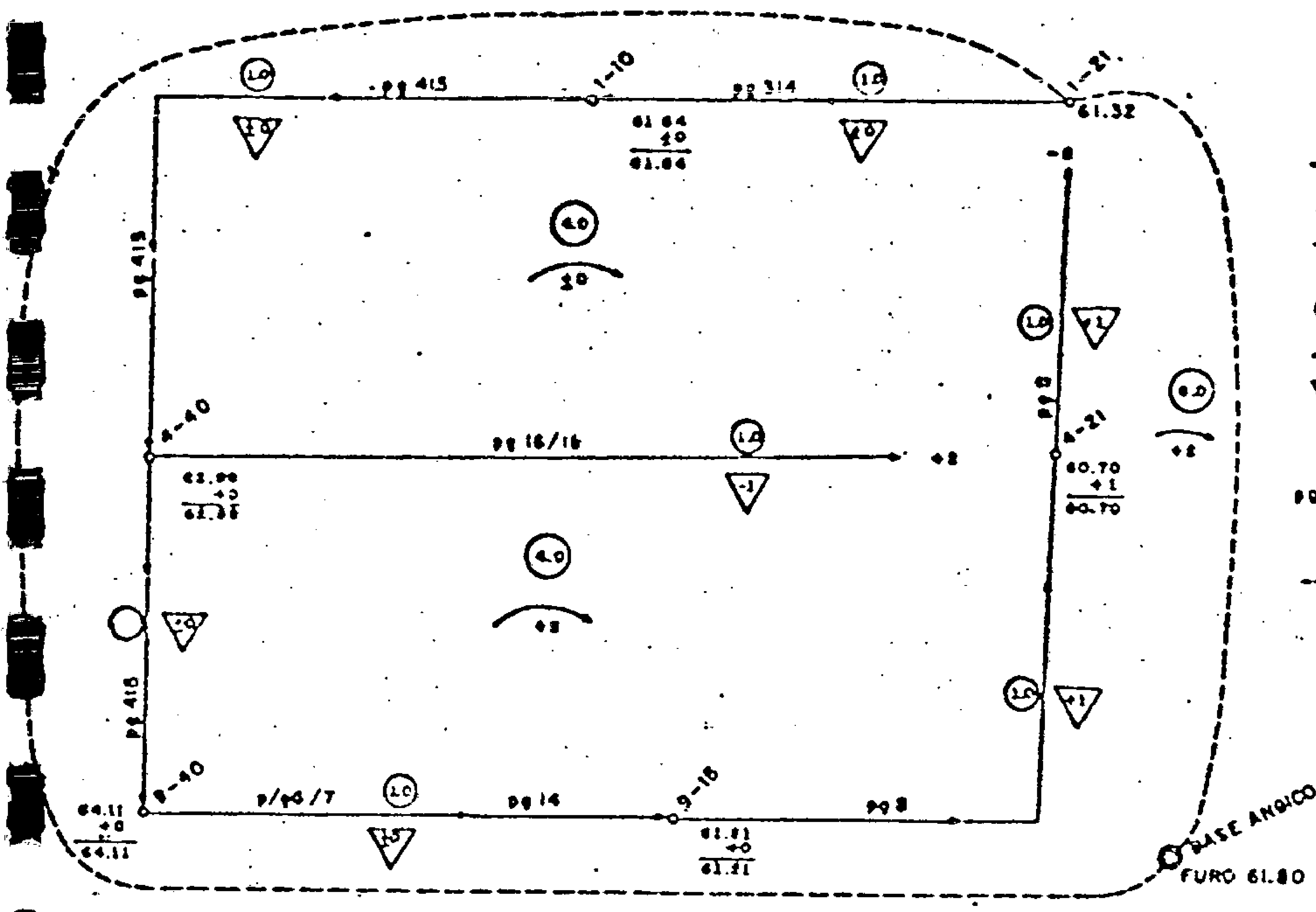
⊙ = 1st Order Station

. = Snd Order Station

→ = Trajetory direction 978148,10: iniciated station gravimetric value (exit) of the polygonal

-3 = Closing error value for the arriving value of 978148,10

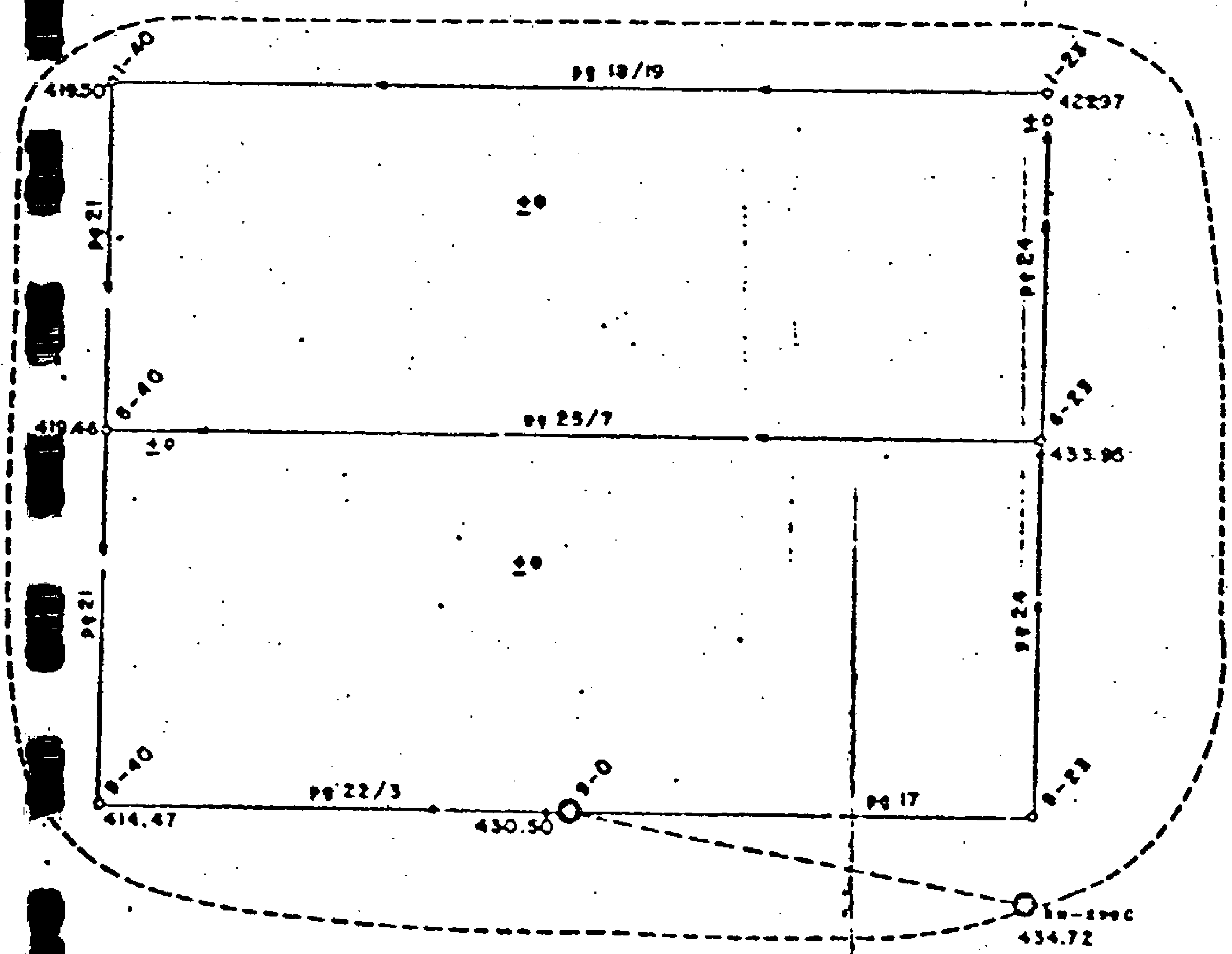
Illustration 17 - Gravimetric measures of polygon boundering at Angico form area



