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GEOCHEMICAL ORIENTATION SURVEY OF THE FORTALEZA DE MINAS O'TOOLE Ni DEPOSIT SOUTHWESTERN MINAS GERAIS, BRAZIL

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ABSTRACT

Results from a geometrical orientation survey conducted at the Fortaleza de Minas O'Toole Ni sulphide deposit are reviewed. The applied use of ironstone-gossan discrimination, soil geochemistry, coffee plant biogeochemistry, and stream drainage geochemistry is presented and discussed.

Gossans from the O'Toole deposit are readily distinguished from barren ironstones based on Ni-Cu-Zn proportions and on Pt, Pd contents. Various size fractions of soil yield pronounced aqua regia Ni and Cu anomalies over the deposit and EDTA partial extractions of these metals are shown to be useful in confirming the origin of Ni anomalies. Analyses of coffee leaves and stems provide discernible anomalies in Ni and Cu, but coffee plant biogeochemistry is inferior to soil geochemistry on a practically applied basis. Analytical data from various drainage sediment size fractions along with sediment pan concentrates indicate preferred drainage sample types for geochemical exploration in this environment. EDTA (ethyline diamine tetra-acetic acid) partial extraction results from stream sediments are consistent with the weathering and chemical dispersion patterns for Ni and Cu observed in soils, and EDTA results in both stream sediments and soils considered together are useful in defining anomalies related to Ni-sulphide mineralization.

RESUMO

São examinados resultados de levantamento geoquímico orientativo efetuado no depósito O'Toole de níquel sulfetado em Fortaleza de Minas, MG. A aplicação de métodos de discriminação de "gossan-ironstone", geoquímica de solo, biogeoquímica de pés de café e geoquímica de sedimento de corrente é apresentada e discutida. Os "gossans" do depósito O'Toole são prontamente discriminados dos "ironstones" estéreis com base nas proporções de Ni-Cu-Zn, bem como pelo seu conteúdo de Pt e Pd. Expressivas anomalias de Ni e Cu por água régia são obtidas sobre o depósito em frações de solo de granulometria diversa e extração parcial destes metais por EDTA mostrou ser útil para confirmar a fonte das anomalias de Ni. A análise biogeoquímica de folhas e talos de pés de café fornece anomalias reconhecíveis de Ni e Cu, porém de pouca aplicabilidade prática quando comparada com a geoquímica de solo. Dados analíticos de frações granulométricas diversas de sedimento de corrente, bem como de concentrados de bateia de sedimento indicam tipos preferenciais de amostra para exploração geoquímica em sedimento de corrente. Os resultados de extração parcial por EDTA de sedimento de corrente são consistentes com os padrões de dispersão geoquímica e de intemperismo observados no solo para Ni e Cu e resultados por EDTA tanto em sedimento de corrente como em solo, quando considerados em conjunto, mostraram ser úteis na definição de anomalias relacionadas a mineralizações niquelíferas sulfetadas.

INTRODUCTION

While the practical application of geochemical techniques to exploration for peridotite-hosted or dunite-hosted Ni sulphide mineralization is in many respects straight-forward, individual mineral belts or ore occurrences generally display specific characteristics which warrant a clear definition of the geochemical signal given off by the deposit. These characteristics are functions of geologic setting, ore forming processes, metamorphism, weathering and other features which, case-by-case, distinguish individual ore deposits within the same classified deposit type. At the Fortaleza de Minas O'Toole Ni deposit, straight-forward application of soil geochemistry yields high contrast Ni and Cu anomalies in − 80 mesh soils, but the highest contrast anomalies are not directly superposed on the highest grade ore (Fig. 1). Observation of this relationship between soil anomaly and ore led to the effort presented in this paper to closely characterize the geochemical response of the O'Toole orebody.

GEOLOGIC, GEOCHEMICAL AND CLIMATIC SETTING

The O'Toole orebody is located about 5 km southeast of the town of Fortaleza de Minas in soutwestern Minas Gerais. The deposit crops out as weathered gossan within a sequence of mafic-ultramafic volcanic rocks, and cherts comprising the Fortaleza de Minas greenstone belt (Teixeira, 1978). The predominantly volcanic sequence occurs as a northwest-trending 2-kilometer-wide package with felsic gneiss of the regional basement complex exposed to the northeast and southwest.

The deposit contains 5.3 million tons of ore grading 2.6% Ni, 0.4% Cu, 0.05% Co, and 1.1 g/tonne combined platinum group elements. The orebody extends about 1.5 km along strike, has a prevailing true thickness of from 2 to 10 m, and attains a depth of 500 m. Fresh ore is comprised mainly of pentlandite/pyrrhotite with minor chalcopyrite and cobaltite. This weathers to violarite (bravoite) and pyrite above about 80 m depth, and then to gossan in the oxide zone above 15 m to 25 m depth. In its weathering behaviour, the O'Toole orebody is similar to a number of nickel sulphide deposits of Western Australia including the Kambalda deposits (Nickel *et al.*, 1974), Mt. Windarra (Blain & Andrew, 1977; Watmuff, 1974), Agnew (Nickel *et al.*, 1977), and Mt. Keith (Butt & Nickel, 1981).

At surface, gossan occurs over the northwestern portion of the deposit. The southeastern 1000 m of the orebody is represented at surface only by red, iron-rich soil, much of which is cultivated as part of a coffee plantation.

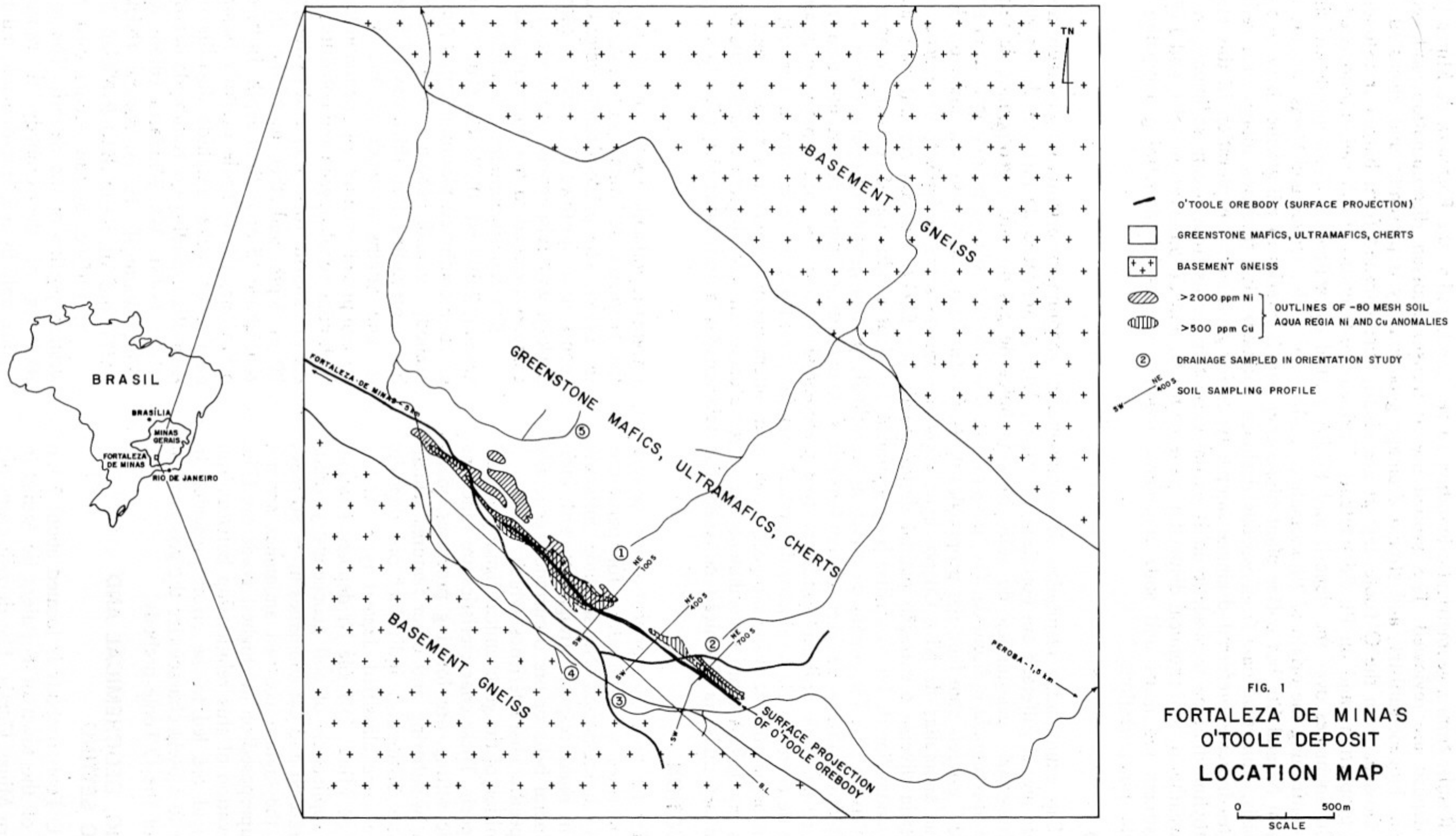

FIG. 1

FORTALEZA DE MINAS
O'TOOLE DEPOSIT
LOCATION MAP

The region around the Fortaleza de Minas O'Toole deposit falls within the Minas Gerais Southern Plateau morphological and structural province. Its climate is humid tropical with a dry season from June to August and a rainy season from December to February. Rainfall averages 1600 mm per year. The mean annual temperature is 10°C with usual maxima and minima of 35°C and 0°C respectively. The area is covered by a mixture of scrub vegetation and deciduous forest with a large proportion of the land devoted to crop raising and pasture (Geography of Brazil, Southeast Region, Volume 3).

