DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Results of a geochemical survey, Aban Al Ahmar Quadrangle, Sheet 25F, Kingdon of Saudi Arabia

by

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RESULTS OF A GEOCHEMICAL SURVEY, ABAN AL AHMAR QUADRANGLE, SHEET 25F, KINGDOM OF SAUDI ARABIA

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ABSTRACT

The interpretation of geochemical data from a regional survey of the Aban al Ahmar quadrangle resulted in the selection of areas for follow-up studies. The results of detailed geochemical studies of these areas, combined with field observation, resulted in the selection of areas of moderate to high mineral resource potential. The most important areas are (1) the Jibal Minyah area, Aban al Asmar area, Jibal Suwaj area, and Nubayah area where tin and tungsten mineralization are associated with Abanat-suite rocks or possible buried Abanat-suite plutons; (2) several areas containing rocks of the Murdama group in the northern part of the quadrangle, the Buqaya al Luaah area, and the Jabal Akkash area where precious- and base-metal mineralization are generally associated with small Idah-suite plutons; and (3) the southern periphery of Jibal Qitan associated with skarn mineralization.

The Aban al Ahmar quadrangle (sheet 25F) lies in the northeastern part of the Proterozoic Arabian Shield. Plots showing the distribution of single elements and factor scores of the regional geochemical data for wadi concentrates were used to select favorable areas for follow-up work. Detailed follow-up studies consisted of the collection of samples of rocks, wadi concentrates, and wadi sediments. The most useful pathfinder elements for precious- and base-metal mineralization are Cu and Pb, and for tin and tungsten mineralization they are Sn, La, Nb, Y, and Be. R-mode factor analysis of the regional geochemical data resulted in two factors that reflect mineralization: precious- and base-metal mineralization; and Abanat-suite lithology and, therefore, tin and tungsten mineralization.

A major problem in the interpretation of the regional geochemical data resulted from incomplete removal of magnetite from the samples prior to analysis. The presence of magnetite can cause anomalous values of Ni, Fe, V, Cu, and Co in samples because of it's ability to incorporate these elements into its structure during magmatic crystallization.

INTRODUCTION

GEOGRAPHIC SETTING

The Aban al Ahmar quadrangle (sheet 25F) occupies 16,560 square km between lat 25°00' and 26°00' N. and long 42°00' and 43°30' E. in the northeastern part of the Proterozoic Arabian Shield of the Kingdom of Saudi Arabia (fig. 1). Buraydah, the nearest city with a commercial airport, is located about 120 km northeast of the center of the quadrangle. Access to the study area (fig. 2) is by a paved highway that runs from Al Madinah through Uqlat aṡ Suqur in the northwest corner of the quadrangle. From Uqlat as Suqur, secondary paved roads, dirt roads, and desert trails provide access to most areas.

The topography of the study area is characterized by a relatively flat peneplain with isolated and grouped inselbergs. The peneplain has an average elevation of 700-900 m and is widely covered with thin deposits of grus, alluvium, and eolian material. Jibal Shawfan, located in the south-central part of the quadrangle, is the highest point, with an elevation of 1,346 m. Aban al Ahmar in the central part of the area and Jibal Timiyah at the western edge of the quadrangle are both about 1,310 m high. Most drainages in the quadrangle are poorly developed and partially filled with eolian sand. Drainages associated with prominent jibals are better developed and contain less eolian material. Wadi ar Rumah traverses the west-central part of the area to the northeast and forms the major drainage for the quadrangle. Wadi al Mahalani and Wadi al Jarir are tributaries of Wadi ar Rumah. All other drainages belong to the Wadi ar Rumah drainage basin. The area has an average annual rainfall of 100 mm (Whitney, 1983), which supports desert-shrub vegetation. The population of the area is sparse, concentrated primarily in small villages and scattered bedouin encampments.

KNOWN MINERAL OCCURRENCES

There are 41 locations within the quadrangle listed in the Mineral Occurrence Documentation System (MODS) of the DMMR, of which 31 are sites of ancient workings and contain gold and(or) silver and base metals. The majority of these sites contain quartz veins located within or near small granodiorite plugs within contact-metamorphosed sandstone (Cole, 1986).

Tungsten, tin, and related elements are found at four MODS locations, with Baid al Jimalah West being the best example of granite-hosted tungsten mineralization in Saudi Arabia (Cole and others, 1981; Lofts, 1982; Cole, 1986).

The other MODS location consists of quartz-fluorite veins containing lanthanum, niobium, and tin in elevated but uneconomic concentrations. These veins are located in peralkalkine granitic rocks and appear to be genetically related to them (Cole, 1986).