LEGEND

- 1st order station
- Trajetory direction
- Closing error
- Inicial value
- Correction
- Final value
- Polygon total weigth
- Closing error of the polygon
- Poligon total weight
- Drift weight
- Profile page
- Base
- Base connection

Illustration 18 - The map of the closing, ajustment and distribution of gravimetric errors for the test area at Lagoa da Mina (1st order ponts)



- First order station
- Trajetory direction
- Closing error
- Final value for absolute altitude (meters)
- Closing error or the polygon
- RM (Base)
- Base connection

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Author

Geophysical A. C. Motta

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Illustration 19 - The map of the closing, ajustment and distribution of altimetric errors for the test area at Lagoa da Mina (1st order points.

Regional Separation - residual - Residual and Second Derivate maps were made from the Bouguer map.

Positive residual anomaly - As the mafic-ultramafic formations present a higher density than the embedded rocks, the profiles of such formations present a 'mas excess' characterized by positive values, as shown in the illustration bellow:

(This illustration is in the annexed page)

Gravimetric model of the formation - Geophysically speaking, the geologic formations were simplified into geometric regular figures. For instance, the Lagoa da Mina formation was transformed into a vertical cylinder having its horizontal measure smaller than the vertical one, which was attributed to tend to infinite (Illustration 21). The formule used was:

$g = K.f\ (X/Z)$, being:

$K = 6,39 \sigma R^2\ Z$ and $f(X/Z) = (1 + X^2/Z^2)^{-\frac{1}{2}}$.

The adopted were: $R = 45m$; $Z \simeq 30,5m$; $g_{max} = 0,22$ mgal and $\sigma = 0,16\ g/cm^3$.

4.3.3.3. Limitations and Production

Taking into consideration the relatively high costs of this method, its use is advisible for the detailing or semi--detailing stages, when the other routine and less expensive methods may present doubtful geologic interpretations. In these cases, this method may be used alongside previously selected profiles.

Other specific situations may also call for the use of this method. However such method has to be combined with other geophysic methods.

On the other hand the production may be considered intense due to the regular topography that requires no ground

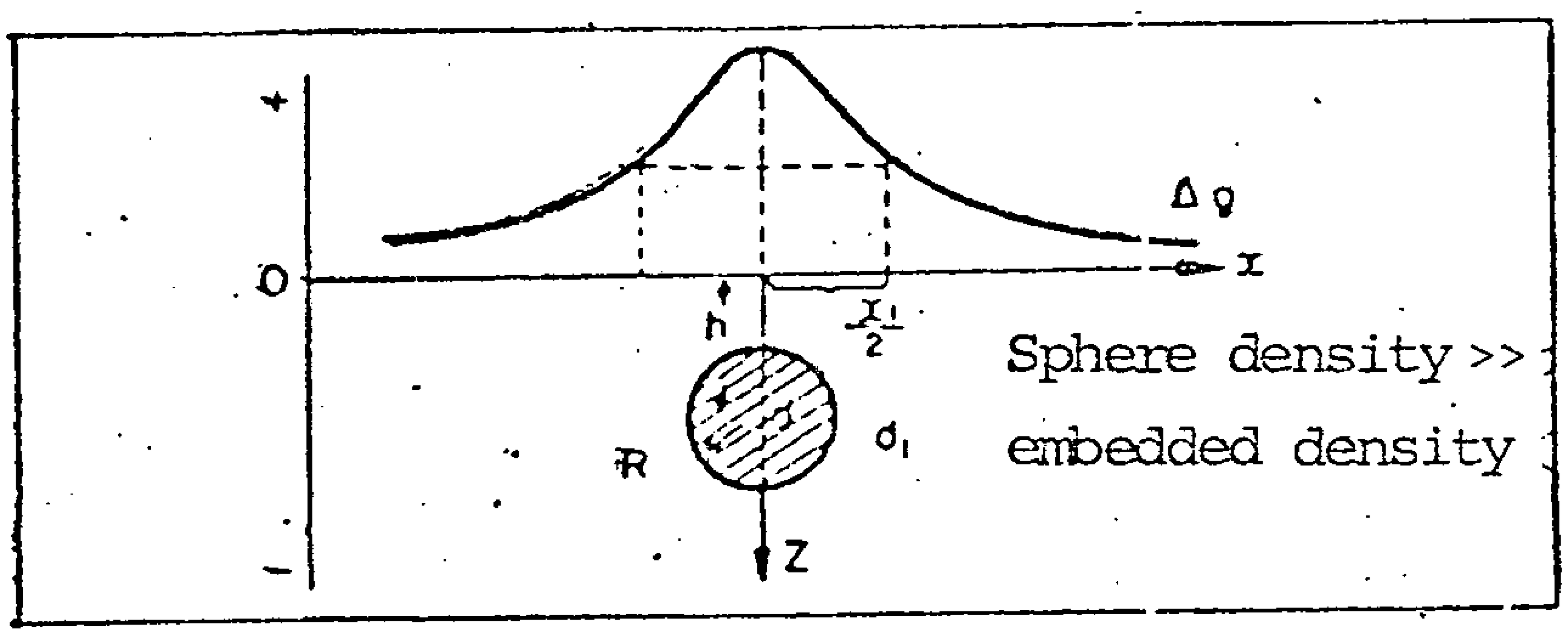
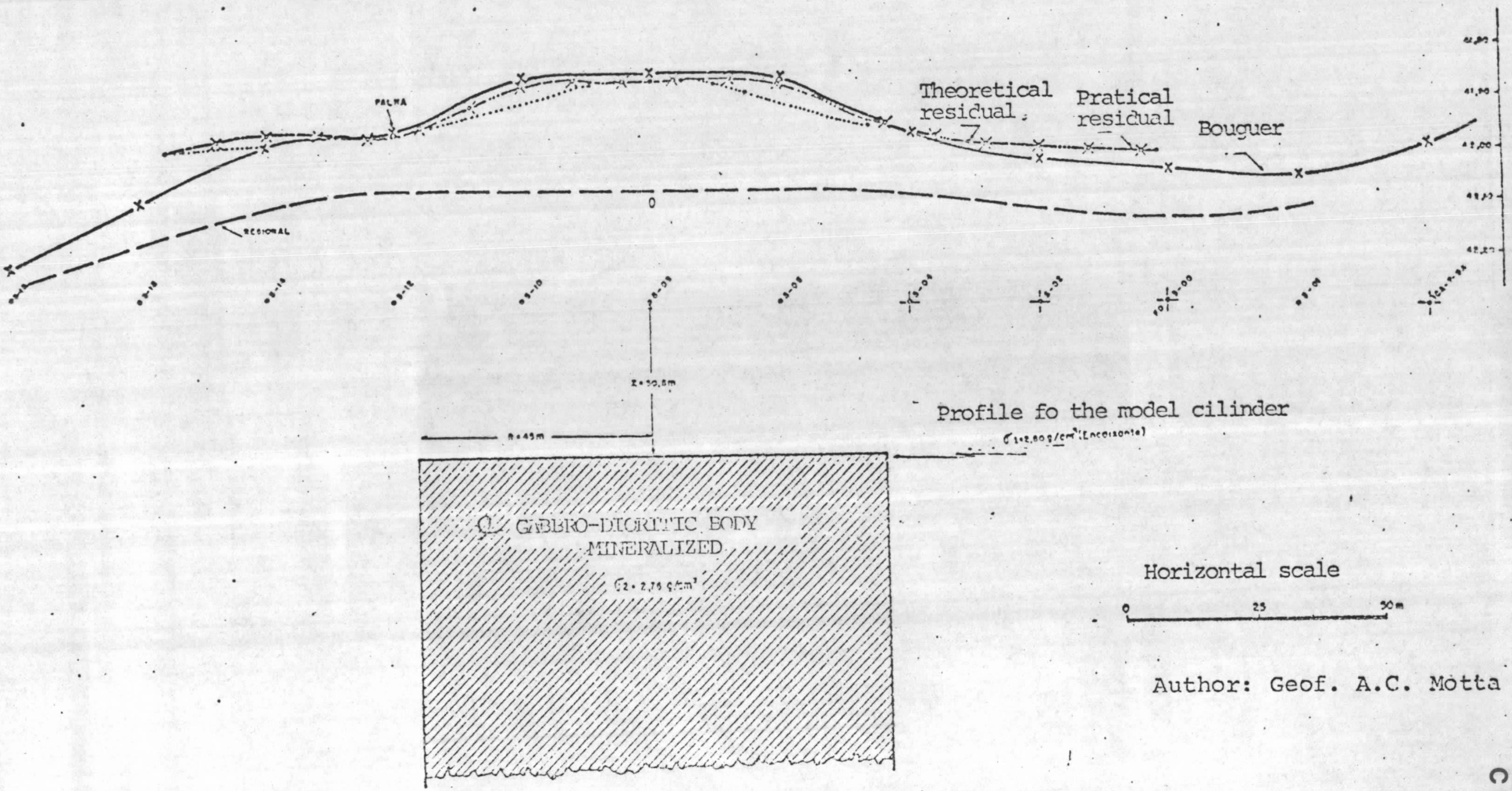