SAMPLING AND ANALYTICAL PROCEDURES

Ironstones

Ironstone samples were collected from known Ni-sulphide-derived grossan outcrops and from exposures of weathered Ni-rich ultramafic rocks barren with respect to sulphide Ni. Samples were pulverized and analyzed routinely by aqua regia/A.A. (atomic absorption) for Ni, Cu, and Zn with occasional analyses by fire assay/A.A. for Pt and Pd in an effort to define the ability of these elements to discriminate true Ni gossans from ordinary ironstones.

Soil samples

Soils were sampled along 3 profiles over the O'Toole deposit and along one profile over barren ultramafic rocks at Peroba, 2.5 km to the northeast. Sampling profiles are located or indicated in Figure 1. Extensive trenching along the entire strike extension of the orebody has provided a good opportunity to examine soil profile development along the sampling lines.

Figure 2 displays a schematic drawing of the weathered profile, exhibiting the spatial relationships among argillitic, limonitic soils, the "stone line"* and saprolite.

Soil samples were collected generally from horizons of uniform argillic limonite underlying the superficial poorly-developed organic horizon and overlying the "stone line" comprised of coarse-grained, pebble to small cobble-sized, residual rock fragments and coarse-grained limonite fragments. On rare occasions, soils were collected from the "stone line" itself comprised of some gossan rock fragments along with other residual weathering products. Soil samples were handled using several approaches in parallel. In general, soils were pulverized or sieved without pulverization into 3 separate granulometry fractions: +80 mesh (+180 microns); −80, +200 mesh (−180 microns, +75 microns); and −200 mesh (−75 microns). For soil profiles 400S and 700S, a −80 mesh fractions was utilized as well. All fractions were analyzed by aqua regia/A.A. for Ni, Cu, and Zn. In addition, the −200 mesh fraction soils were analyzed by 0.25N EDTA/A.A. for Ni, Cu and Zn to examine the easily-leachable metal expressions.

Minus 80 mesh soils from the 400S and 700S profiles at O'Toole were analyzed for Pd as well by fire assay/A.A.

Coffee plant samples

Samples of coffee leaves and coffee stems were collected along two profiles over the O'Toole deposit at 400S and 700S. Samples were washed with water to remove any Cu-bearing pesticide which may have been present. Samples were then dried, weighed, ashed and reweighed,then analyzed by aqua regia/A.A. for Ni and Cu. Results were expressed as unadjusted concentrations of Ni, Cu in ash and as (ppm metal × % ash ÷ 100) to account for the variability in concentration inherent in ashing vegetation samples.

Stream drainage samples

Stream drainage samples from 5 streams draining the O'Toole deposit were collected at 300 m spacing along the drainages up to 5 km from the deposit. Composite samples from each

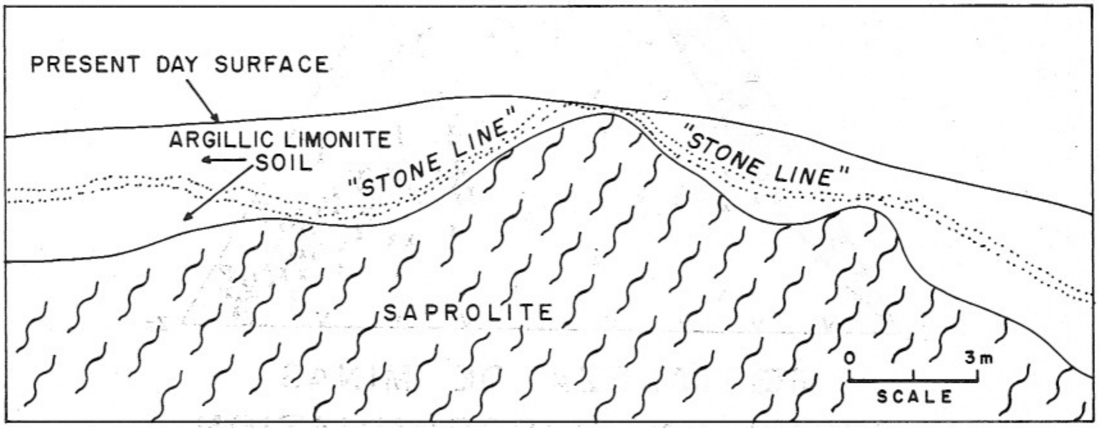

Figure 2 — Schematic drawing of the weathering profile at the O'Toole orebody: in general the 'stone line' directly overlies saprolite of ultramafic volcanics and interbedded chert. The 'stone line' is commonly overlain and at times underlain by argillic limonite.

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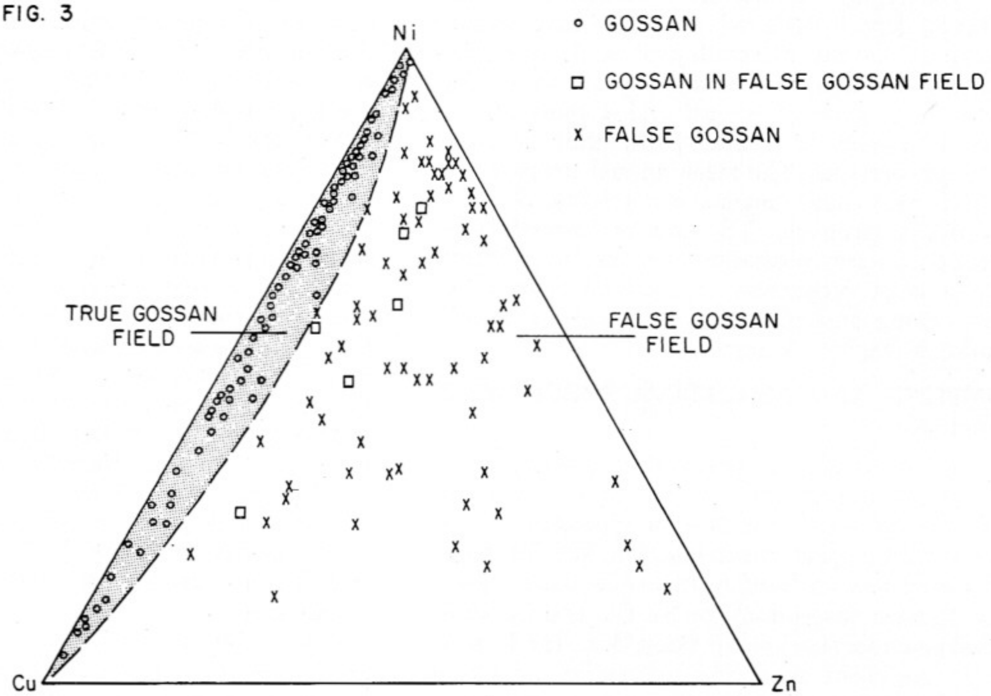
* The "stone line" is comprised of a horizontally continuous rubble zone of stable and resistate minerals interpreted as stable products of a former, possibly lateritic weathering surface.