PREVIOUS INVESTIGATIONS

A 1:500,000-scale geologic map of the Wadi ar Rimah quadrangle by Bramkamp and others (1963) includes the Aban al Ahmar quadrangle. The U.S. Geological Survey (USGS) has recently produced 1:100,000-scale geologic maps for the following quadrangles: Uqlat as Suqur, sheet 25/42A (Cole, 1985a), Al Abanat,

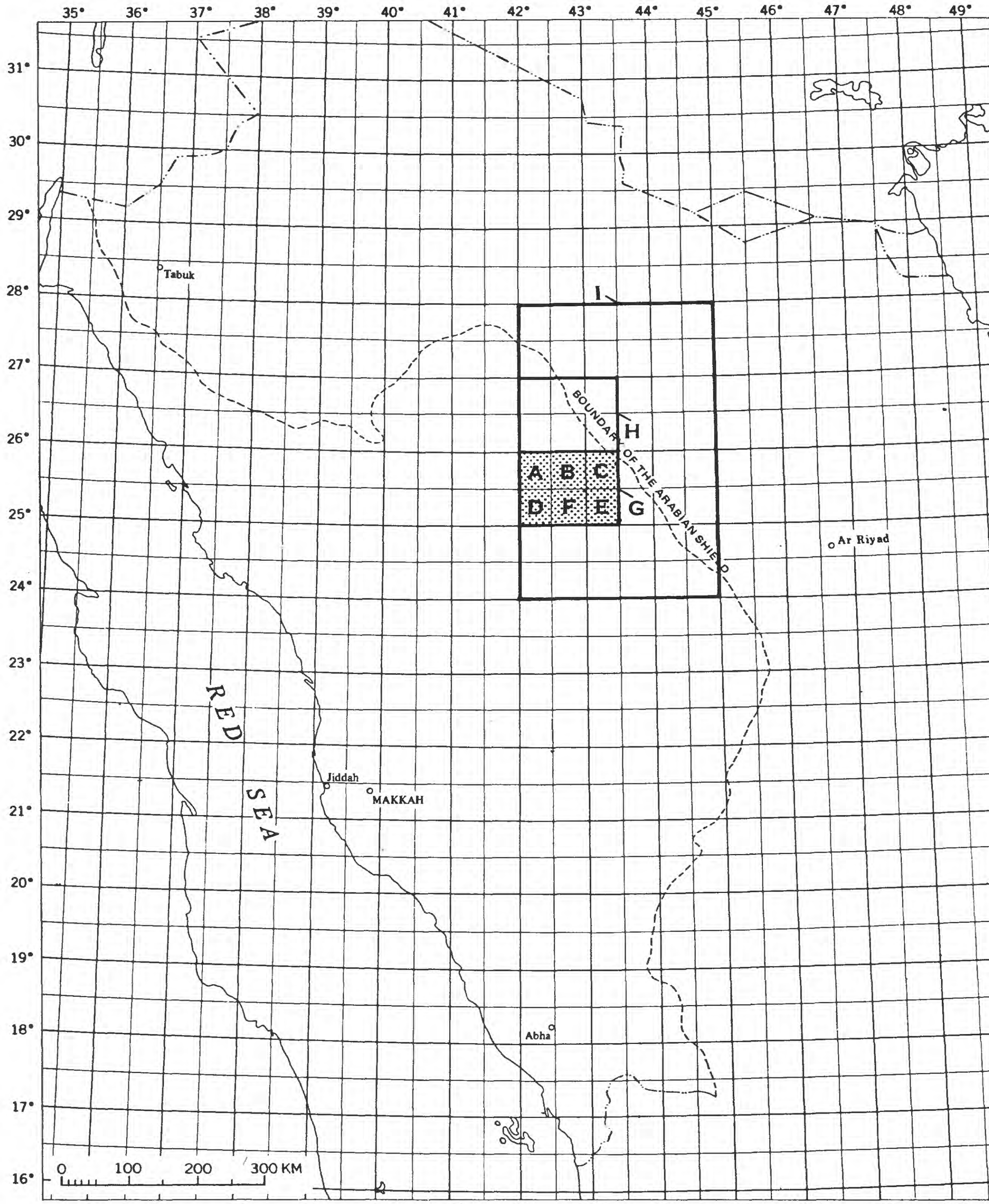

Figure 1.--Index map of western Saudi Arabia showing location of the Aban al Ahmar quadrangle (shaded) and quadrangles referred to in the text: A. Uqlat as Suqur 25/42A (Cole, 1985a); B. Al Abanat 25/42B (Cole, 1985b); C. An Nabhaniyah 25/43A (Cole and Bohannon, 1985); D. Wadi al Jarir 25/42C (Young, 1982); E. Al Jurdhawiyah 25/42D (Cole, 1981); F. As Shubaykiyah 25/43C (Bohannon, 1984); G. Aban al Ahmar 25 F (Cole, 1986); H. Jabal Habashi 26 F (Allen and others, 1984); I. Wadi ar Rimah (Bramkamp and others, 1963).