Illustration 20 - Shows a positive gravimetric anomaly which is related to a spheric body.



Author: Geof. A.C. Motta

Illustration 21 - Gravimetric model of Lagoa da Mina Formation correction helping, therefore, both the field and office works.

The following illustration shows the average production obtained in the surveys:

(This table is in the annexed page)

4.3.3.4. A summary of the results

The gravimetric method doesn't usually indicate the existence of disseminated sulphite. From all tested methods, only the IP method is able to indicate the presence of such sulphite. The IP is an excellent indirect prospection method to indicate the existence of mafic and ultramafic formations. A high concentration of sulphite can produce such a big density difference that even a person who knew the area well could interpreter such concentration as mineralization. It has been observed that density contrasts higher than 0.25g/cm^3 relate to mafic and ultramafic mineralized formations. After checking the specific density of each lithologic formation involved, such criteria may be extrapolated to other areas of the Curaçá Valley.

The following situations may be considered perfect to the use of the gravimetric method in the Curaçá Valley.

1) In flat areas, as a whole;
2) During target detailing or semi-detailing stage. Whenever other less expensive and routine methods render the geologic interpretation ambiguous;
3) Replacing the aerogeophysics, associated to magnetometry or regional IP, in semi-detailing stages to select targets. This is a future use of the method is to be recommended only when the difficulties in selecting the targets increase.

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Detailed	Semi-Detailed
12 stations per hour	8 stations per hour
84 stations por day	56 stations per day
1.680 stations per month*	1.120 stations per month*
67,2 km/month *	112 km/ month *
month* 20 days of field work	

Table XI - Average production of the gravimetric work at Angico farm area.

4.3.4. AFMAG

There are many fault zones in the Curaçá Valley. Therefore, it's essential to know the fault zones of the Curaçá Valley, once such formations interfere in the IP method interpretation. Due to this fact, the AFMAG method use was considered as a means to help the geophysic interpretation. The AFMAG is one of the most efficient methods to trace such structures. Hence, the method was included in the copper geophysic prospection procedures.

4.3.4.1. Equipment and operational techniques

The surveys used a Mc Phar set, model AG51. The operational frequencies are 470 cps and 140cps.

Two operators make the field measures. It's better that the operator in charge of the readings be a undergraduate technician, once such readings must be precise.

4.3.4.2. Elements used in the interpretation

Using the AFMAG method, an anomalous zone determination is obtained by the invertion of the "TILT ANGLE" sign called "CROSSOVER" (curving points).

A graphic illustration of the concept is shown in the illustration bellow

(This illustration is in the annexed page)

It's also possible to make a semi-quantitative estimate of the conductivity from the relation between the pick amplitudes registered in the instrument and the low and high frequency readings.

The diving direction of the conductor body may be inferred from the relative positions of the crossovers at low and high frequencies. When the crossovers concur, the