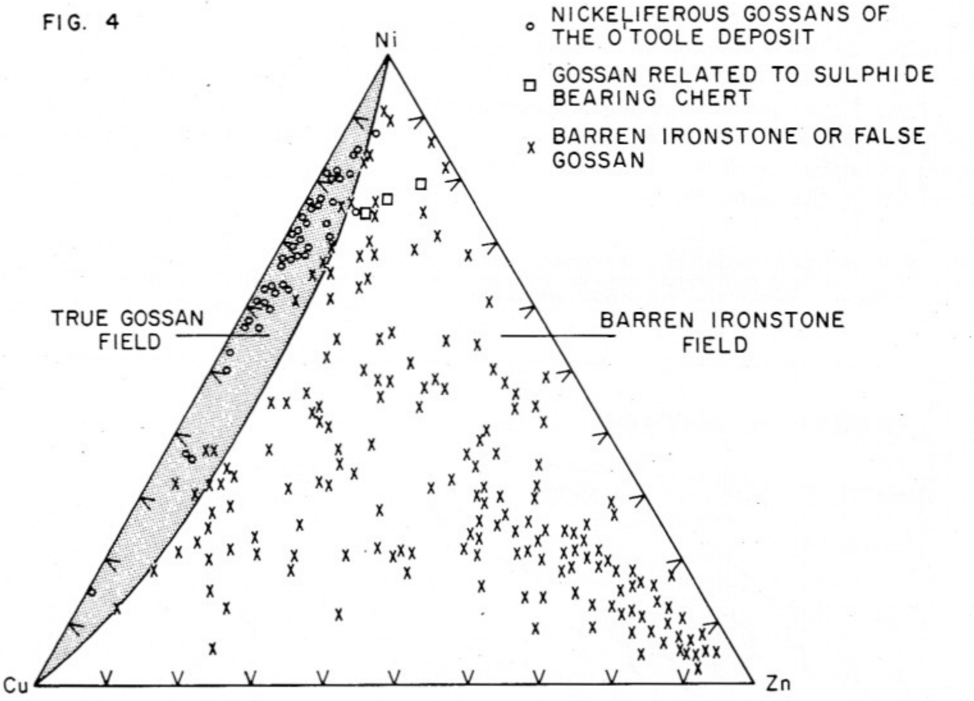
FIG. 3



YILGARN IRONSTONE DISCRIMINATION

After Moeskops, 1977

FIG. 4



FORTALEZA DE MINAS
IRONSTONE DISCRIMINATION

sampling site were sieved into fractions of + 80 mesh (180 microns), − 80 + 200 mesh, and − 200 mesh (75 microns). It addition, a pan concentrate was collected from 5 liters of sediment at each site. All stream drainage samples were analyzed for Ni and Cu by aqua regia/A.A..

RESULTS AND INTERPRETATIONS

Ironstones

Ironstones in the Fortaleza de Minas district were evaluated utilizing criteria shown to discriminate Ni-sulphide-derived gossan from ordinary ironstones in Western Australia (Keays and Davison, 1976; Moeskops, 1977). In his published Ni gossan work Moeskops (1977) utilized Ni, Cu, Zn proportions to classify true gossans in the Yilgarn of Western Australia. The triangular diagram containing his data is reproduced here as Figure 3. In an earlier paper by Keays & Davison (1976), the importance of the platinum group elements Pd and Ir in evaluating Ni gossan in Western Australia was presented and discussed.

A triangular Ni-Cu-Zn diagram presenting ironstone results from Fortaleza de Minas is presented as Figure 4. It may be seen from this diagram that nickeliferous gossans from the O'Toole deposit are effectively distinguished from other ironstones in the area based on their increased Ni and Cu contents together with their low Zn contents. This may be understood in terms of Cu enrichment in primary pentlandite-pyrrhotite-chalcopyrite ores, source rocks for the gossans, versus comparatively lower Cu in mafic and ultramafic volcanic and plutonic rocks, predominant source rocks for the other ironstones. Acidic* solutions formed from oxidation and weathering of sulphide-rich ores at O'Toole leach Zn causing Zn depletion in gossans; weathering of mafic and ultramafic igneous rocks without the formation of strongly acid solutions yields ironstones undepleted in Zn. In the weathering of sulphides to gossans, Cu is most likely stabilized in the surface and near surface rocks by iron oxide/hematite complexing despite the prevalent acidic environment. Strong Cu complexing by iron oxides in weathered rocks has been noted elsewhere (Butt, 1979) and the stability of Cu with respect to Zn at pH's below 6 is consistent with the observations of Mann (1982). The increased resistance to dissolution of Cu versus Ni in the sulphide--weathering and gossan-formation environment at O'Toole accounts for similar absolute concentrations of Cu and Ni in gossan despite a 6 to 1 Ni to Cu ratio in fresh ore. Of 172 O'Toole gossan analyses examined, 96 displayed Cu concentrations greater than Ni concentrations while 76 exhibited Ni concentrations greater than Cu concentrations.

Platinum and palladium ironstone analyses were found to be additionally useful in discriminating true Ni gossans from other ironstones in the Fortaleza de Minas greenstone belt. The O'Toole gossans almost invariably contain above 100 ppb Pd, generally contain above 100 ppb Pt, and have been found to contain up to several ppm's of both metals. Barren ironstones, on the other hand, seldom contain greater than 60 ppb Pt or Pd in the Fortaleza de Minas greenstone belt.

Soil samples

Soil profiles completed along lines 100S, 400S and 700S at the O'Toole deposit are shown in Figures 5 through 7. An additional soil profile, shown in Figure 8, was completed over background ultramafic rocks along line 400S in the Peroba area. At soil profile 100S (Fig. 5) over the O'Toole deposit, soils are derived from outcropping gossan. Strong aqua regia Ni and Cu anomalies occur in pulverized soils and in all three granulometry size fractions directly overlying the gossan and dispersed downslope about 60 m, with concentrations commonly exceeding 2000 ppm Ni and 1000 ppm Cu. It is noteworthy that anomalous Cu (above 400 ppm) accompanies the Ni anomalies over the exposed gossan and the nearby soils derived from it. The metal response in soils derived from gossan is shown to be quite similar to the metal response in the grossans themselves with respect to Ni, Cu and Zn. Responses in gossan and soil both may be understood in terms of the same metal accumulation and weathering dispersion processes described earlier in the section on gossans. EDTA (.25N ethylene diamine tetra-acetic acid) extractions of fine-grained soils exhibit a well-expressed Cu anomaly and a flat Ni response. This response in easily extracted metal is consistent with the liberation of Ni and Cu upon oxidation and weathering of their sulphide minerals, the leaching and removal of Ni in the prevailing acid environment, and complexing during weathering of Cu in an easily extractible form by iron oxides/hematite.

At soil profile 400S (Fig. 6), no gossan or other rock exposure is available and only red argillic, limonitic soils may be seen at surface. A relatively weak Ni-Cu anomaly (> 1000 ppm Ni, >350 ppm Cu), expressed in pulverized soils and all granulometry size fractions, is visible overlying the blind gossan and extends downslope about 50 m. The Ni-Cu soil anomaly exhibits a downslope chemical-mechanical dispersion similar in length to the anomaly at 100S, but here, at 400S, the magnitude of the Ni and Cu concentrations is significantly lower apparently due to increased chemical weathering. It is important to note that anomalous Cu accompanies anomalous Ni, suggesting a Ni-sulphide source despite the suppressed absolute concentrations of both metals. Easily extractible Ni and Cu indicated by EDTA analyses of fine-grained soil also help to identify the blind ore, displaying increased concentrations of extrac-

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* A sample composite from the oxide zone at O'Toole yielded a measured pH = 3.

tible Cu together with low concentrations of extractible Ni in soils over the gossan. Palladium analyses of −80 mesh soils further identify the blind gossan displaying increased concentrations above and downslope from the gossan source. A second weak Pd anomaly accompanied by over 800 ppm Ni at the SW end of the profile reflects weak Ni-sulphide mineralization in the underlying serpentinite.

At soil profile 700S (Fig. 7), gossan again is not exposed at surface but is completely covered by argillitic, limonitic soils. Minus 80 mesh soils reveal coincident Ni, Cu, Pd anomalies over blind gossan and coincident Ni, Pd anomalies over weakly mineralized serpentinite to the southwest.

