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GEOLOGY AND GEOCHEMISTRY OF A PART OF THE ABLA FORMATION AT JABAL RUMUR KINGDOM OF SAUDI ARABIA

by

Paul K. Theobald, Jr., and Charles E. Thompson
U. S. Geological Survey

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PREFACE

In 1963, in response to a request from the Ministry of Petroleum and Mineral Resources, the Saudi Arabian Government and the U. S. Geological Survey, U. S. Department of the Interior, with the approval of the U. S. Department of State, undertook a joint and cooperative effort to map and evaluate the mineral potential of central and western Saudi Arabia. The results of this program are being released in USGS open files in the United States and are also available in the Library of the Ministry of Petroleum and Mineral Resources. Also on open file in that office is a large amount of material, in the form of unpublished manuscripts, maps, field notes, drill logs, annotated aerial photographs, etc., that has resulted from other previous geologic work by Saudi Arabian government agencies. The Government of Saudi Arabia makes this information available to interested persons, and has set up a liberal mining code which is included in "Mineral Resources of Saudi Arabia, a Guide for Investment and Development," published in 1965 as Bulletin 1 of the Ministry of Petroleum and Mineral Resources, Directorate General of Mineral Resources, Jiddah, Saudi Arabia.

GEOLOGY AND GEOCHEMISTRY OF A PART OF THE ABLA FORMATION AT JABAL RUMUR, KINGDOM OF SAUDI ARABIA

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Introduction

The area referred to here as Jabal Rumur comprises about 1-1/2 square kilometers in the Abla Formation in the extreme southeast corner of the Southern Hijaz quadrangle (Brown and others, 1962), Kingdom of Saudi Arabia. The area is west of Wadi Ranyah and south of Wadi Qirshah along the road connecting Al Aqiq with the ancient mine site of Ablah and with points farther south along Wadi Shuwas. Topographically the outcrop area of the Abla Formation in this vicinity is split by a medial ridge of syenite. The area of reference extends, generally, from the crest of this medial ridge eastward to the bordering fault on the east side of the formation.

The area was mapped and sampled June 24 through July 24, 1964, at the suggestion of G. F. Brown and Victor Kahr who suspected copper mineralization in the Abla Formation. Kahr had trenched one malachite-rich zone at the base of the andesite flows (the single prospect shown on figure 1). The geologic map and sample site locations were made by Theobald on overlays of the KLM Mining sites series of aerial photographs for the Ablah-Muckahal area. Photos providing the base are: run 1 number 277, and run 2 number 39. The base is an uncontrolled mosaic compiled directly from the photo overlays.

The samples were collected and prepared by Hamad Marsuq al Mutair. The sample localities are shown on figure 1, where it may be seen that the majority, represented by small circles, are in wadi sediment. Ninety-two samples of wadi sediment were sieved through 30 and 80 mesh sieves, the material coarser than 30 and that finer than 80 mesh being discarded. Two samples, 9603 and 9605, were collected from the major feldspathic intrusive rocks for use in the isotope laboratory of the Directorate General of Mineral Resources, Jiddah. Four samples of the breccia zone beneath the andesite flows, numbers 9588, 9611, 9612, and 9613, were collected to assess the copper content of this zone. One specimen of native copper, number 9561, was located and collected by Hamad Marsuq for the mineral collections of the Ministry of Petroleum and Mineral Resources, Kingdom of Saudi Arabia. On figure 1, only the last three digits of the sample numbers

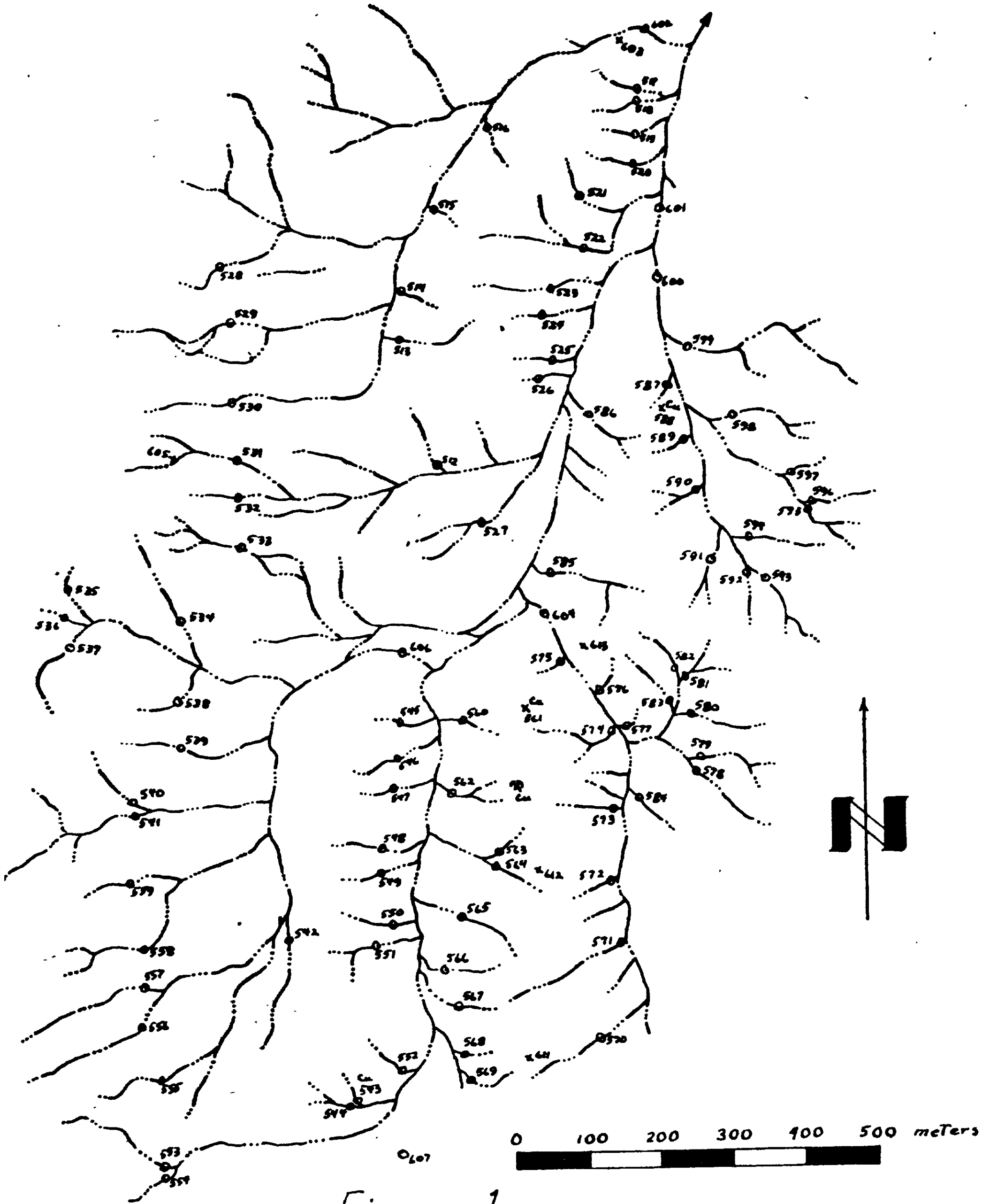

Figure 1
Location of samples and visible occurrences of copper minerals at Jabal Rumur

are shown, and this convention is also used in the following text. All samples are in the 9000 series.