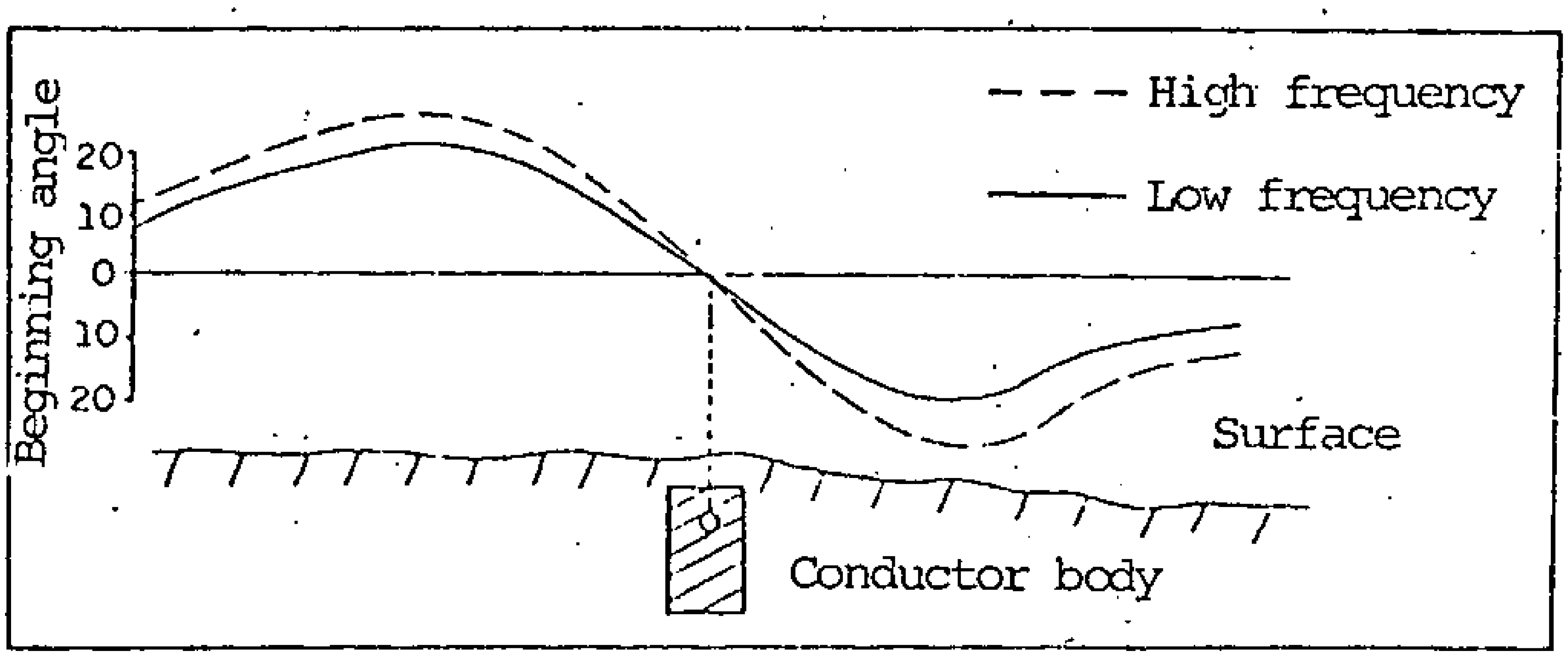


Illustration 22 - Shows the crossover movement of a conductor body of vertical position anomalous body is vertical.

The conductor body depth may be obtained from the following formule:

$$D = (\sigma\, O\, 2f/2)^{-\frac{1}{2}}$$, being:

D = depth, O = magnetic inductivity
f = used frequency
σ = average conductivity

Illustration 23 shows the profiles obtained in Macambira area (Target S-1). At this mark one can see an approximate North/South alignment direciton and typical crossovers like the ones indicated by "A" and "B" in profiles G and H.

4.3.4.3. Limitations and production

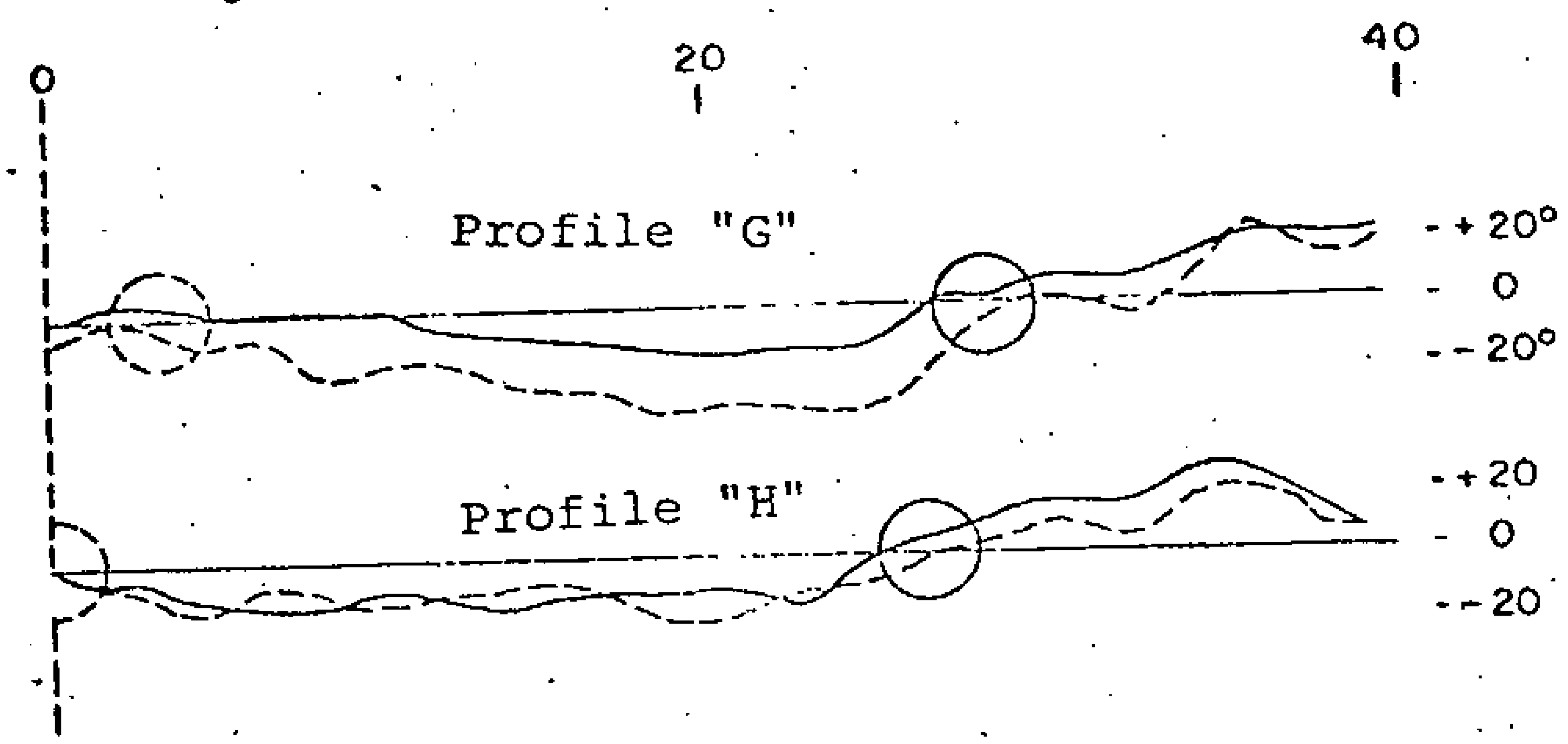
This method can not be used during all day long due to the fact that the eletromagnetic reflexions are better during the afternoon and night. Moreover, the fields created by the high tension lines, which are usually higher than the natural field, affect the AFMAG readings. Besides, the athmosphere discharges render the measurings difficult or even impossible of being carried out.

There is also another aspect to be considered: from January to June it's almost impossible to use this method at the Curaçá Valley. From January to March the rains render transportation very difficult; from April to June the eletromagnetic reflexions mentioned above occur during day time.

Production was calculated on the basis of an average estimated time of three minutes for displacement and reading to stations set at 50m intervals. Therefore, a 1km profile is completed within 60 minutes.

Apart from the difficulties found in the use of the AFMAG method mentioned above, an average production of 4 to 5km for favourable day has been estimated.

TARGET S-1 - MACAMBIRA



◯ Crossover Alignment ≅ NS — HIHG ----475 HZ

◌ Crossover Alignment ≅ NE — LOW ——340 HZ

Illustration 23 - Typical crossovers obtained from profiles carried out at S-1 target, using the AFMAG method.

4.3.4.4. Summary of the results

The AFMAG method has proved to be adequate to delineate the conductive shafts normally related to faults. It is also useful in determining the average conductivity of an area by means of a qualitative and quantitative study of the typical "crossovers".