For comparison with the three soil profiles presented above and completed over known Ni-sulphide mineralization, a fourth soil profile was completed over known sterile ultramafic volcanics at the Peroba area, 2.5 km NE of the O'Toole orebody. Results from this profile are displayed in Figure 8. At Peroba, a strong aqua regia Ni anomaly commonly exceeding 2500 ppm Ni is expressed over komatiite, serpentinite, and komatiitic basalt in pulverized soils and in all granulometry size fractions tested. Importantly, this Ni anomaly is unaccompanied by anomalous Cu (less than 200 ppm Cu). The absence of associated anomalous Cu distinguishes these Ni-rich ultramafic volcanics as barren with respect to Ni-sulphides, an indication confirmed by diamond driling. EDTA-Ni and Cu analyses of fine grained soils display anomalous Ni over komatiite and komatiitic basalt along with strongly anomalous Ni over serpentinite, and a flat, low-level Cu response over all rock types. These extractible metal results help confirm the barren nature of these ultramafics. Nickel, weathered from ultra-

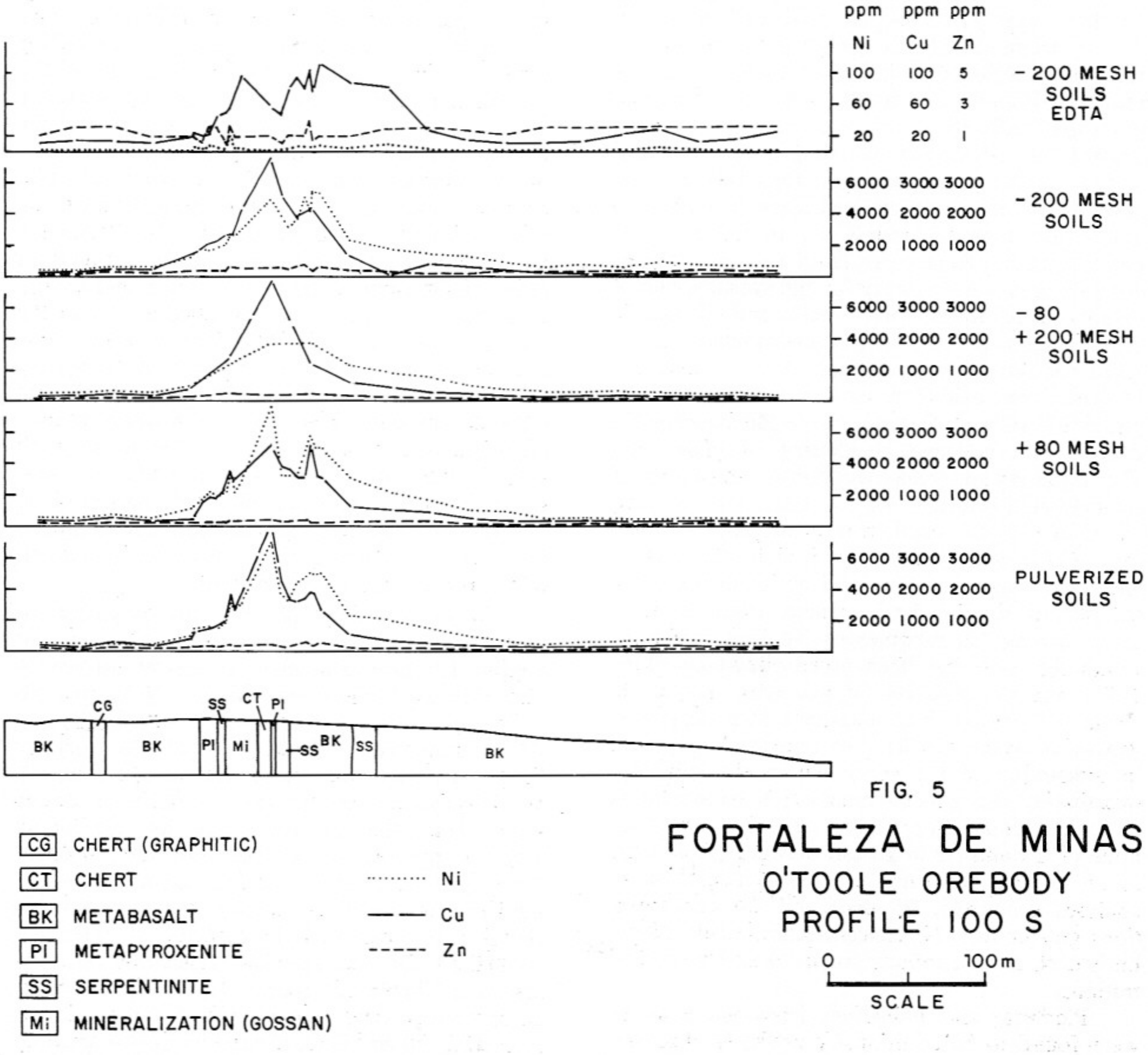


FIG. 5

FORTALEZA DE MINAS
O'TOOLE OREBODY
PROFILE 100 S

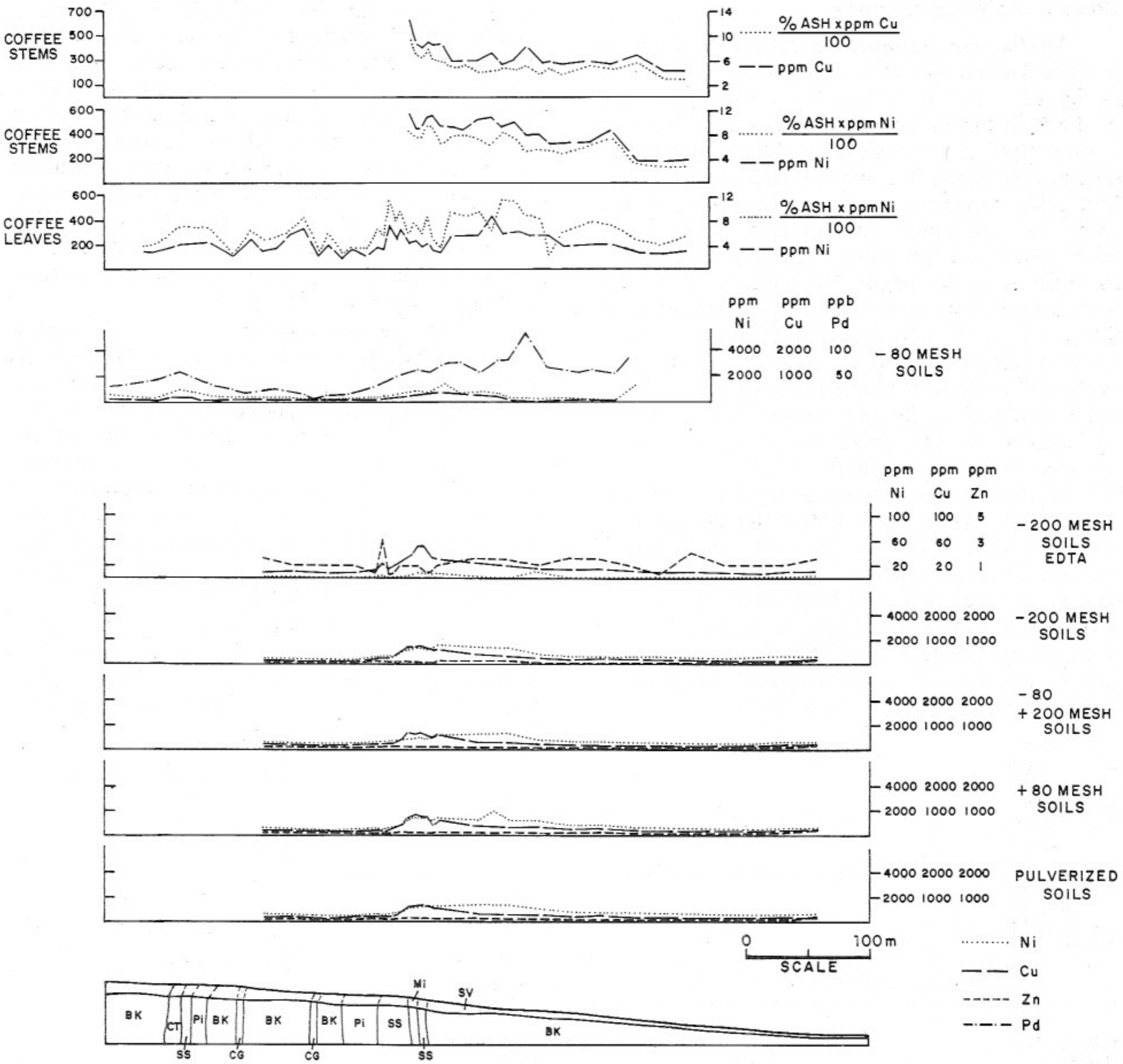


FIG. 6

FORTALEZA DE MINAS
O'TOOLE OREBODY
PROFILE 400 S

mafic rock-forming minerals in the absence of sulphide-derived acid, remains undepleted and leachable in nearsurface soils as extractible Ni. Copper, not enriched in the barren ultramafic, displays uniformly low concentrations in the soils weathered from these rocks.

Coffee plant samples

Coffee plant sample profiles are displayed in Figures 6 and 7. Ni analyses of coffee leaves collected along soil profiles 400S and 700S weakly reflect unexposed gossan. A distinctive yet low-contrast Ni anomaly at 700S reflects the blind gossan while Ni responses in coffee leaves at 400S are erratic and not uniquely related to the gossan source. Analyses of Cu coffee leaves poorly reflected Ni-sulphide mineralization and are not displayed here.

Analyses of Ni and Cu coffee plant stems appear to distinguished the blind gossan effectively, although the anomaly is low-contrast and a suitable number of background samples was unavailable due to seasonal cutting of the coffee field.

The use of coffee plant samples is not preferred over soils as a sampling medium in this environment.