The samples of the breccia zone and wadi sediment, after grinding, were analysed by Thompson in the laboratories of the Directorate General of Mineral Resources. A total of 27 elements were sought by semiquantitative spectrographic analysis, and four elements were sought by rapid wet chemical techniques. Mercury was determined instrumentally.

Archaeology

There is little evidence of cultural features predating the current Bedouin inhabitants of the immediate area of study. No evidence of early mining was uncovered. Near localities 523 and 584, fitted dimension stones are arranged in the form of building foundations providing the only direct evidence of early inhabitants. At locality 523 the single large enclosure is on the pediment surface in the valley floor. At locality 584 several smaller building sites and probably a monument are located near the divide.

Geology

The lithologic units exposed in the area studied (figure 2) consist of a sequence of sedimentary rocks which is part of the Abla Formation and here ranges in composition from shale to conglomerate. A contorted limestone lens is exposed in this sequence in the southeast corner of the area studied, and continuous limestone beds are present in the sequence west of the area studied. A pair of andesite flows are present in the upper part of the sequence and beneath them there are fairly common andesite dikes and sills. Felsite dikes disrupt the sedimentary sequence to the east of the andesite flows, and feldspathic granite and plagioclase porphyry sills inflate the sedimentary sequence in the middle part of the area. A stock of hornblende syenite intrudes the sequence along the west margin of the area, and a single rhyolite dike cuts the andesite flows in the northern part of the area. The sedimentary sequence terminates to the east against a broad fault zone which is commonly marked by a coarse crystalline-carbonate vein. East of the fault mildly metamorphosed quartzite, diorite, and limestone are exposed.

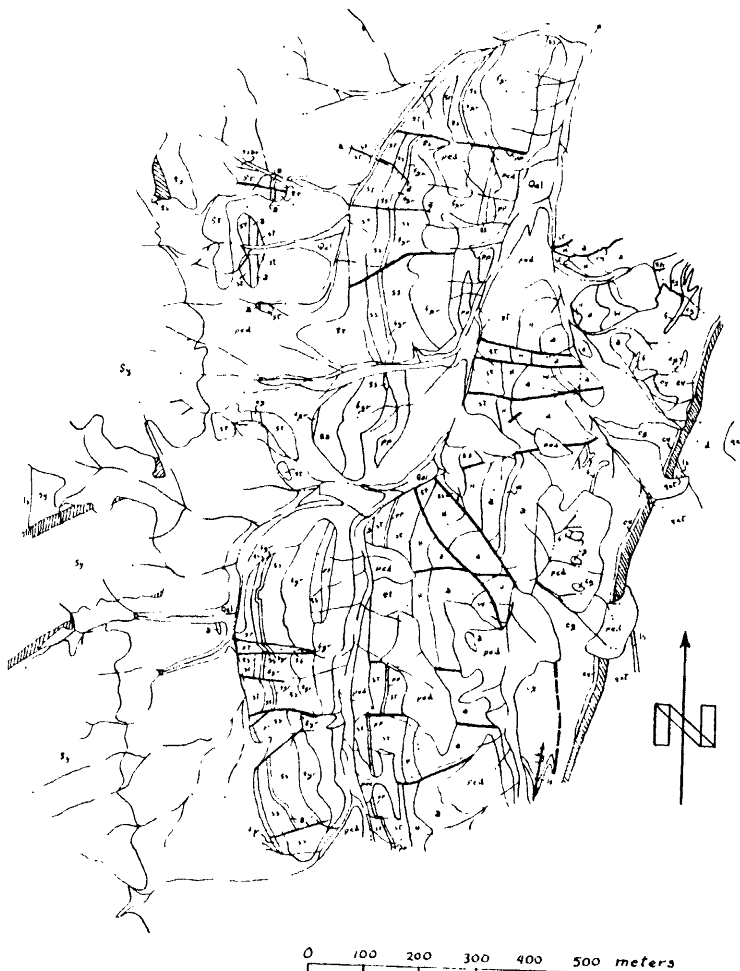

Figure 2.
Geologic map of the Abla formation at Jabal Rumur

A generalized stratigraphic sequence may be defined for the Abla Formation despite the jumbled, blocky structural pattern. The first unit to the east of the syenite mass, the lowest unit whose position in the sequence is known, is a red, laminated siltstone or fine-grained sandstone. White, bleached spots 8 to 15 mm in diameter are locally common. The few lenses of granule conglomerate generally have a light greenish hue. A unit of gray sandstone and conglomeratic sandstone overlies the siltstone. Although no angular discordance has been recognized, the general presence of a ledge of conglomerate at the base of the sandstones suggests at least a disconformity between the siltstone and sandstone. The sandstone is commonly crossbedded and the bedding units are more gross and uneven than those in the siltstone. One minor occurrence of malachite was found in the sandstone near a fault occupied by an andesite dike at the south edge of the area.

Another sequence of siltstone and conglomerate, in which conglomerate is fairly common, rests on the sandstone. At the one locality where the contact is exposed, near the middle of figure 2, the siltstone has a basal conglomerate that truncates the bedding of the underlying sandstone in an angular unconformity of about 20 degrees.

Altered and deformed graywacke rests on the upper siltstone unit at what appears to be another disconformity. The graywacke ranges in grain size from sandstone to fine-grained conglomerate and in color from reddish brown to greenish brown. The greenish hue results from the abundance of chlorite and what has been tentatively identified in the field as glauconite. The brown and red hues result from hematite, most of which appears to be secondary. Most of the unit is brecciated, and the brecciation increases upward. Locally the brecciation has a prismatic structure similar to prismatic structures found in soils. The amount of hematite increases upward and is accompanied by calcite. The top of the unit is irregular and at least locally is composed of massive hematite with coarse-crystalline calcite which resembles a fossil laterite. Almost everywhere the top of the unit is thoroughly brecciated and mixed into the brecciated base of the overlying andesite flows. Malachite is a fairly common accessory stain in the hematite-rich breccias.

At least two andesite flows were extruded on the graywacke. These are separated by an irregular and discontinuous unit of graywacke similar in appearance to the unit beneath the flows, including brecciation and hematite enrichment. The bases of the flows are brecciated and the tops are porphyritic and vesicular. Locally a scoriaceous mass is preserved at the top of the lower flow. Hematite is common throughout the flows where it seals fractures and fills breccias. Malachite locally accompanies the hematite. Hematite- and malachite-sealed breccia zones are particularly common in the vicinity of locality 561 (figure 1), and at this locality Hamad Marsuq dug from one of the minor breccia zones a sheet of native copper up to a centimeter thick and several centimeters across.

The unit above the andesite flows, extending east to the border fault, is badly deformed composite in which conglomeratic layers appear to predominate. In the vicinity of locality 571, in the southern part of the area, a gray to buff sandstone rests on the andesite, whereas to the north, at the head of the drainage above locality 599, a thin red shale rests on the andesite. At most localities, however, the unit shown on figure 2 as conglomerate is a brown, sheared relic of a sequence of conglomerate, sandstone, and siltstone. The shearing increases to the east toward the border fault to which it is evidently related. Only locally along the western part of the outcrop area is the original sedimentary lithology sufficiently preserved for identification. The metamorphism of this unit is dynamic; no evidence of recrystallization was uncovered. In the extreme southern part of the area a thin bed of limestone provides the best evidence of the nature of the deformation. It is contorted into a tight series of overturned chevron folds on both a large and small scale. Corrugations of the bedding surfaces are shear folds, and in aggregate these lead to the outcrop pattern shown on figure 2.