However, the method's failure resides on the fact that the eletromagnetic reflexions interfere on its readings. Therefore, it's very difficult to stabilize the readings during certain hours of the day and during a specific period of the year. Hence, the restrictions to the use of such method increases its operational costs.

Considering these restrictions and the fact that the same elements can be obtained using a magnetic method, the magnetometry has been selected to be used together with the IP survey.

4.4. Research trenches and wells

At first the GEOSOL used 10 meter deep research wells to study the formation of Lagoa da Mina, Cercado Velho, Bela Vista and Senhor de Lisboa.

This method is very useful in determining the cubature of the copper oxidated ore, hence its utilization in the survey. However, this method furnishes no discarding criteria to mining area in pre-sounding stage.

Nevertheless, the trenches are important research equipment necessary to the production of detailed geologic mapping (scale 1:500 to 1:2500).

Not very significant geochemical anomalies and geophysic anomalies of induced polarization caused by fault zones or graphite may be discarded it trenches are made. Such procedure avoids the continuation of subsequent researches and saves a lot of money.

The study of oxidated mining displays disclosed

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at surface as well as their representability in terms of the mineral existence potential which indicates prospection sounding tests can only be obtained with the use of trenches.

4.5. Drilling

There are two things to be considered when one speaks of drilling diameter and drilling prospection net.

As to the diameter, it's well known that the more one increases the drilling diameter the more precise becomes the estimated copper percentage. This is true mostly to cases of irregulary distributed mineralization, as is the case of Curaçá Valley. However, drilling costs increase in the same ratio as the diameter of hole does.

Bearing in mind both technical and economical aspects, it was established the use of AX diameter.

In practical terms, it's necessary to use BX diameter until the decomposed stone is surpassed due to the alteration zone that usually reaches (15 to 30)m of depth. Such fact renders the coresampling recovering very problematic. This is true mostly to situations when water is used as drilling fluid once it necessarily requires coating of the hole.

The use of EX diameter is not at all recommended, except when excessive drilling diameter reduction is required due to operational problems. Such reduction may be used to avoid hole loss when the objective is about to be reached.

The drillings carried out in this project followed the average depth intervals in relation to the drilling diameters:

Diameter	Depth Intervals
NX	(0 + 03)m
BX	(3 + 030)m
AX	> 30m

A gutter coresampling was made every meter at the alteration zones using special holes distribution that

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traveled across the oxidated part of the ore. In other situations, a gutter sample was collected at every maneuver interval. In most cases, the chemical analysis of the gutter samples were only carried out at the oxidated zones or whenever the recovered samples were confirmed to be sulphite mineralized at less than 50%.

Experience acquired in interpreting ore formations at Lagoa da Mina, Cercado Velho and Pirulito have demonstrated that:

1) In places where the mineralization has been largely remobilized a fact that normally concurs with folded zones, like at Lagoa da Mina and Caraíba, the ore formation interpretation is more difficult to be carried out. In this case it's also necessary to drill more holes.

2) In cases of ore formation presenting a tabular shape, like at Cercado Velho, Pirulito and Baraúna (located south of Caraíba formation) the drilling of holes may be reduced to a more economical level. The 100m spacing between the transversal sections proved to be adequate to ore cubage at Cercado Velho and Pirulito. The same spacing may be used for similar formations studies.

4.6. Drilling coresamples

The coresamples obtained through drilling were divided into two parts. One part was to be chemically analysed in selected sections. The other part was put away in wooden boxes which had 4 to 5m capacity. The boxes for the AX diameter for coresamples had five divisions of 1m each. The examples of BX diameter were stored in boxes containing four 1m divisions. Before the boxes were put away, each of them received a number (in most cases a multiple of 5) depending on the depth at which the coresample was obtained. A metal tag was placed in each box bearing the hole prefix and the coresampling interval. Until the date of the elaboration of this report this material has been kept at Juazeiro da Bahia, in the drilled coresamples storage for the Copper Project.

The separated intervals for the analysis were listed in specially made cards (illustraton 24). In these cards the numbers of the holes and of the sampling boxes, as well as the coresampling interval and the length in meters were written down. Therefore, these cards constitute an excellent document to calculate the average percentage of the ore formations whenever the recoverage is inferior to 100% (4.9).

The physical data obtained from the daily drilling reports as well as the coresample studies that included the length distribution recovered meter by meter (apart from the losses) and the lithologic and structure aspects descriptions were transcribed in drilling compound profiles (illustration 25). Both the analitic results written in the report and the average percentage of the ore formations used for the reserve estimate were attached to this profile.

4.7. Chemical analysis

The geochemical analysis of the residual soil aimed to determine the copper by means of atomic absortion. The samples were completely sprayed at less than 100 meshs. Except for Pirulito's formation semi-quantitative espectrographic analysis for 30 elements were carried out. The reason of such exception was to complement the geochemical oriented studies.

In the current deposit geochemical analysis total copper, soluble copper and nickel determinations were made, in the samples natural fractions inferior to 80 meshs, by means of atomic absortion, according to the geological Survey Bulletin techniques 1152. However, in the oriented studies, colorimetric and espectrometric methods of analysis were also used.

Quantitative chemical analysis for copper in drilled coresamples were mostly made partly using atomic absortion and partly using thiosulphate absortion and partly using thiosulphate soluction and X Ray fluorescence.

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COPPER PROJECT - CURAÇÁ

CORESAMPLES ANALYSED

Place ....

nº of holes	nº of boxes	Coresamples		Ahalised interval (m)			% Cu
		No	lenght(m)	from	to	lenght	

Illustration 24 - It shows the cards used in the Copper Project to file the coresamples analysed for copper