Stream drainage samples

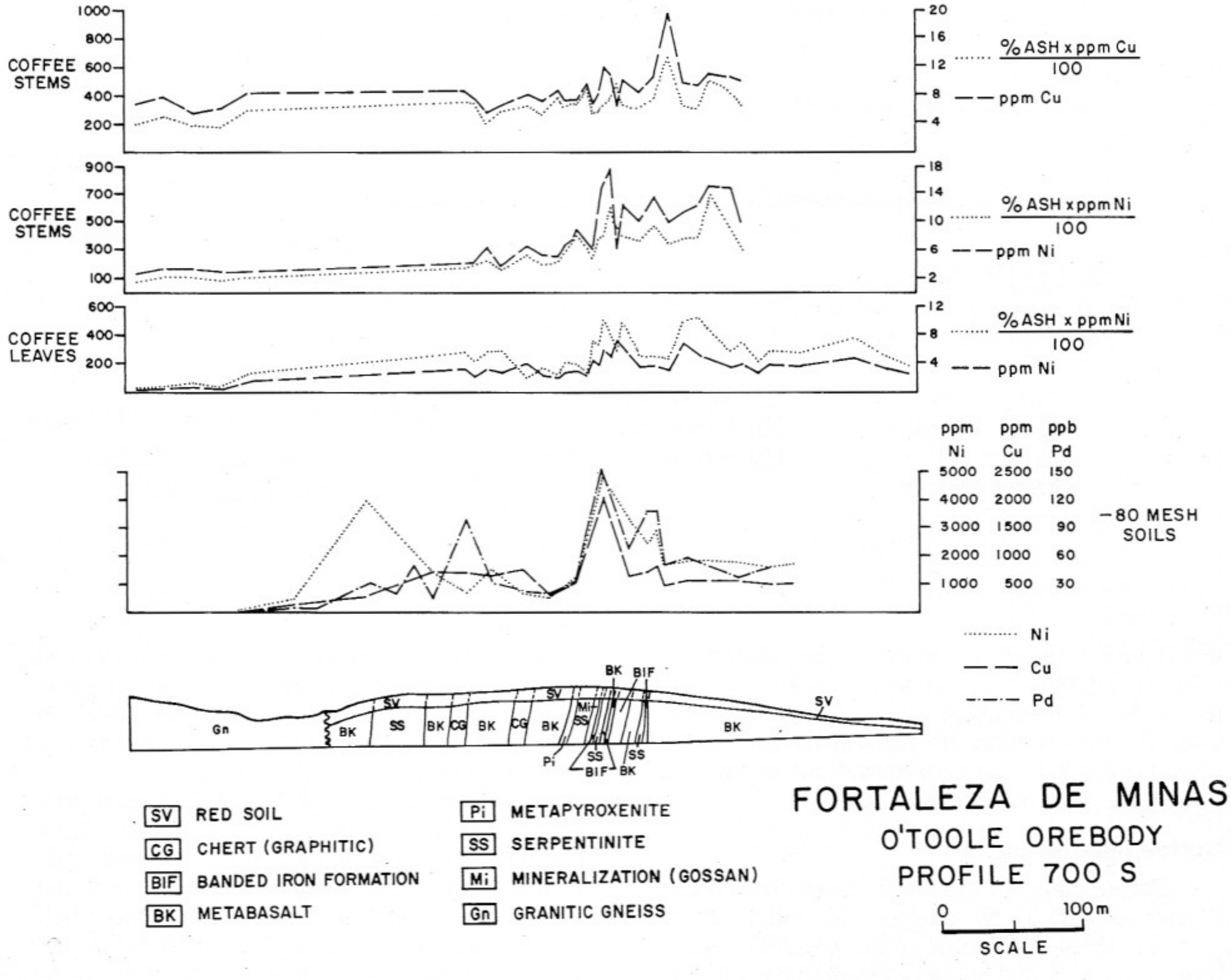
The streams sampled to determine drainage profiles around the O'Toole orebody are shown in Figure 1. It may be seen from this figure that of the 5 drainages sampled, drainages 1, 2, 4 and 5 flow from the Fortaleza de Minas greenstone sequence of cherts and mafic/ultramafic volcanics into felsic basement gneiss within 1 to 3 km from the orebody. In contrast, drainage 3 flows within the greenstone sequence throughout its entire sampled lenght. Drainages 1, 2, 4, and 5, therefore, flow from a lithologic package relatively high in Ni and Cu to a lithologic complex relatively low in Ni and Cu, augmenting the well-expressed contrast of both elements in the various mesh sizes and in the pan concentrates collected.

The Ni and Cu profiles for all sampled drainages are displayed in Figures 9 to 13.

Of the various granulometry size and pan concentrate sample types tested and analyzed by hot aqua regia digestions, the +80 mesh stream sediment fraction appears to give the best combined Ni-Cu response to the Ni orebody in terms of anomaly contrast and distance of anomaly dispersion. Using anomaly thresholds of 350 ppm Ni and 30 ppm Cu, the +80 mesh size fraction yields anomaly dispersions of from 1500 m to 4000 m along the sampled drainages. Furthermore, in stream #3 where the drainage stays within greenstone cherts and mafic/ultramafic volcanics, Ni and Cu analyses in +80 mesh sediments provide the best contrast and dispersion when other sediment fractions fail to effectively reflect the O'Toole deposit mineralization in both metals. The factor (Ni + 10 × Cu) improves the anomaly contrast at times versus Ni or Cu alone. The Ni + 10 × Cu factor is shown in general to be useful in identifying mineralization for stream drainage surveys in this region.

EDTA partial extractions of −200 mesh stream sediments provide anomalous expressions in Ni for each of the drainages, including stream #3 where hot aqua regia Ni and Cu results fail to define the known Ni mineralization in two of the granulometry size fractions or in pan concentrates. Cu in EDTA extractions of fine-grained sediment is less effective in identifying the O'Toole mineralization, displaying a clear anomalous response in streams 1, 2, 4 and 5, but failing to identify the deposit in stream #3.

Based on the interpretation of EDTA extractions of soils and on more complete chemical analyses of soils and gossan, Ni has been more thoroughly leached than Cu from oxide ore and