A thin, persistant bed of limestone borders the syenite on the west for the entire length of the belt mapped, but this limestone is only shown near the middle of the map. The intense white outcrop of the limestone, and particularly the hogback-forming bed of limestone farther to the west, are clearly visible on the aerial photographs. The position of this limestone with respect to the sedimentary sequence just described is unknown.

A variety of igneous rocks intrude the sedimentary sequence. All are at least locally discordant, but the general sill-like nature of the major masses and spacial separation of the minor dikes precludes establishing the relative ages within the suite. Only the thin andesite dikes were seen to cut the older feldspathic granite. All of the igneous rocks appear to be feldspathic and are probably of an alkaline clan. Petrographic studies have not been made so varietal designations are strictly a field classification.

The largest of the igneous masses is the syenite forming the medial range of rugged, high hills in the otherwise subdued hogback and questa topography of the Abla Formation. Typically the syenite is a light gray, equigranular, granitic aggregate of what appears to be sodic plagioclase with varietal hornblende. Its structure is normally massive. Near the east contact of the mass, fine-grained, porphyritic varieties evidently mark a broad zone of chilling in which a strong flow foliation and grooving define a flow pattern generally conformable with the overlying sedimentary rocks. The contact is buried everywhere beneath the blanket of gravels shed by the rugged core of the mass. The west contact was not examined outside of the limited outcrop of limestone shown on figure 2. At this locality it appears to be conformable though the relations are confused by complex faulting. In general, the limestone is nearly vertical, suggesting that, though conformable, the sedimentary rocks along the west contact were sharply folded during intrusion. The evidence favors a lacolithic style of emplacement.

The feldspathic granite supports a series of hogbacks and questas traversing the middle of the area studied. The rock weathers to a strong red color thus providing the name used by the local Bedouin inhabitants. The rock is extensively altered, and only a few of the primary constituents can be recognized. The principal constituent is fairly coarse-grained, pink potassium feldspar. Plagioclase and relics of a presumed mafic varietal mineral can be recognized locally. Quartz is sparse or absent. Unusual accessory minerals include fluorite and possibly molybdenite. On weathering, the red coloration of the feldspar is intensified and commonly a quasi-orbicular structure is developed. The feldspathic granite forms two sills, the larger of which is higher in the section than the smaller and supports the hogback. The smaller forms a secondary ledge in the face of the hogback. At several places the lower sill may be seen to change stratigraphic position, establishing the intrusive nature of the rock even though the textural impression is that of metasomatic emplacement. Both sills are cut by andesite dikes, providing the only evidence of relative ages in the igneous suite.

Plagioclase porphyry is exposed at the base of the dip slope of the hogback on the feldspathic granite and a thinner sill of the porphyry is exposed along the lower slopes below the andesite flows. The rock is dark gray where weathered and has a reddish hue on intermediate-fresh surfaces. The outcrop is generally subdued, the rock is only a little more resistant than the enclosing sediments. The most conspicuous feature of the rock is the clear to milky white, zoned plagioclase phenocrysts up to a centimeter across. These are set in an aphanitic to very finely crystalline groundmass that constitutes the bulk of the rock. The manner of intrusion of the larger mass of plagioclase porphyry, lying along the west side of the valley east of the feldspathic granite, is not known. Where contacts are seen, they are conformable, but from the distribution of outcrops it is clear that the rock is not at a consistent stratigraphic position. The smaller sheet is clearly a sill in most outcrops, but it abruptly changes stratigraphic position at several localities and is absent in several well exposed sections of the host sequence.

Andesite dikes and irregular, discontinuous sills are common in the interval beneath the andesite flows and above the syenite. These are generally similar to the flows but are finer grained and lack the structures characteristic of extrusion. The rock is dark gray and generally aphanitic. It commonly weathers to black spherical masses in a yellow-stained matrix. The general similarity of the dikes and flows and the presence of the dikes only below the flows suggest that the dikes may be feeders to the flows. However, clean dikes of andesite cutting the feldspathic granite require a considerable time interval between these rocks. This time interval is not in harmony with the thin sedimentary sequence separating the feldspathic granite and the flows, unless the unconformities at the base of the upper siltstone unit and at the base of the flows are major breaks in the sequence.

Two felsic rocks intrude the Abla Formation in the northeastern part of the area. The felsite only intrudes the conglomeratic unit, where it forms highly irregular, discontinuous masses that may be phacolithic. The rock is red, very fine-grained, and slightly porphyritic. The phenocrysts are small grains of feldspar. The rhyolite forms a single dike, about 1 meter thick, that has a sinuous course across the hematite-rich graywacke and andesite flows. It apparently fills one of two parallel and closely spaced minor faults. Beneath the yellow-weathered surface the rock is brown and slightly prophyritic. Phenocrysts are quartz and feldspar.

Three lithologic units were mapped to the east of the border fault in order to fill out drainage basins represented by samples of wadi sediment, but the rocks were not examined carefully. All three units have been mildly metamorphosed, and evidently represent a sequence of rocks older than the Abla Formation.

Structure of the area is complex, and despite the excellent stratigraphic control offered by the numerous, relatively thin and continuous rock units, interpolation of the fault zones through the areas covered by pediment gravels is largely by guess. This is particularly true of the interrelations between the east-northeast-trending faults and the northwest-trending fault zone (figure 3).

The dip of bedding planes in the sedimentary sequence is fairly consistently 30 to 50 degrees to the east. As suggested by the outcrop patterns of figure 2, the strike of the bedding swings from northwesterly in the southern part of the area to north or northeasterly in the northern part of the area defining a broad synclinal structure plunging to the east. Local irregularities in the trend of bedding are common adjacent to the fault zones, and, as noted earlier, the bedding in the uppermost, conglomeratic sequence is contorted and often obliterated by small-scale shear folding related to the border fault zone.