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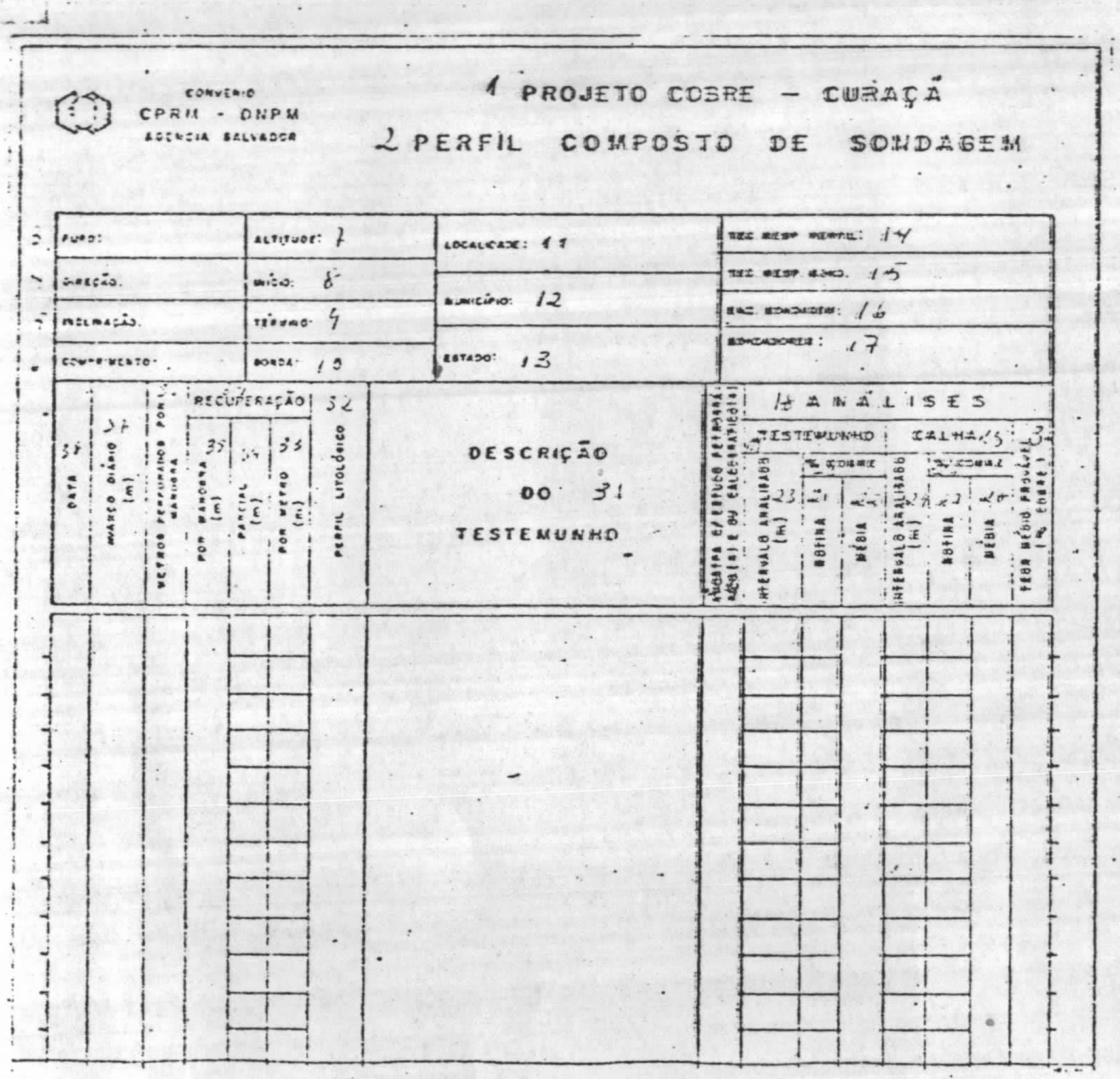

Illustration 25 - It shows the drilled compound profile used by the Copper Project. Such profile contains both field and lab data of a specific hole.

1 - Copper Project - Curaçá
2 - Drilled Compound Profile
3 - Hole
4 - Direction
5 - Inclination
6 - Lenght
7 - Altitude
8 - Begining
9 - End
10 - Drill
11 - Place
12 - District
13 - State
14 - Technician in charge of the profile
15 - Technician in charge of the drilling
16 - Drilling engeneer
17 - Drillers
18 - Samples
19 - Coresamples
20 - Copper
21 - Routine
22 - Average
23 - Analysed interval
24 - Sample with petrographic and/or calgraphic study
25 - Gutter
26 - Copper
27 - Routines
28 - Average
29 - Analysed interval
30 - Probable percentage (% copper)
31 - Coresamples description
32 - Lithologic profile
33 - Permeter
34 - Partial
35 - Per maneuver
36 - Meters
37 - Daily progress
38 - Date

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In 93 mineralized samples of the Lagoa da Mina, Cercado Velho and Pirulito formations semi-quantitative espectrographic analysis for 30 elements were made. The elements in question were: Fe, Mg, Ca, Ti, Mn, Ag, As, Au, B, Ba, Be, Bi, Cd, Co, Cr, Cu, La, Mo, Nb, Ni, Pb, Sb, Se, Sn, Sr, V, W, Y, Zn and Zr.

Specific analysis for gold were carried out in 72 copper ore samples using atomic absortion.

The control of the specific analysis for copper was obtained through the correspondance of the results with a spectrograph and through macroscopic observations of the samples. The copper percentage of ore deposits at Lagoa da Mina, Cercado Velho e Pirulito were the ones that were more intensively researched bu the project. Such control entrusts to the copper percentage of the ore at these sites.

4.8. Density calculations

According to Melo Jr, Pouchain and Castiel (1962), the average ore density at Caraíba are:

Oxidated ore = 2,80g/cm^3
Sulphite ore = 3,26g/cm^3

The oxidated ore density was determined at the site by means of a global method made with the material obtained from the research wells. Such conditions render the calculated value of 2,80g/cm^3 unquestionable.

As to the sulphite ore, a series of lab determinations of the various lithologic tupe densities were carried out, using mineralized and sterile rocks obtained from drilled coresamples of Lagoa da Mina, Cercado Velho, Pirulito e Paredão. The lab data can be found in table XII and the average densities are presented in table XIII.

The ultramafic pyroxenitic mineralized rocks with no doubt presented the highest density (3.30g/cm^3). Such density comes very close to the $3.26g/cm^3$ value found by Melo Junior et alii for the Caraíba ore. Such close values may be explained by the fact that there are a lot of pyroxenitic rocks at Caraíba site. However, in the mafic-ultramafic non-mineralized and mineralized rocks the densities varied from $2.93g/cm^3$ to $3.12g/cm^3$ respectively.

For the sulphite ore reserve calculations, the compatible densities with the more mafic or more ultramafic nature of the embedded rocks of mineralization have been used. For Lagoa da Mina and Cercado Velho the density used was $3.00g/cm^3$ amd for Pirulito the value was $3.20g/cm^3$.

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Types of rocks	Density g/cm^3	Sample's reference meter/hole
Gneiss biotite	2,82	65,60/1JO-1-BA
Gneiss feldspar quarts	2,56	120,80/1CA-11-BA
Gneiss biotite	2,60	41,00/1CA-16-BA
Gneiss biotite	2,94	168,18/1CA-27-BA
Gneiss feldspar quarts	2,52	43,44/1CA-33-BA
Rosy granit	2,50	51,32/1CA-33-BA
Rosy granit	2,57	244,66/1CA-33-BA
Rosy granit	2,51	106,65/1CA-34-BA
Rosy granit	2,56	137,67/1CA-34-BA
Gneiss feldspar quarts	2,84	162,70/1CA-34-BA
Gneiss biotite	2,77	62,59/1CA-35-BA
Gneiss biotite	2,88	116,08/1CA-38-BA
Gneiss	2,47	310,90/1CA-40-BA
Gneiss hornblend biotite	2,67	345,00/1CA-40-BA
Gneiss biotite	2,63	498,66/1CA-40-BA
Gneiss biotite	2,72	292.35/1CA-45-BA
Rosy granit	2,61	309,00/1CA-45-BA
Biotite	2,88	59,90/F-2
Mineralized melanorite	2,82	85,79/F-2
Gneiss diorite augite	2,90	116,00/F-2
Mineralized norite	2,82	196,21/F-0
Norite	2,82	91,22/1CA-19-BA
Mineralized norite	2,92	91,80/1CA-19-BA
Hornblend gabbro	3,02	49,32/1CA-37-BA
Diorite clinopyroxenic	3,14	53,19/1CA-37-BA
Diorite orthopyroxenic	2,76	82,39/1CA-37-BA
Meladiorite orthopyroxenic	3,03	83,57/1CA-37-BA
Diodorite orthopyroxenic	3,00	160,20/1CA-40-BA
Diorite pyroxenic	3,07	368,10/1CA-40-BA
Leucodiarite pyroxenic	2,87	379,77/1CA-40-BA
Amphibolite	2,95	32,00/1CA-16-BA
"	3,16	94,19/1CA-19-BA
"	3,15	42,25/1CA-33-BA
"	2,95	115,21/1CA-33-BA
"	3,25	134,00/1CA-33-BA
"	3,14	139,90/1CA-34-BA
Mineralized pyroxenic biotite	3,36	127,18/1CA-33-BA
" " "	3,43	149.06/1CA-33-BA
" " "	3,20	66,54/1CA-35-BA
" " "	3,25	83,00/1CA-38-BA
" " "	3,30	250,00/1CA-40-BA
" " "	3,37	354,00/1CA-40-BA

Table XII - A list of the drilled coresamples densities determined in lab (Source: 05/LAB/74 Bulletin) - Determinations made by Raymundo Loureiro Falcão.