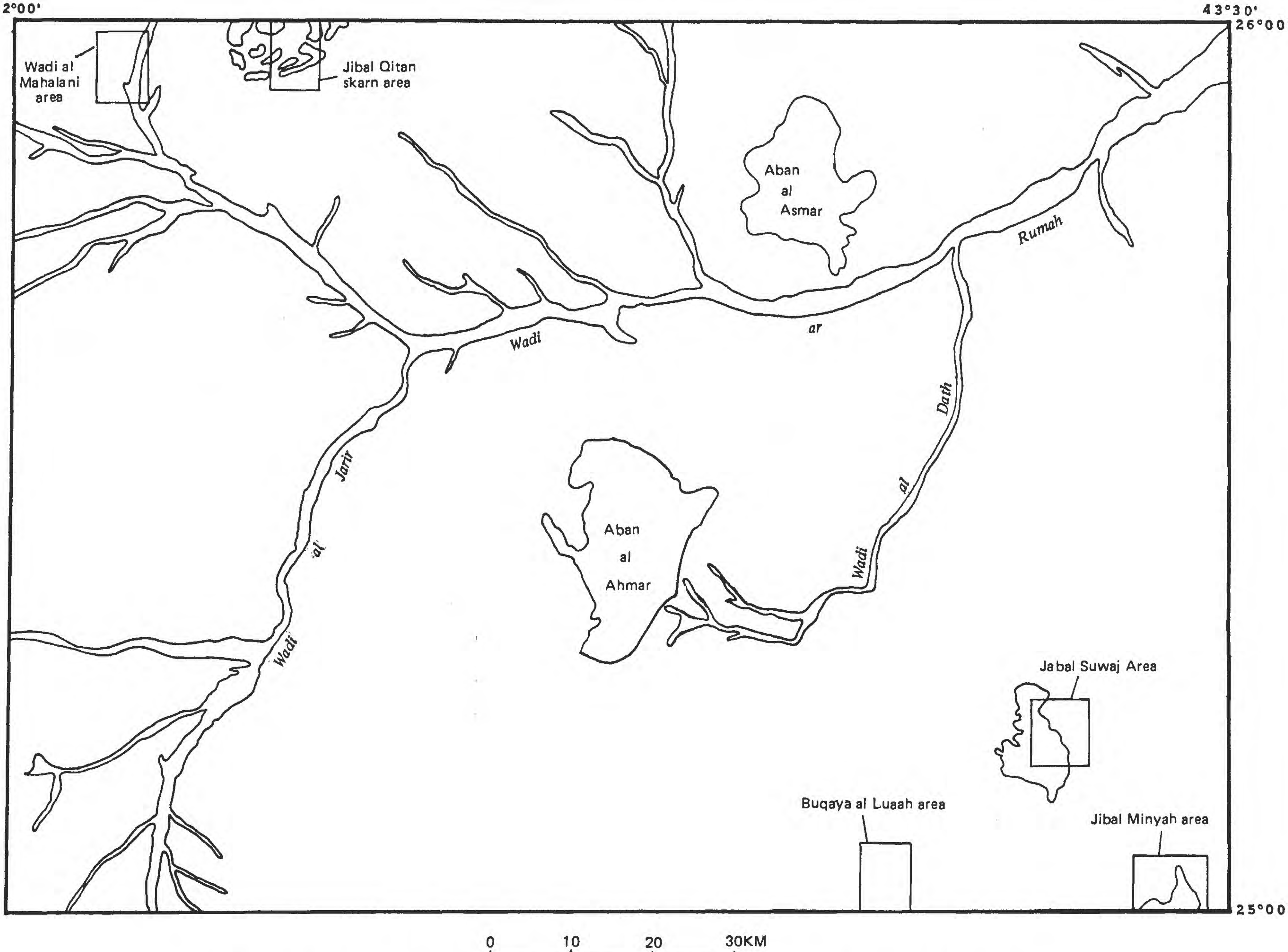

Figure 2.--Index map of the Aban al Ahmar quadrangle, showing locations of detailed study areas.

sheet 25/42B (Cole, 1985b), Wadi al Jarir, sheet 25/42C, (Young, 1982), Al Jurdhawiyah, sheet 25/42D (Cole, 1981), An Nabhaniyah, sheet 25/43A (Cole and Bohannon, 1985), and Ash Shubaykiyah, sheet 25/43C (Bohannon, 1984). These 1:100,000-scale geologic maps were compiled into a 1:250,000-scale geologic map of the Aban Al Ahmar quadrangle by Cole (1986). Geochronologic studies by Cole and Hedge (1985), geochemical and isotope studies by Stuckless and others (1982a, 1982b, and 1984), and wadi geochemistry by Samater (1982) include the Aban al Ahmar quadrangle.