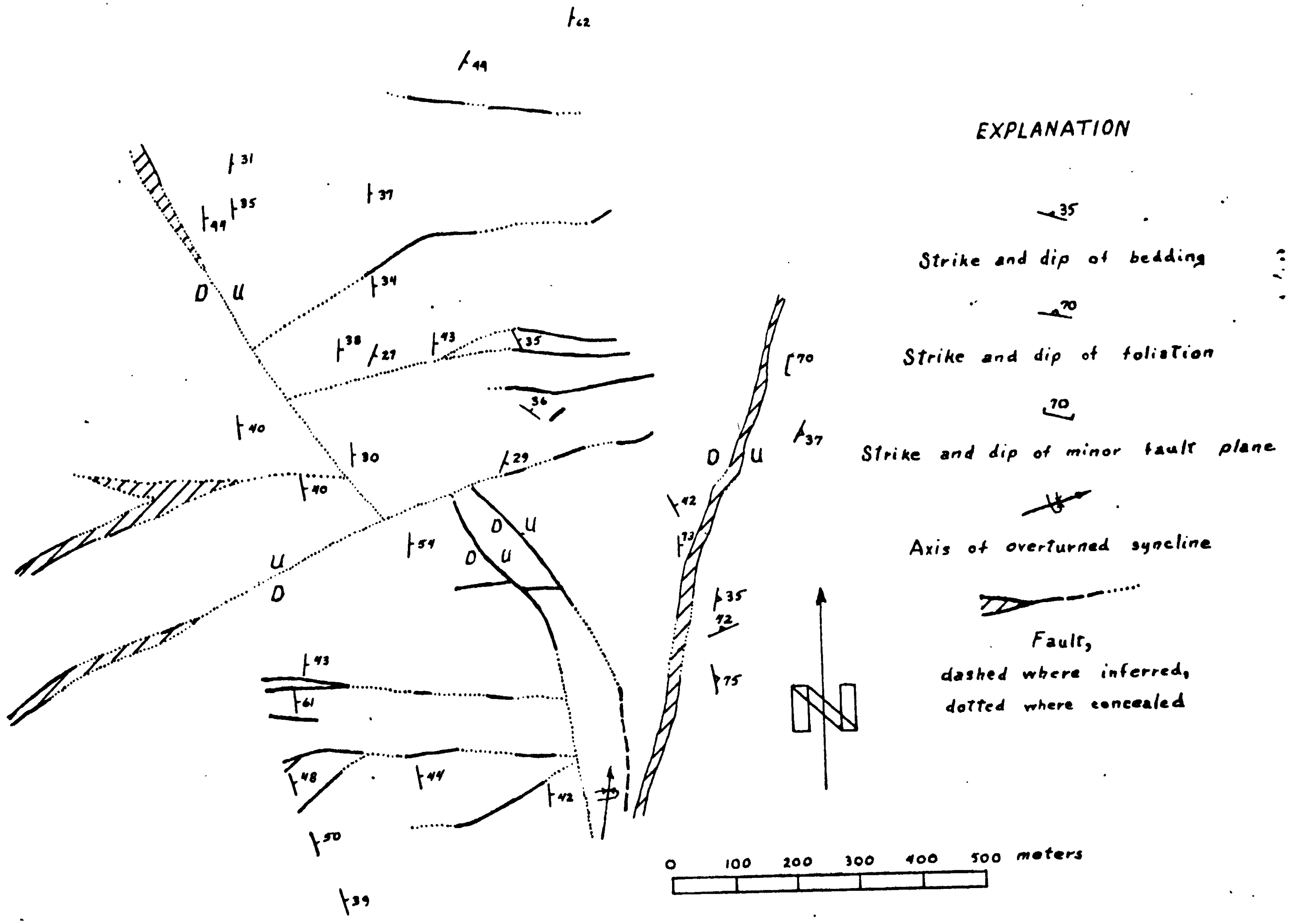

Figure 3.
Structure of the Abla formation at Jabal Rumur

The dominant structural feature is the border fault zone which is a fairly regular east-northeast-trending, steep, east-dipping reverse fault. The border fault is matched by a similar fault about a kilometer to the west of the area studied. The two faults bound the graben in which the unmetamorphosed Abla Formation is preserved in an otherwise metamorphic terrane. The border fault zone as mapped is a fairly well defined zone of gouge and mylonite. A narrow zone of closely spaced shears marks the gradation from this material to the crystalline rocks on the east. The main zone of movement is bounded on the west by a vein of coarsely crystalline carbonate that, from its brown color, is presumably rich in siderite or other members of the ankerite group of minerals. To the west of the vein there is a broad zone of shear folding as noted earlier.

The mesh of faults within the graben would appear to be a conjugate set of block faults along which the foundering block adjusted to the imposed strain from the bordering faults. The resultant of the senses of movement along these minor faults is down to the south. The visual effect on the outcrop pattern of the faults and prevailing east dip produces an eastward stepping pattern to the north which greatly exaggerates the pattern derived from the broad east-plunging synclinal structure defined by bedding.

Areal geochemistry

Spectrographic and chemical analyses of the samples of wadi sediment are summarized in figures 4 and 5. Of the 29 elements sought, 24 were present in detectable quantities. Boron and arsenic vary little about the modal values of 20 ppm (parts per million) and mercury has an average of 10 to 15 ppb (parts per billion). The remaining 21 elements vary systematically with the lithologies contributing to the drainage basins. From a comparison of the chemical and spectrographic analyses for copper, zinc, and molybdenum it is clear that the two methods of analysis have produced similar results. Inasmuch as the majority of the elements are available from spectrographic analysis only, the spectrographic results will be given preference in the interpretation that follows.

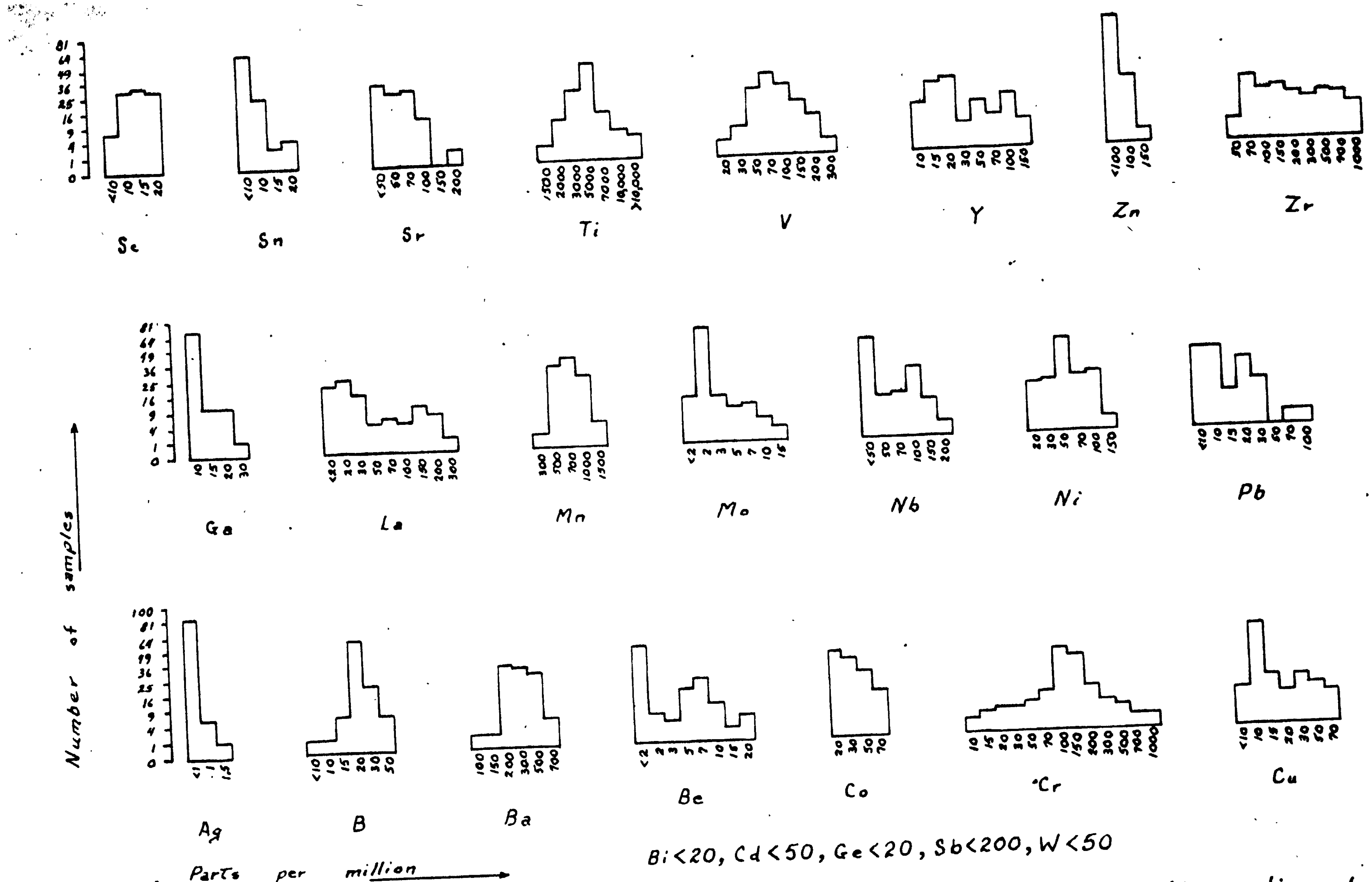

Figure 4.
Summary of spectrographic analyses of 92 samples of wadi sediment
Abla formation at Jabal Rumur