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Type of Rock	Average Density g/cm^3
Felsite rocks	2.65
Grabbo - dioritic rocks	2.93
Amphibolitic rocks	3.10
Mineralised pyroxenitic rocks	3.30
Mineralised mafic - ultramafic rocks	3.12

Table XIII - Lab average densities of felsite, mafic and ultramafic rocks obtained from drilled coresamples.

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4.9 - Estimation of reserves

The estimation of the mineral reserves of oxidized copper in the analysed bodies was based on the literature, and was not done in strict accordance with the classical evaluation methods.

The estimation of sulfite copper ore in the deposits of Lagoa da Mina, Cercado Velho and Pirulito was done according to the parallel section method, generally obeying the following criteria:

1) Vertical sections,on a transversal line to the bodies, on horizontal and vertical scales of 1:500.

2) Plotting of geological data along the line of holes, readings and geological profiles.

3) Evaluation of average copper content of mineralized intervals, by wighted average, from the data recorded in the chemical analysis cards of coresamples and drilling composite profiles.

In the case of recuperation of coresamples being below 100%, the average content of the interval in question was obtained through the formula:

$$C = \frac{C' + C''}{2}$$; where C' is the average content of coresamples calculated proportionally to the lenght of advance of the drilling equipment(sampled interval); and C'' is the average content of the proofs calculated proportionatelly to the actual length of the recuperated coresamples in the sampled interval.

The values of C' and C'' have been calculated by means of the following formulas:

$$C' = \frac{C_1 l_1 + C_2 l_2 + \ldots + C_n l_n}{l_1 + l_2 + \ldots + l_n}$$ and

$$C'' = \frac{C_1 l_1' + C_2 l_2 + \ldots + C_n l_n'}{l_1 + l_2' \quad + \quad + l_n'} \quad ,$$

where C_1 , C_2 ... C_n are the copper contents of the analysed coresamples; and

l_1, l_2 ... l_n are the lengths of the sampled intervals; and

l_1', l_2' ... l_n' are the lengths of the recuperated coresamples.

4) Calculation of the average of the contents mentioned in the previous item according to three classes of ore:

Class A ore: ore with a cutting content of 0.07%Cu;

Class B ore: ore with a cutting content between 0.4% and 0.7% Cu.

Class C ore: ore with a cutting content between 0.2% and 0.4% Cu.

For the Pirulito deposit, owing to the registration of a low copper content and aiming at a greater utilization of the reserves, the interval of the ore classes was slightly altered, as follows:

Class B ore: ore with a cutting content between 0.3% and 0.7% Cu;

Class C ore: ore with a cutting content between 0.15% and 0.3% Cu.

5) Plotting of the intervals with calculated average contents along the line of holes and interpretation of the vertical sections of the ore bodies.

6) Tracing, in the profiles, the influence zones of the holes equal to half the distance to the nearest hole (when holes are parallel) or bisectrix of the angle made by concurring holes.

When the drilling hole was not near any other that

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might influence the behaviour of the bodies of ore, influence zones equal to those established for other holes were established, in the same section.

7) Separation of the sections of the ore blocks contained between two consecutive holes (measured section) ; between the hole and the oxidation zone measured section); between the hole and its own area of external influence (indicated section); below the hole's external influence zone (inferred section).

8) Calculation of the area of the sections of the mineral ore blocks. In this case an ARISTO 1130 L planimeter was used.

The average content of the section of the mineral block is equivalent to the weighted average content of the hole, in the interval that crosses the section.

9) Determination, for each profile, of an influence zone equal to half the distance to the adjoining profile, except in the external sections that were inferred until the probable external limit of the mineral bodies.

10) The product of the areas of the sections of the blocks by the respective length of these areas of influence is the volume of the mineral bodies. For the areas of influence of some mineral bodies, the volume of the extreme block was calculated by means of the "trapezium" formula $V= \frac{S.1}{2}$, in which S stands for the area of the section of the mineral block and 1 stands for the length of the area of influence.

11) The product of the volume of the mineral blocks by the density of the ore is the tonnage of the mineral blocks.

12) The addition of the tonnage of the mineral blocks, per section, is the section's reserve. The average content of the section of the weighted average of the average content of the blocks according to their respective tonnages.

13) The addition of the reserves of the sections is the reserve of the deposit.

The procedure for separation of measured, indicated and inferred reserves was established, firstly, in the sections of the mineral blocks, according to the criteria presented in item 7; and, secondly, in the characterization of the areas of influence between profiles (length of the areas of influence of the mineral blocks). If the area of influence is measured, the measured, indicated and inferred reserves shall be determined by means of the section of the mineral blocks. If the area of influence is indicated, the measured and indicated sections of the blocks shall is inferred, the reserves shall always be inferred. In any situation, the section of the inferred blocks shall always constitute inferred reserves.

Thus the criteria adopted were such that the reserves measured are those totally contained within the areas of influence of the holes and geological sections, and thus known in their three dimensions.

4.10 - Prospection procedures

Three prospection procedures characterized by three separate stages of the evolutions of the research work, were used to find the copper deposits in the region.

The first stage consisted of the geophysical survey directed to the MAFIC : ULTRA MAFIC bodies identified in the aerial photographs through their photographic texture, of a dark grey color, thus called "spots". This prospection was based mainly on the lithological control which determines

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mineralization. Prospections during this stage was done according to the following procedures:

1). Recognaissance prospection

Sampling of soil along an axial trail, opened according to the greatest extension of the "spot", with collection of samples at 100m intervals, and geochemical analyses for Cu, Co and Cr.

2) Detailed prospection

Geochemical detailing, according to a pre-determined grid, of zones with geochemical anomalies established in the previous stage. In case of confirmation of anomaly, opening of research wells, trenches and canal sampling. Preparation of geological maps and distribution of copper isomerides.According to potentiality of the area, execution of exploration holes.

The second stage of prospection was based on the geochemical recognaissance, through active sediment sampling . This research was developed parallel to the geological mapping on a 1:25,000 scale and was aimed at the selection of the anomalous areas which were called"Target-S" by convention. At this time, the majority of "spots" had already been surveyed, thus making necessary a metodology capable of selecting areas up until them unknown from the standpoint of copper mining . This need was based on the fact that a few of the MAFIC : ULTRAMAFIC bodies,confirmedly mineralized, did not present photo-geological connotations, as for instance: the bodies of Surubin and Cercado Velho, which for this reason would probably not appear in the geological mapping in the seale 1:25,000.