PRESENT INVESTIGATION

The purpose of this investigation was to (1) interpret the regional wadi-concentrate geochemical data and to select anomalous areas based on the regional geochemical data; and (2) conduct detailed follow-up geologic and geochemical studies in order to determine the source and economic significance of the geochemical anomalies. The results will then be used as part of a multi-disciplinary approach in which geology, geochemistry, geophysics, and remote sensing are integrated for the mineral assessment of the Aban al Ahmar quadrangle.

The interpretation of the pre-existing regional geochemical data consisted of producing plots of selected elements and factor scores, and a discussion of their significance. Follow-up studies were conducted during 1984 and consisted of visiting areas containing geochemical anomalies identified by the regional interpretation of the geochemical data, and examining and collecting samples of rocks and wadi sediments for later laboratory study.

ACKNOWLEDGMENTS

The authors are indebted to J. C. Cole of the USGS for his help in understanding the geology of the Aban al Ahmar quadrangle and the northern Arabian Shield and for his review of the manuscript. G. L. Selner was helpful with computer manipulation and plotting of the regional geochemical data. R. S. Samater, R. T. Tucker, and J. L. Doebrich assisted in collection of wadi-sediment and rock samples. The wadi sediments were panned in the field by Ali Muhammen Jaberti. Heavy liquid and magnetic mineral separations on the wadi concentrates were preformed by members of the USGS Mineralogical Laboratory in Jeddah under the direction of C. R. Thornber. Emission spectrographic and atomic-absorption spectrometric analyses of rocks, wadi sediments and wadi concentrates were preformed in Jeddah at the DGMR-USGS Chemical Laboratory under the supervision of K. J. Curry and at the USGS Chemical Laboratory in Denver, Colorado by R. T. Hopkins and J. B. McHugh. M. S. Allen provided panned-concentrate samples collected from Jibal as Silsilah for mineralogic and geochemical comparisons. Discussions of the general geology with D. B. Stoeser and E. A. du Bray, and technical review of this manuscript by R. J. Kamilli are appreciated.

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GEOLOGIC SETTING

This section briefly describes the geology of the Aban al Ahmar quadrangle and has been generalized and condensed primarily from the 1:250,000-scale geologic compilation by Cole (1986) and the geochronology by Cole and Hedge (1985).

The Aban al Ahmar quadrangle encompasses part of the northeastern Arabian Shield. This part of the Arabian Shield is a large cratonic area that formed during the interval 700 to 570 Ma by four major crust-forming events. The oldest layered and intrusive rocks were formed in an ensimatic magmatic arc above a southwest-dipping subduction system active from about 700 to 670 Ma. Subduction ceased at about 670 Ma and was followed by a period of epeirogenic uplift and erosion. Batholithic leucocratic-granite bodies were produced between 655 and 645 Ma and were followed by a period of general uplift and erosion. At about 640 Ma, calc-alkaline volcanic and intrusive rocks were produced, and local fault-bounded basins were filled with volcaniclastic sediments. These volcanoclastic sediments were intruded by calc-alkaline granodiorite and monzogranite between about 630 and 615 Ma. This was followed by a period of considerable uplift and erosion that continued for as much as 30 million years. The final crust-forming event produced leucocratic, evolved granite bodies that intruded high into the crust about 585 Ma and 570 Ma.

DHIRAN-SUWAJ TERRANE

The Dhiran-Suwaj terrane (fig. 3) contains both layered and intrusive rocks that have been interpreted to be the magmatic and derivative products formed between about 700 and 670 Ma by subduction of oceanic lithosphere within a southwest-dipping zone of plate convergence. The Dhiran layered rocks consist of meta-andesite, immature metasediments, and minor sodic-felsic volcanic rocks that were deposited prior to about 700 Ma. The Suwaj intrusive suite consists primarily of low-potassium diorite and tonalite that were emplaced in the Dhiran meta-andesite and other layered rocks between about 690 and 670 Ma. The combined Dhiran-Suwaj rocks are discontinuously exposed in north-to-northwest-trending blocks that are bounded by major fault zones. Some of these fault zones are believed to have formed as major wrench structures at about 670 Ma, during a regional orogenic-metamorphic event that marked the end of subduction in this part of the Arabian Shield.