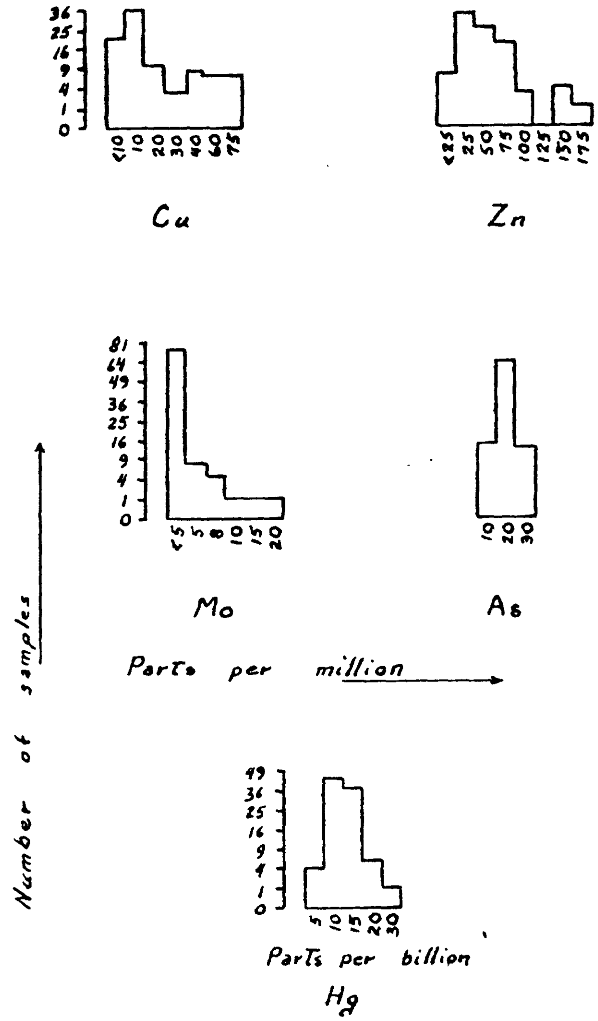

Figure 5.
Summary of chemical analyses of 92 samples of wadi sediment from the Abla formation at Jabal Rumur.

The range exhibited by most of the elements, figure 4, is considerably greater than analytical spread, but maximum amounts are not strongly anomalous for any of the elements. Because copper mineralization was suspected in the area, and copper minerals are indeed common in the hematite-rich breccia and andesite flows, it is surprising that the amount of copper in the wadi sediments does not exceed 70 ppm. In other copper-rich areas of the Arabian shield, as in the vicinity of Mahd adh Dahab, local background is in the vicinity of 70 ppm. Possibly the occurrences of copper minerals may be small, local features of segregation rather than of addition and enrichment.

Several of the other elements are present in much more unusual concentrations than the copper, notably beryllium, lanthanum, molybdenum, niobium, tin, titanium, yttrium, and zirconium. This suite of elements is commonly associated with and concentrated in alkaline igneous rocks. Herein lies the evident explanation for the spread of analyses reported for this suite of samples. In order to illustrate the point, the samples have been divided according to the nature of the dominant igneous rock type in the drainage basin; a division facilitated by the trellis drainage pattern. Admittedly the three dominant types of igneous rock, the hornblende syenite, the feldspathic granite, and the andesite flows, are stratigraphically controlled intrusions; but the suites of elements developed by the division, with the possible exception of the andesite flows, are suites too commonly associated with the igneous rock types and too rarely concentrated in the associated sedimentary rocks to allow more than passing notice of the sediments. In addition to the three divisions based on the dominant igneous rock type, a fourth division is used to cover samples from drainage basins in the conglomerate, the border fault, and the crystalline rocks east of the fault. The border fault appears to be the dominant feature of this division.

Regrouped as outlined above, the data for elements enriched in wadi sediments derived from the hornblende syenite are presented in figure 6. With the exception of manganese and zinc, these elements are the ones commonly enriched in alkaline granites. Again with the exception of manganese and zinc these elements are also

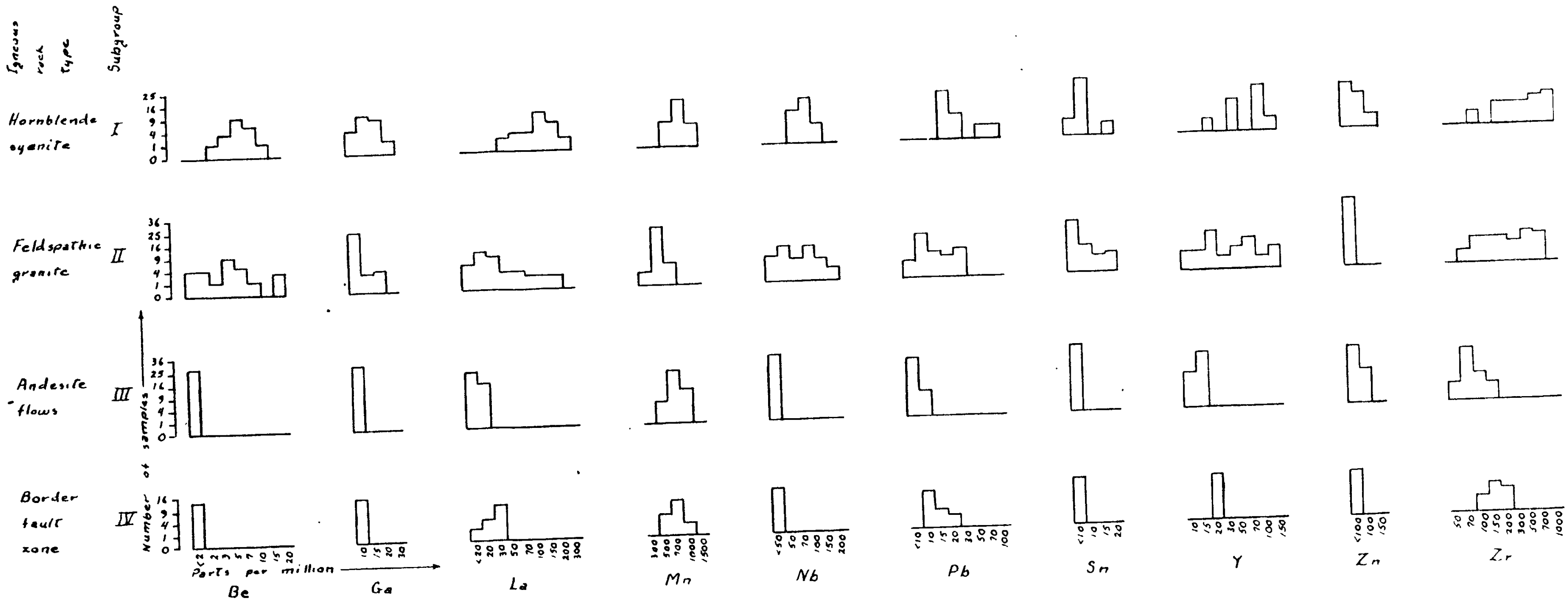

Figure 6.
Distribution of elements enriched in streams draining the hornblende syenite in the Abla formation at Jabal Rumur

copper and zin anomaly is associated with the extension of this same border fault system. It is not possible from the limited data available to establish relatively enriched in the feldspathic granite though the medians are not as high as in the syenite. The dual enrichment further substantiates the alkaline association. Manganese and zinc are commonly associated with the ferride elements, an association substantiated by second highs for these elements in samples derived from the andesite flows and associated rocks.