FORTALEZA DE MINAS
O'TOOLE OREBODY
PROFILE 700 S

FIG. 7

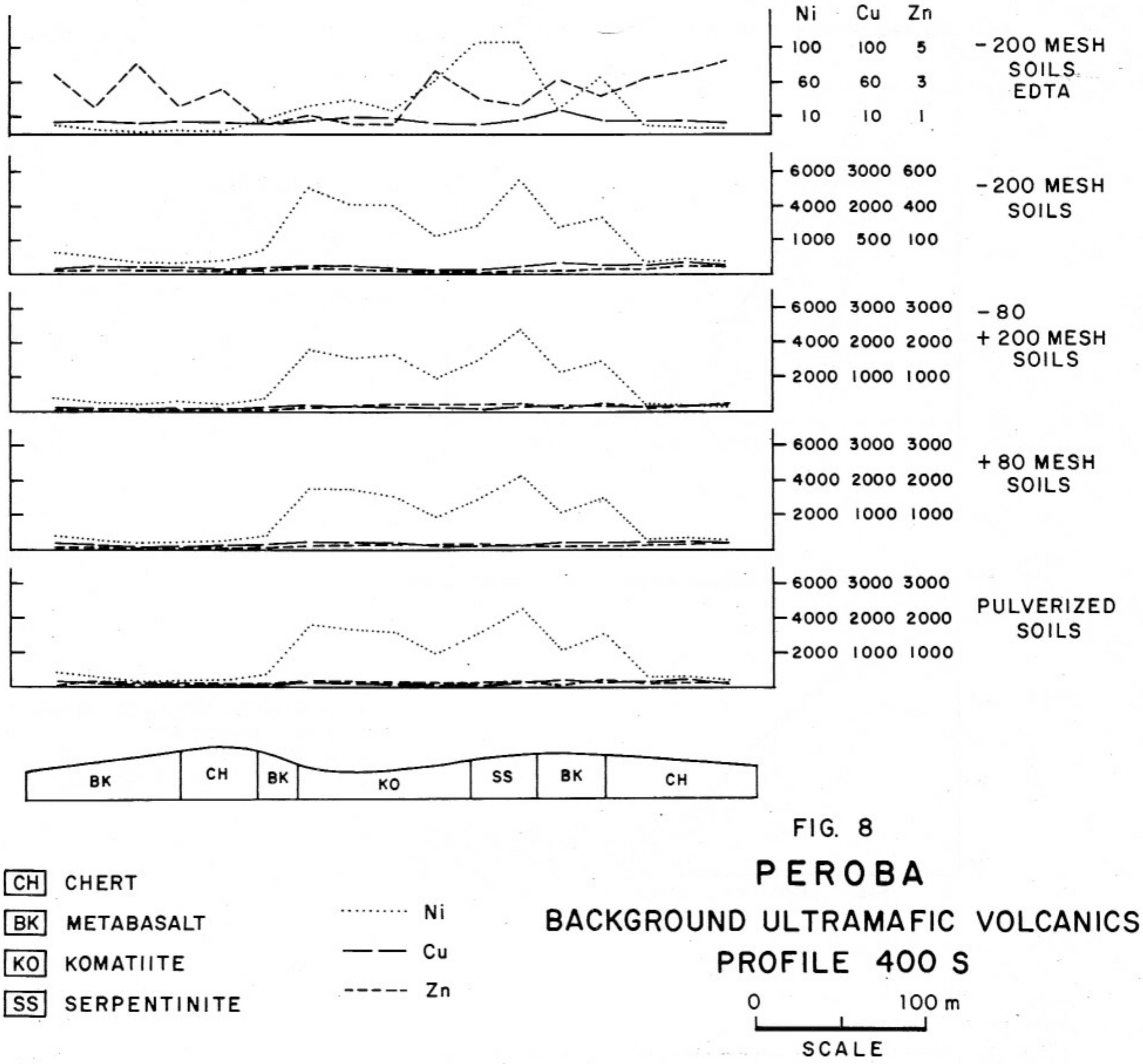


FIG. 8

PEROBA

BACKGROUND ULTRAMAFIC VOLCANICS

PROFILE 400 S

weathered gossan. The leached Ni was presumably chemically dispersed in groundwater and streamwater and subsequently adsorbed onto stream sediment in an easily extractible form. The more complete leaching and chemical dispersion of Ni versus Cu is consistent with the better-expressed Ni anomaly versus Cu anomaly observed in EDTA extractions from fine-grained sediments. Based on stream 3 results, Ni appears to display a broader hydromorphic dispersion than mechanical dispersion, yielding an EDTA-Ni anomaly 300 m upstream from the more mechanically-dispersed +80 mesh or pan concentrate aqua regia Ni values.

Discussion

Within ultramafic volcanic greenstone belts hosting Ni sulphide mineralization, increased Ni concentrations generally are encountered in two dominant primary forms: 1) within pyroxene, olivine, and other silicate minerals rich in Fe and Mg, and 2) as sulphide minerals either disseminated within the silicate matrix or in massive occurrences forming discrete bodies.

In the first instance, Ni in silicates, rocks made up of the crystallized Fe and Mg silicate minerals probably reflect the Ni concentrations (i.e., generally 2000 ppm Ni to 4000 ppm Ni) present in the solidifying magma from which they were derived. Furthermore, if these rocks have not experienced a metal-concentrating event, they probably reflectt original magma concentrations of other metals as well.

In the second instance, Ni in sulphides, enough sulphur is present to saturate the ultramafic magma and form a separate immiscible mineral phase. This phase probably crystallizes prior to the overal silicate mass in most Ni-sulphide deposits based on the cumulate textures observed at O'Toole, in other massive Ni-sulphide deposits where gravitational setting of Ni sulphides is considered important (Groves *et al.*, 1979; Marston & Kay, 1980; Naldrett, 1973) and even in deposits where a volcanogenic exhalative