The choice of geochemical method of active sediments for the recognaissance stage was based on the pioneering work of LADEIRA et alii. (1969) and in the orienting studies developed a posteriori.

For the detailing stage, the use of geophysical techniques, which had already been tested in the deposit ' s known up until then, and been found satisfactory for an adequate analysis of the pontential of the geochemical anomalies in a pre-drilling stage, was begun , thus avoiding excessive expenditure owing to the highs cost of drilling in no very favorable areas.

With his aim in mind, the prospection in this second stage obeyed the following procedures:

1) Recognaissance prospection

Geological mapping and geochemical recognizance through current sediment, in the scale 1:25,000, with selection of anomalous areas called TARGETS-S.

2) Semi-detailed prospection

Over the TARGET-S detailed geochemical survey through soil sampling in a 200 x 100m grid and analysis for copper. Preparation of maps of geochemical distribution and, depending on the conditions of the area, preparation of geological maps in the scale 1:10,000.

3) Detailed prospection

Over the zones with geochemical anomalies defined in semi-detailed research, geochemical detailing in 100 x 50 m grid; geophysical prospection through IP (dipole - dipole arrangement) and magnetometrycs;opening of trenches; delailed mapping and, in case of confirmation of potentiality of the target, prospective drilling.

The third stage of prospection, after the conclusion of the geological mapping work in teh scale 1:25,000, meant a very quick evolution of the geological knowledge of the area and of the mineralization controls. At this new methodology tests were concluded, mainly in the area of geophysics , using AFMAG and IP(pole-dipole arrangement), to be applied in the geophysical work on a semi-detailed scale.

The recognition of the geological controls of mineralization, particularly regional control, "SUBSTRATGRAPHIC", made possible the selection of new areas, called TARGET-L by convention, which were selected according to the geological elements shown int the mapping in the scale 1:25,000.

The orientation given to prospection work during this stage, obeyed the following procedures:

1) Semi-detailed prospection

Over the TARGET-L selected based on the geological controls of mineralization, sampling of residual soil on a 300 x 100m recognaissance grid with chemical analysis for copper. Simultaneously, geological mapping of the TARGET in a scale of 1:10,000. Depending upon these results, geophysical survey with utilization of AFMAG and/or magnetometry and induced polarization (pole-dipole arrangement).

2) Detailed prospection

Over the "anomalous zones" selected in the previous stage according to type of anomaly (geochemical, geophysical or both, superimposed), detailed research, according to one of the following alternatives: detailed geochemistry for definition of geochemical anomalies: detailed geophysics (IP-dipole-dipole and magnetometry) for definition of geophysical anomalies; and, eventually, gravimmetry, in sections previously selected to clear doubts as to the meaning of the IP anomalies. Depending on results: opening of trenches, detailed geological mapping of the traces and prospective drilling.

Finally, it is pointed out that the prospection procedure models presented are ideal and naturally theoretical. During execution, many variables were allowed according to particular problems of each prospected target, owing to technical-economical factors.

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4.11 - Physical data of production

In table XIV all work carried out for the Copper Project is presented, including the survey done directly by GEOSOL, by DNPM by CPRM, according to the demonstrative tables in tables I, II, III and IV.

Figure 26 is an illustration of the degree of participation of CPRM, GEOSOL and DNPM in the execution of the research work.

In the last stage of the work, carried out by CPRM, the research presented a more gradual development with well-defined stages and applied in a systematic fashion, as a result of the metodology developed by the technical staff of the Copper Project, for the Curaçá valley.

In the geological mapping, a greater participation of CPRM is evident in the survey done in the scales 1:25,000, 1:10,000 and 1:2,500, while GEOSOL leads the survey of areas mapped in the detailed scales, 1:1,000 and 1:500.

In the geochemical study of the current sediments, owing to the procedures of prospection used, CPRM gathered an impressive number of samples, while in the geochemistry of residual soil, the research sistematicaley employed by both companies a total of 14,423 samples were collected.

The great employment of the geochemistry in current sediments, a method adopted in the last stage of the Copper Project, according to the optimal results obtained, brought to CPRM an area, corresponding to the "spots" or targets prospected, equal to approximately three times the prospected by GEOSOL in the beginning of the research, before employment of this geochemical method.

The continuous employment of the geophysical method by CPRM, applied experimentally in the beginning and

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sistematically in later stages, brought about a continuous improvement of this fundamental tool in the prospection of mineralized bodies in under-surface, contributing to the development of a technology of research previously unknown in the Curaçá valley and whose application can be visualized quantitatively in table XIV.

During the Copper Project, 62,803 geochemical determinations were carried out, with expressive participation of the two research companies.

The drilling program carried out for the Copper Project reached a meaningful metreage of perfuration, around 12,689.51m, of which CPRM contributed 62.30%, followed by DNPM (23.73%) and GEOSOL (13.97%),and the fact that the drilling program was lead by CPRM is a consequence of the evaluation of the reserves of the deposits in Lagoa da Mina, Cercado Velho and Pirulito.

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Illustration 26 - PRODUCTION OF GEOPHYSICAL DATA FOR COPPER PROJECT AND DEGREE OF PARTICIPATION GEOSOL, DNPM AND CPRM IN DIRECT EXECUTION OF RESEARCH SERVICES.

Mod. 002

NATURE OF SERVICES	UNITS	GEOSOL 1965- april to 1968- march	DNPM 1968- april to 1970- june	CPRM 1970- july to 1973- september	GENERAL TOTAL	Percent Participation in the services execution		
						GEOSOL	DNPM	CPRM
Geological mapping 1:25.000	km^2	760	-	2,280	3,040	25.00	-	75,00
Geological mapping 1:10.000 - 1:5.000	ha	3,189	400	6,252	9,841	32.40	4.07	63.53
Geological mapping 1:2,500	ha	-	-	145	145	-	-	100.00
Geological mapping 1:1,000 - 1:500	ha	42	38	10	90	46.67	42.22	11.11
Geochemistry of current sediments	sample	244	-	6,095	6,339	3.85	-	96.15
Geochemistry of residual soil	sample	8,193	-	6,230	14,423	56.80	-	43.20
Induced Potarization	km	-	-	118	118	-	-	100.00
Magnetometrics	km	-	61	150	211	-	28.71	71.05
AFMAG	km	-	-	58	58	-	-	100.00
Gravimetrics	km	-	-	19	19	-	-	100.00
Trenches and research wells	m	3,780	591	2,015	6,386	59.19	9.25	31.56
Drilling	m	1,773.63	3,013.96	7,910.96	12,698.51	13.97	23.73	62.30
Chemical analyses	N.of determinattions	29,699	954	32,150	62,803	47.29	1.52	51.19
Area of prospected Targets, or "spots"	ha	3,189	400	9,014	12,603	25.30	3.18	51.52

Table XIV - Production of geophysical data for Copper Project, distributed acording to the stage of direct execution of services by GEOSOL, DNPM and CPRM (Data gathered from Tables I, II, III and IV).

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