Silver and molybdenum are enriched in wadis draining the feldspathic granite (figure 7). This is in harmony with the possible presence of accessory molybdenite in the feldspathic granite and the general metasomatic appearance of the rock. Both of these elements are also enriched in the hornblende syenite, thereby further strengthening the association of the two rock types and extending the alkaline-associated suite of elements.

The elements enriched in wadis draining subgroup III, the andesite flows and associated rocks, are the ferrides and strontium (figure 8). The concentration as well as the distribution among the subgroups is about what would be expected in an iron-rich suite of rocks when compared with feldspathic, siliceous, or aluminous rocks. The problem with this subgroup is in assigning the source of the ferrides to a specific rock unit. These elements could have been derived either from the andesite flows or from the hematite-rich zones below and between the flows. Strontium may provide a clue, since its relative enrichment in this group of samples is at least suggestive of residual enrichment in a carbonate-rich weathered zone such as is postulated to explain the hematite enrichment beneath the flows.

The fourth subgroup includes the border fault zone and is relatively rich in barium (figure 7) and, as an enrichment secondary to the third subgroup, strontium (figure 8). These two elements are commonly associated in the outermost zones of hydrothermal systems. In this context they may provide the most interesting variation detected in the samples from the Jabal Rumur area. Some kilometers to the north, in the vicinity of the ancient village and mine of Ablah, a pronounced copper and zin anomaly is associated with the extension of this same border fault system. It is not possible from the limited data available to establish

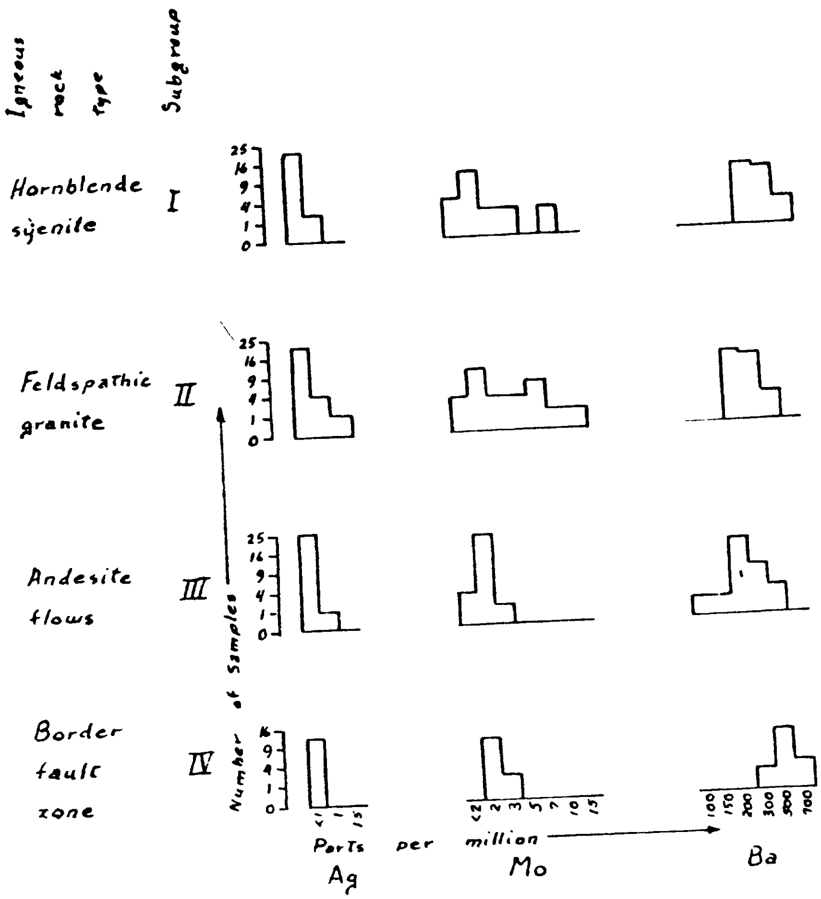

Figure 7.
Distribution of elements enriched in streams draining the feldspathic granite or the border fault zone of the Abla formation at Jabal Rumur

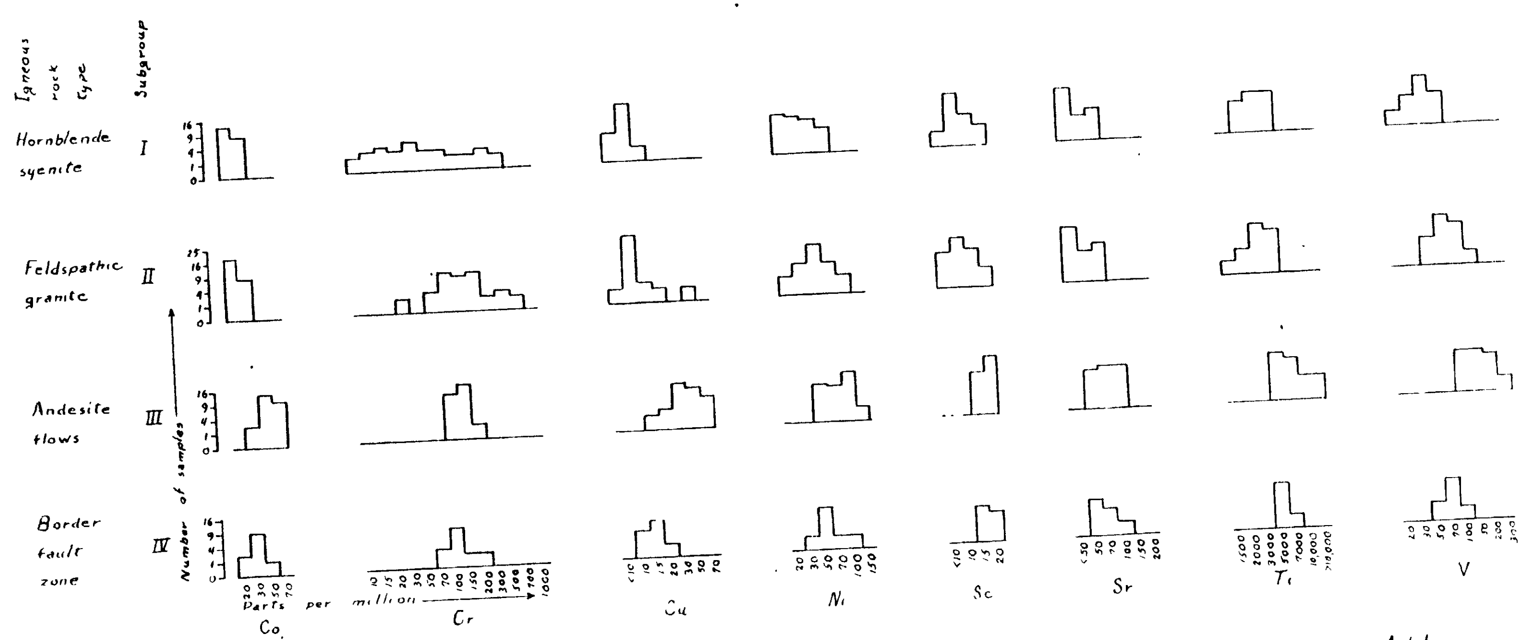

Figure 8.
Distribution of elements in streams draining the andesite flows in the Abla formation at Jabal Rumur

Table 1. -- Distribution of elements among the four lithologic subgroups of the Abla Formation at Jabal Rumur. Elements listed in groups where most abundant. Secondary association shown in paranthesis.