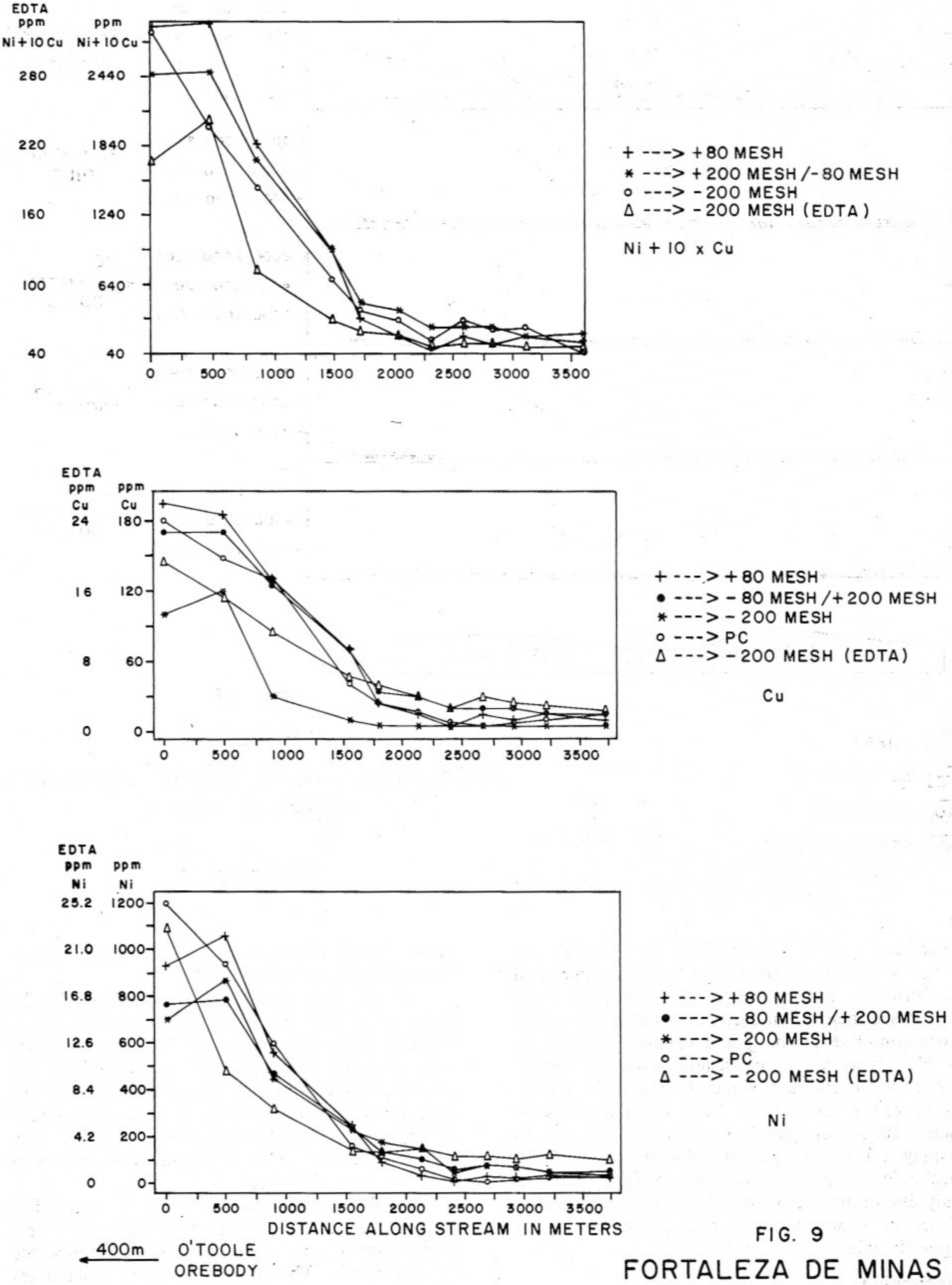


FIG. 9

FORTALEZA DE MINAS
O'TOOLE OREBODY
ORIENTATION SURVEY
STREAM 1

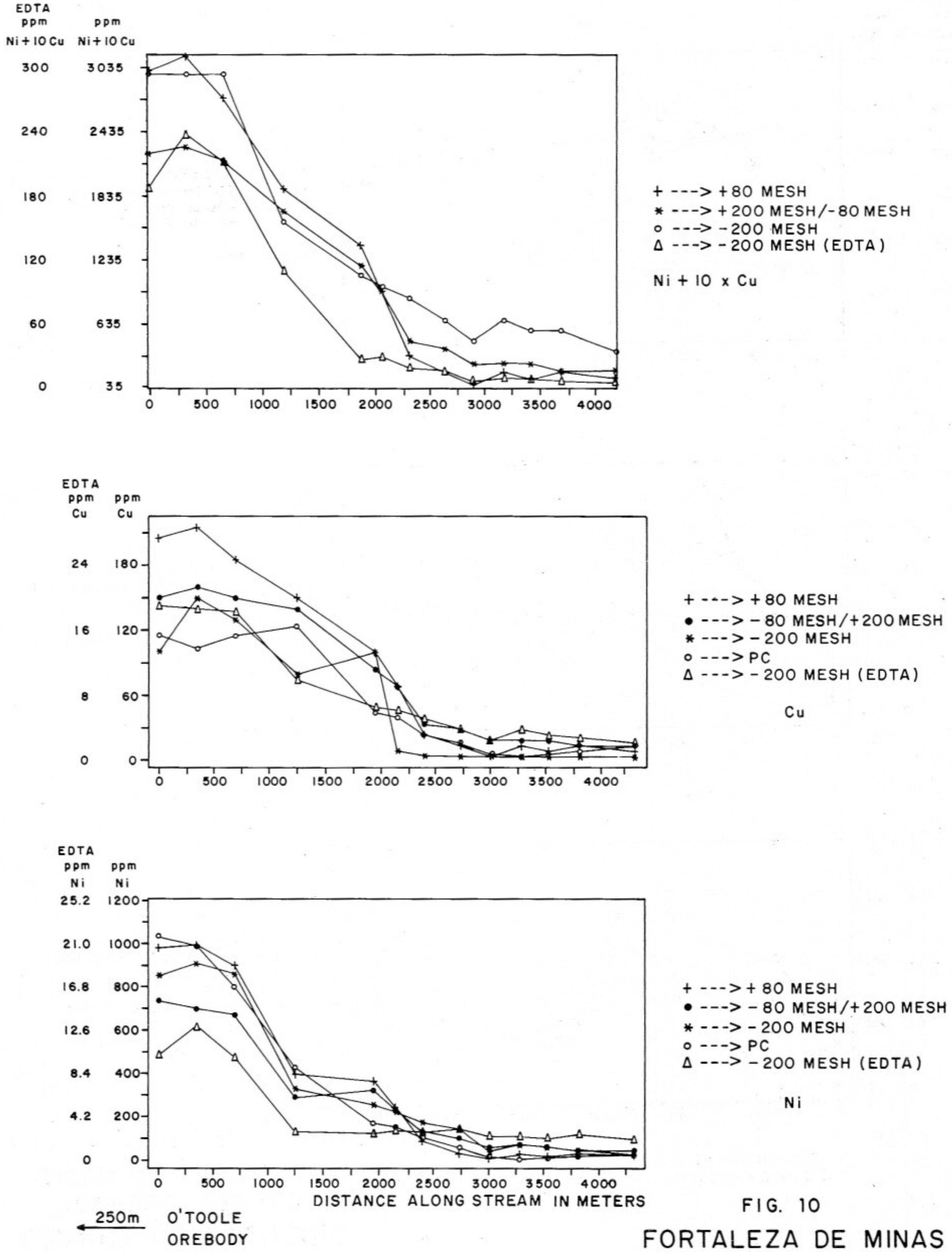


FIG. 10

FORTALEZA DE MINAS
O'TOOLE OREBODY
ORIENTATION SURVEY
STREAM 2

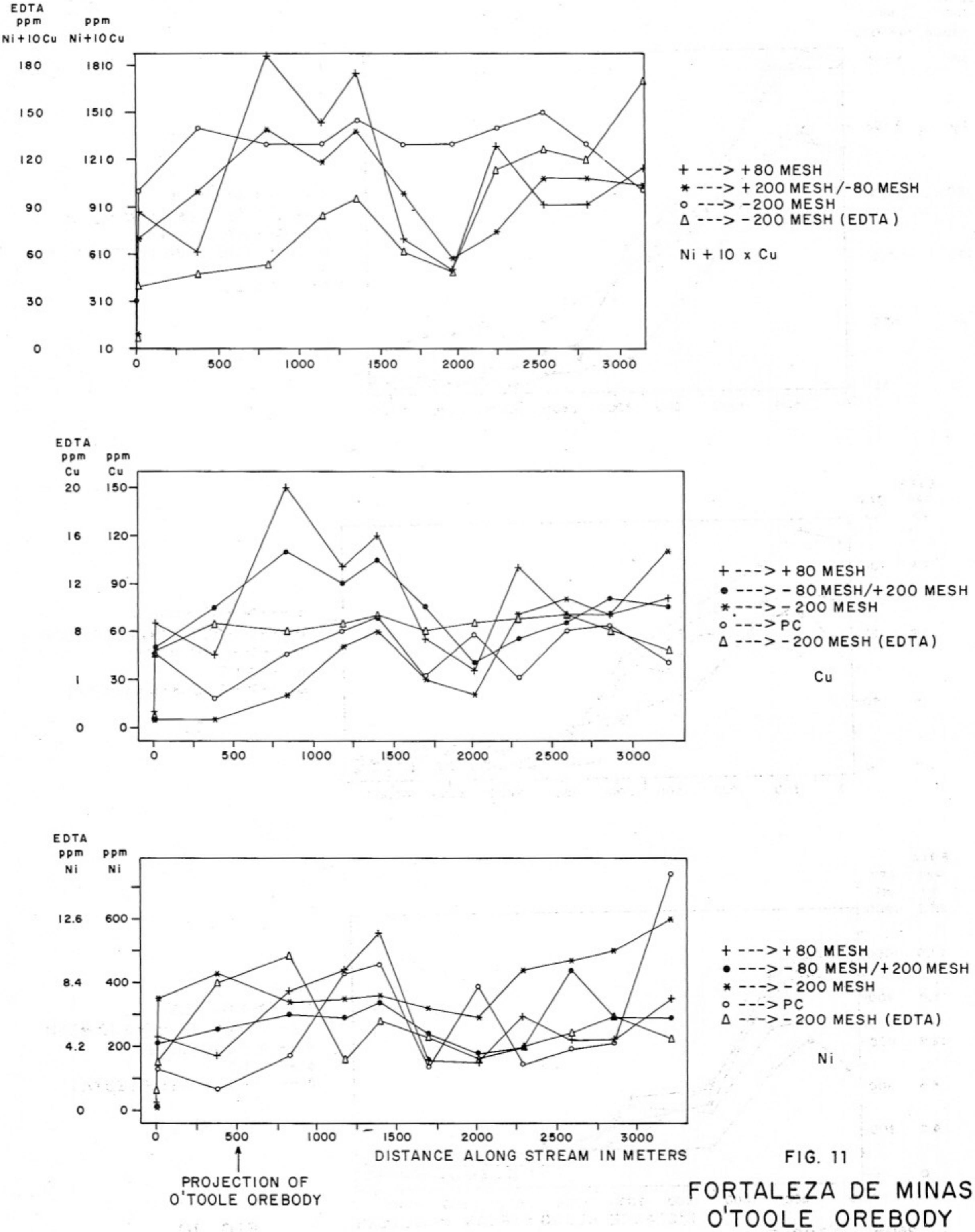


FIG. 11

FORTALEZA DE MINAS
O'TOOLE OREBODY
ORIENTATION SURVEY
STREAM 3

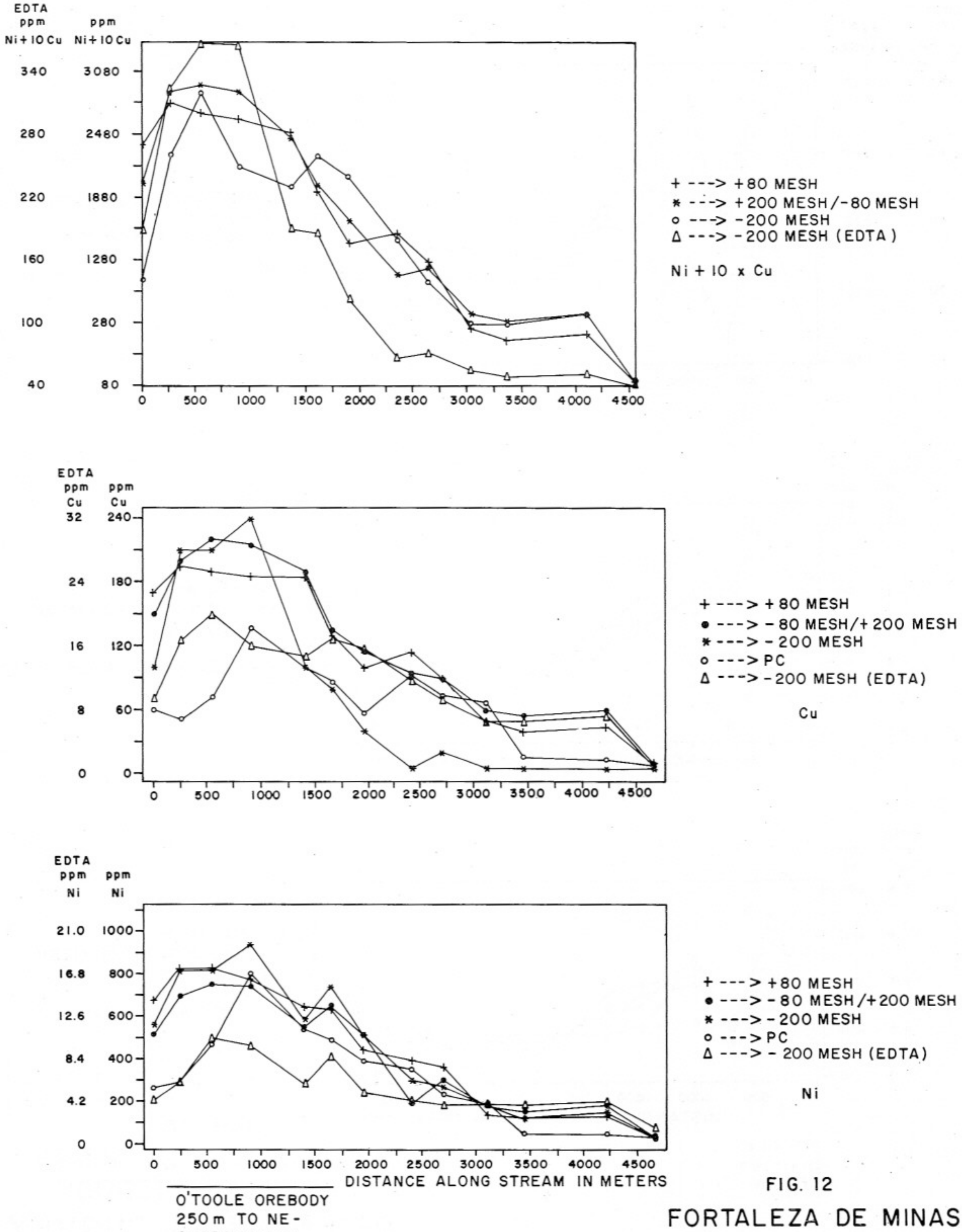


FIG. 12

FORTALEZA DE MINAS
O'TOOLE OREBODY
ORIENTATION SURVEY
STREAM 4

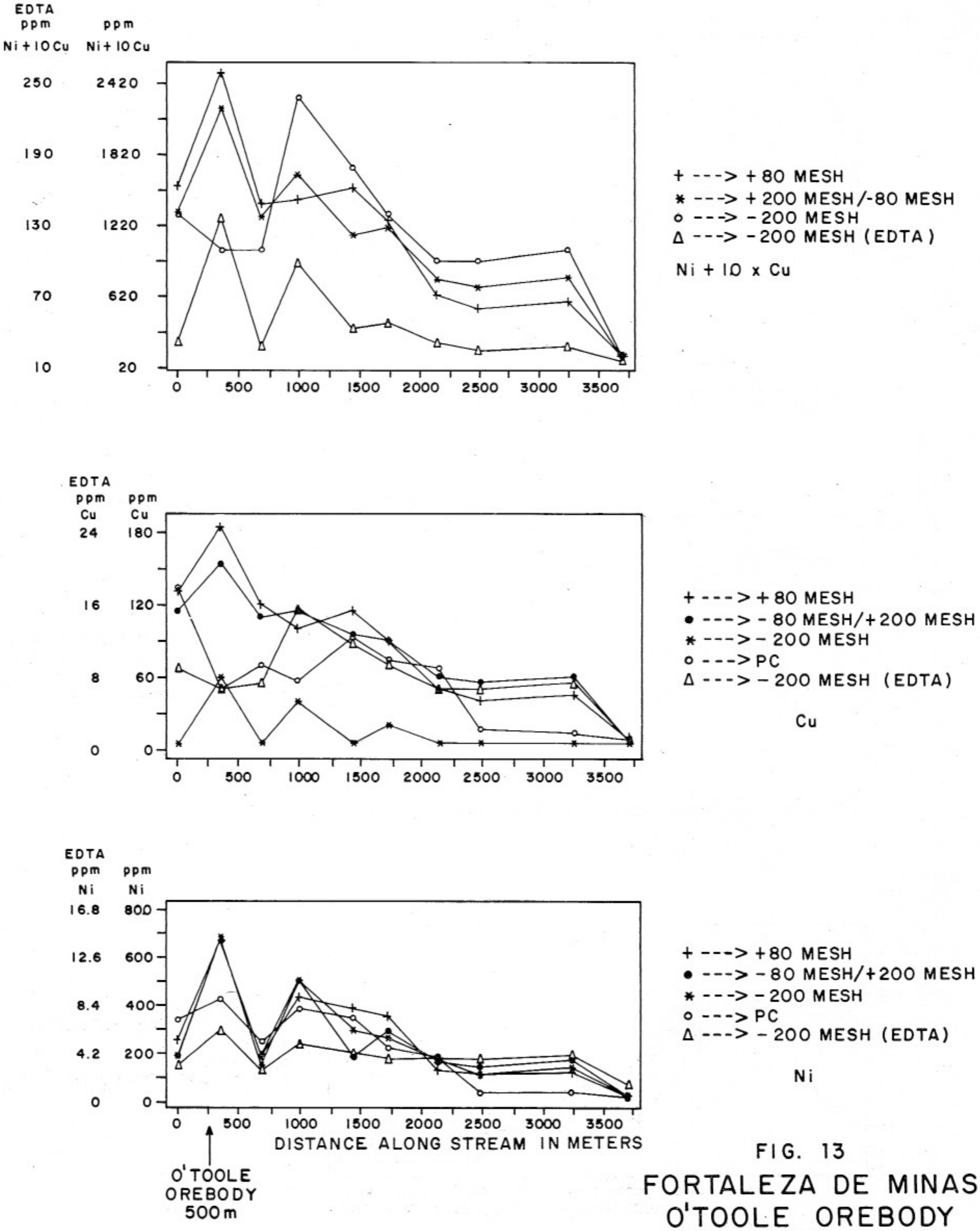


FIG. 13

FORTALEZA DE MINAS

O'TOOLE OREBODY

ORIENTATION SURVEY

STREAM 5

origin is inferred but where a distinct sulphide phase is evident (Robinson & Hutchinson, 1982).

The formation of a separate Ni-sulphide phase represents a distinct, metal-concentrating event in the evolution of an ultramafic volcanic package. The process of metal accumulation by sulphur may be viewed as quite similar to the collecting of metals in forming the Ni-sulphide phase in the Ni-matte fire-assay fusion commonly utilized in the analysis of the platinum group metals (Robert *et al.*, 1971), where the collecting Ni-sulphide phase effectively scavenges metals from the melt and physically settles prior to cooling and crystallization of the silicate slag.

Considered in a geological context, if enough sulphur is present to allow large-scale collecting of Ni and other metals (Cu, Co, PGE's) into a large volume Ni-matte during the cooling of ultramafic igneous rocks, discrete Ni-sulphide mineralization may result.

In fact, the process of preferential partitioning of Ni, Cu, Pt, Pd, and other associated elements into an immiscible sulphide phase is fundamental to the attainment of ore-grade concentrations of sulphide mineralization as has been extensively discussed by Naldrett *et al.* (1984).

The distinction of Ni in sulphide minerals versus Ni in silicate minerals is clearly defined by the presence or absence of associated metals which also partitioned into sulphides during crystallization of ultramafic volcanics hosting Ni ores. It is the presence or absence of these associated metals which geochemically distinguish Ni anomalies related to sulphide ores from Ni anomalies unrelated to sulphide ores, whether in fresh rock, weathered ironstones, soils, or stream drainages.