Subgroup 1. Hornblende syenite

Be, Ga, La, Mn, Nb, Pb, Sn, Y, Zn, Zr

(Ba, Mo)

Subgroup 2. Feldspathic granite

Ag, Mo

(Be, Cr, Ga, La, Nb, Pb, Sn, Y, Zr)

Subgroup 3. Andesite flows

Co, Cr, Cu, Ni, Sc, Sr, Ti, V

(Zn)

Subgroup 4. Border fault zone

Ba

(Sc, Sr)

a tie along the fault. If such a tie should exist, the anomaly would indeed be a large one.

The overall range for the elements determined in this suite of samples is not exceptionally great, and the grouping of relatively high or relatively low values suggests that these are normal concentrations to be expected from the rock types involved. The assemblages, summarized in table 1, suggest that the alkaline suite of igneous rocks are the most likely to be associated with economic deposits

The hematite- and carbonate-rich breccia

The hematite-rich zone at the base of the andesite flows includes most of the visible occurrences of copper and is the zone prospected by Victor Kahr. Three samples of this material were collected to determine the composition of this unit. The analytical results, presented in table 2, provide a basis for evaluatic There is, at least locally, more than usual amounts of copper in the unit, but it does not constitute a resource in itself. Comparing table 2 with figure 8 it is seen that most of the ferrides are more concentrated in stream channels draining the general area of outcrop of the breccias and overlying flows than in the breccias themselves. By elimination, the most likely source for the ferrides, other than copper, is in the andesite flows.

Summary and recommendation

Economically, the most promising units of the Abla Formation in the area investigated are the alkaline igneous rocks. Of particular interest is the feldspathic granite, since it has the general appearance of a "wet", late stage of igneous activity that could be a parent to hydrothermal solutions. If hydrothermal deposits were formed, two styles could be expected from the data presented here: (1) silver-lead-zinc deposits of the Samrah type, or (2) greissen deposits of the beryllium-tin-rare earth-molybdenum type. The levels of concentration of these elements within the area of study do not suggest that such deposits are present; the concentrations only suggest a potential. From this evidence we would

Table 2.-- Semiquantitative analyses of three samples of hematite- and carbonate-rich breccia from the Abla Formation at Jabal Rumur. Only those elements detected are shown. Not detected: Ag <1, Be <2, Bi <20, Cd <50, Ge <20, La <20, Mo <2, Nb <50, Pb <10, Sb <200, Sn <10, W <50, Zn <100. [Analyst: C. E. Thompson]

Sample No.		9611	9612	9613
Element	Analytical procedure	Parts per million		
B	Spectrographic	15	10	15
Ba		50	70	30
Co		10	10	15
Cr		100	100	150
Cu		150	20	150
Ga		10	10	15
Mn		500	700	500
Ni		20	30	20
Sc		15	20	15
Sr		70	100	50
Ti		2,000	5,000	7,000
V		50	30	50
Y		10	15	10
Zr		20	20	20
Cu	Wet chemical	150	20	150
Zn		25	25	50
		Parts per billion		
Hg	Instrumental	130	140	60

recommend continued mapping and sampling of the Abla Formation at the same scale used in this work. The belt should be widened to include the entire syenite massif and particular attention should be given to the syenite and to the feldspathic granite. The belt of mapping should continue to include the border fault zone since (1) this is a favorable site for transport of hydrothermal solutions, (2) there is evidence for barium enrichment along the fault, and (3) the fault zone is mineralized farther to the north.

The copper recognized in this area is interpreted from available data to be a residual enrichment in the zone of weathering beneath the andesite flows. Though small, rich pockets were seen and may exist elsewhere along the zone, no deposits of economic size are expected. Organic-rich sediments that could serve as collectors for copper leached from this zone were not seen during this investigation. The recommendation offered above, if followed, would produce an evaluation of copper in this zone, but what is shown here on the presence of copper does not in itself justify further work. Possible hydrotheral deposits of the other elements are the reason for recommending additional investigation of the Abla Formation.

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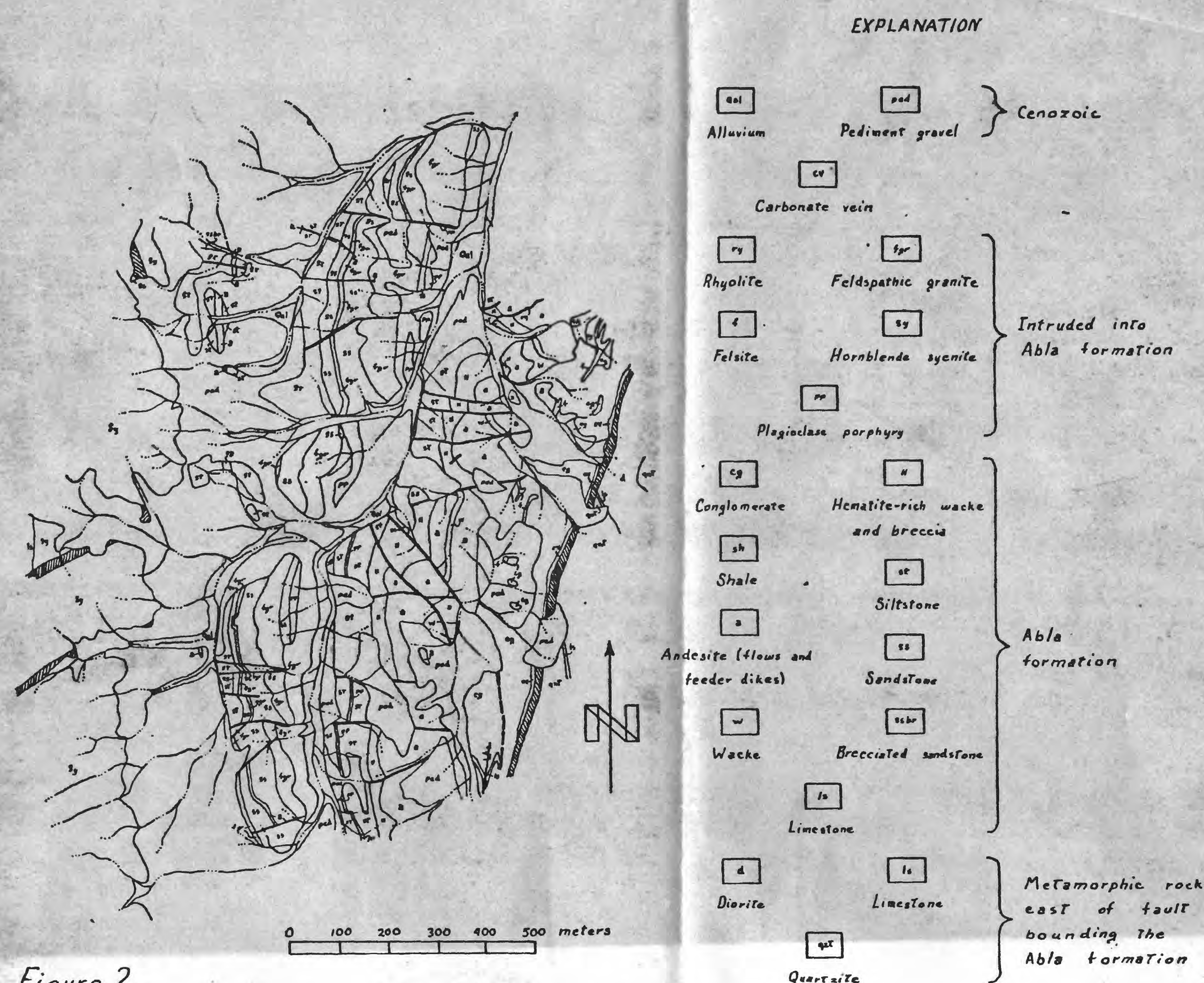

Figure 2.
Geologic map of the Abla formation at Jabal Rumur

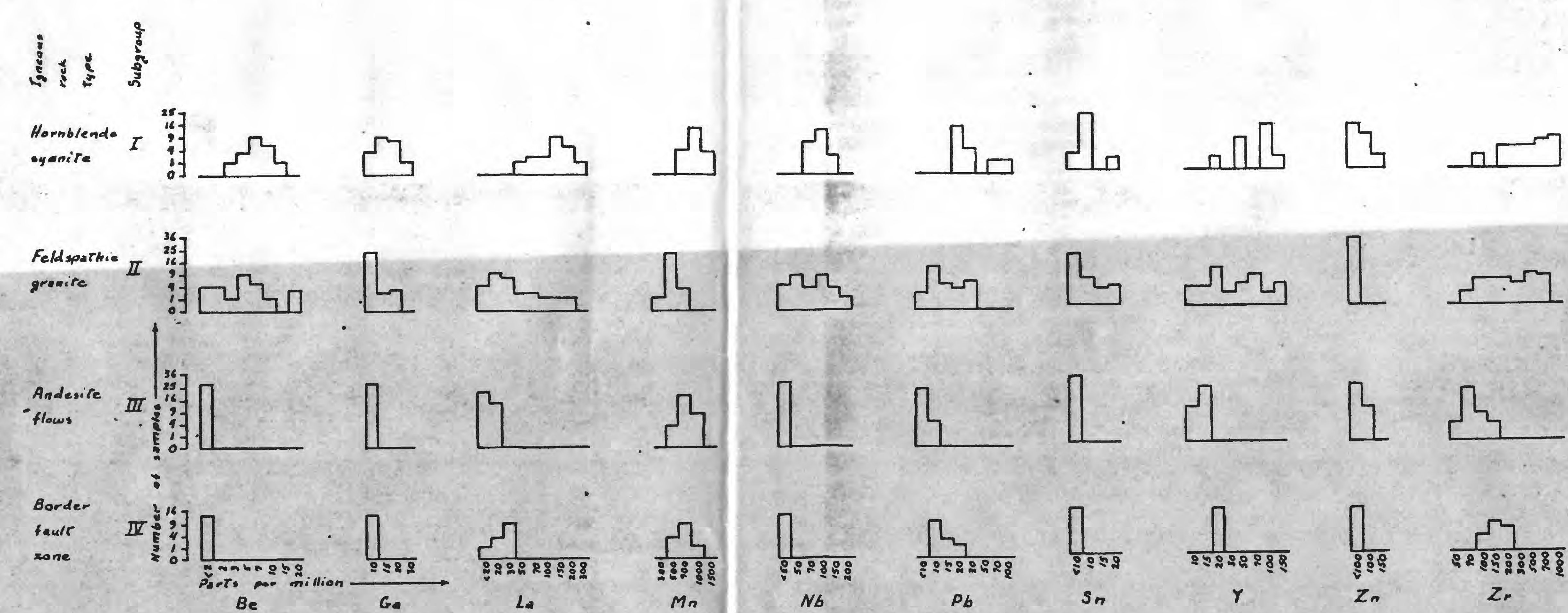

Figure 6.
Distribution of elements enriched in streams draining the hornblende syenite in the Abla formation at Jabal Rumur

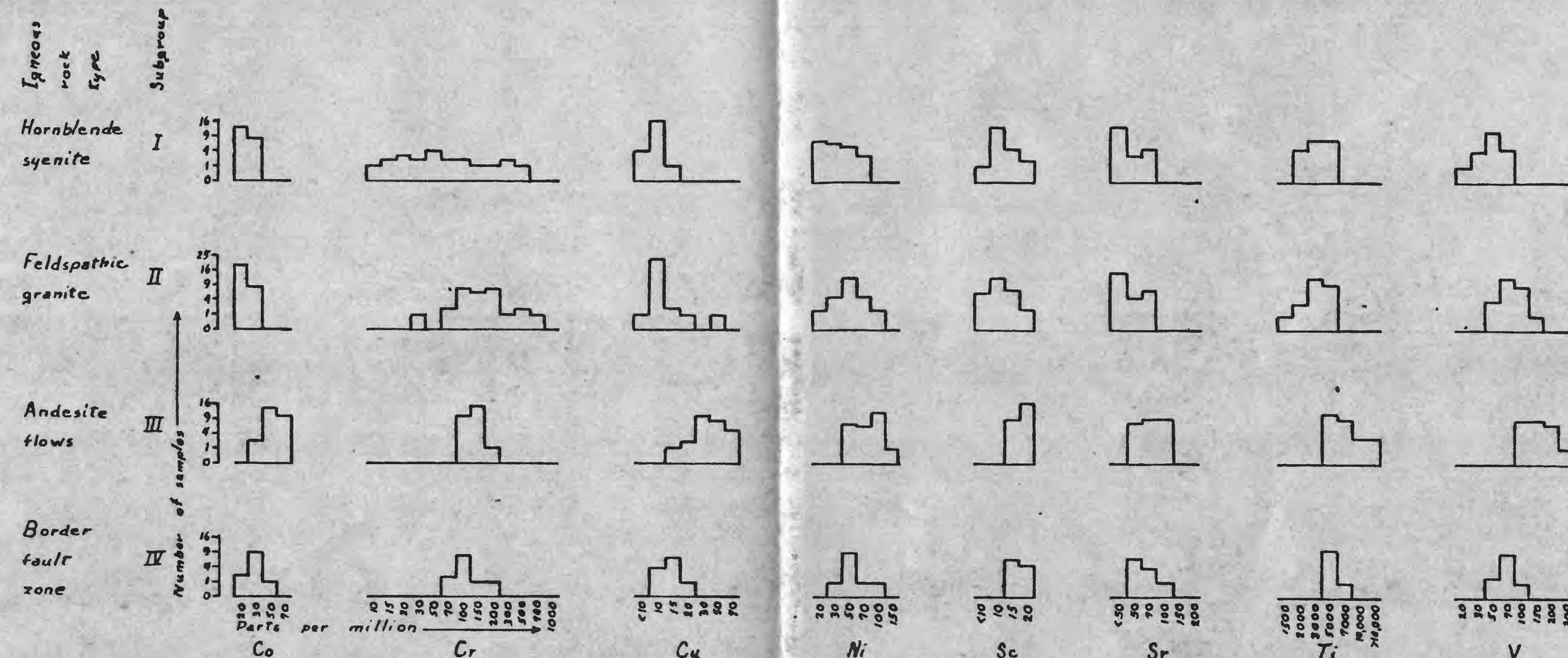

Figure 8.
Distribution of elements in streams draining the andesite flows in the Abla formation at Jabal Rumur