CONCLUSIONS

The geochemical orientation survey conducted at the Fortaleza de Minas O'Toole Ni deposit demonstrates that the metal response from this sulphide orebody is a response in Ni plus associated chalcophile elements thought to have partitioned into a sulphide phase during crystallization of ultramafic magma. The geochemical signature in ironstones, soils, drainage and vegetation samples is much improved by the use of Ni plus associated Cu versus the use of Ni alone. Associations of Ni and Cu or Ni, Cu, and platinum group elements focus on Ni-sulphide mineralization whereas Ni used alone yields unfocused anomalies related not only to Ni-sulphides but to the ubiquitous Ni-enriched ultramafic igneous rocks of the area.

The use of EDTA-extractible Ni and Cu aids in the evaluation of soil and stream sediment anomalies and improves resolution of aqua regia digestion Ni-Cu anomalies related to Ni-sulphide mineralization. Strong acid leaching of Ni from the O'Toole gossan eliminates EDTA cold-extractible Ni anomalies from soil but disperses EDTA extractible Ni to the surrounding drainages where anomalies are manifest. The chemical stability of Cu within the acid gossan-forming weathering environment, probably due to iron oxide complexing, yields EDTA cold-extractible Cu anomalies over the O'Toole gossan.

In exploration for massive Ni-sulphide deposits in this region, stream drainage sampling, soil sampling, and ironstone evaluation may all be effectively applied. In stream drainage surveys, +80 mesh sediments run for Ni and Cu by aqua regia/A.A. along with −200 mesh sediments run for Ni by EDTA/A.A. appear to best define mineralization. In soil surveys, aqua regia digested Ni and Cu together with EDTA extracted Ni and Cu are believed to most effectively identify ore and discriminate against non-ore related Ni anomalies. In ironstone evaluation, traditional Ni-gossan discrimination techniques appear to function effectively in this humid tropical weathering environment.

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