MURDAMA GROUP

The thick clastic deposits of the Murdama group (fig. 3) lie unconformably on the Dhiran-Suwaj terrane and were deposited in several fault-bounded marine basins. They were eroded during orogenic uplift that included folding and metamorphism of the older rocks. The base of the Murdama consists of polymict conglomerate and locally thick deposits of well bedded, shallow-water limestone. The bulk of the Murdama consists of fine-grained, well-bedded, green calcareous feldspathic sandstone that is generally pyritic and locally interbedded with limestone. The Murdama was gently folded into regional flexures prior to about 655 Ma, but was generally not metamorphosed. Weak chlorite-sericite schistosity is locally present, but primary depositional textures are well preserved.

KHISHAYBI SUITE

Leucocratic biotite granitic rocks of the Khishaybi suite (fig. 3) intruded rocks of the eastern and southwestern parts of the quadrangle during or following the folding associated with the end of Murdama deposition (Cole, 1985b). Rocks of the Khishaybi suite range in composition from monzogranite to orthoclase granite and contain associated felsic and rare mafic dikes. The various units are distinguished by texture and cross-cutting relationships, with contacts being locally gradational. All units are interpreted by Cole and Bohannon (1985) as being coeval.

JURDHAWIYAH GROUP

At about 640 Ma, calc-alkaline volcanic rocks and volcaniclastic sediments of the Jurdhawiyah group (fig. 3) were deposited in shallow, fault-bounded terrestrial and epicontinental basins. The andesite unit is generally present at the basal unconformity, filling paleotopographically low areas. The volcaniclastic conglomerate is the most voluminous unit and is present at the base of the group. Volcaniclastic sandstone is interbedded within the conglomerate and throughout the section. Thin, widespread beds and wedge-shaped deposits of lapilli tuff are also present. The Jurdhawiyah has not been metamorphosed and is generally not folded.

IDAH SUITE

Between 625 and 615 Ma, rocks of the Idah suite (fig. 3) intruded Jurdhawiyah and older rocks. Cole (1986) interprets these rocks to be cogenetic with Jurdhawiyah volcanic rocks. Rocks of the Idah suite range in composition from diorite to syenogranite porphyry, with granodiorite being the most voluminous. The intrusions are generally steep-sided, circular, or elliptical bodies that range from 1 to 30 km in diameter. The emplacement of the Idah suite coincides with deposition of gold in hydrothermal quartz veins (Kleinkopf and Cole, 1982; Boyle and Howes, 1983; Cole, 1985a; Cole, 1986).

During 615 and 570 Ma, no layered or intrusive rocks were formed. This was a period of erosion and nondepositon possibly associated with a general epeirogenic uplift following emplacement of the Idah- and Khishaybi-suite rocks.

ABANAT SUITE

Leucocratic and extremely differentiated granitic rocks of the Abanat suite (fig. 3) were emplaced between 615 and 570 Ma (Stuckless and others, 1982a, b, 1984) in the northern and eastern Arabian Shield. These intrusive rocks have been grouped into two geochemical subassemblages, peralkaline and peraluminous, on the basis of mineralogy and minor-element chemistry, with both subassemblages well represented in the quadrangle. The peralkaline and peraluminous granites of the Abanat suite are enriched in Rb, F, Zr, Pb, and rare-earth elements and are low in Sr, Ca, Ba, Mg, and transition metals.

The peralkaline granites are generally coarse-grained, hypersolvus (perthite) granites that contain sodium-enriched mafic minerals, such as arfvedsonite, aegirine, and subcalcic amphibole. These granites are generally enriched in yttrium, niobium, light rare-earth elements, and minor tin. The peralkaline granite of the Ahmar complex is typical of those found in the quadrangle.

EXPLANATION

ABANAT SUITE--Leucocratic, minor-element-enriched, differentiated granite, commonly peraluminous or peralkaline. Forms ring dikes and elliptical plutons

IDAH SUITE--Granodiorite and related diorite and syenogranite porphyry. Forms elliptical to circular plutons

JURDHAWIYAH GROUP--Calc-alkalic volcanic rocks and volcaniclastic sediments deposited in shallow, fault-bounded, terrestrial and epicontinental basins. Includes volcaniclastic sandstone and lapilli tuff. Not metamorphosed

KHISHAYBI SUITE--Leucocratic biotite granite, ranging from monzogranite to orthoclase granite; includes associated felsic and mafic dikes. Forms irregular batholithic intrusions

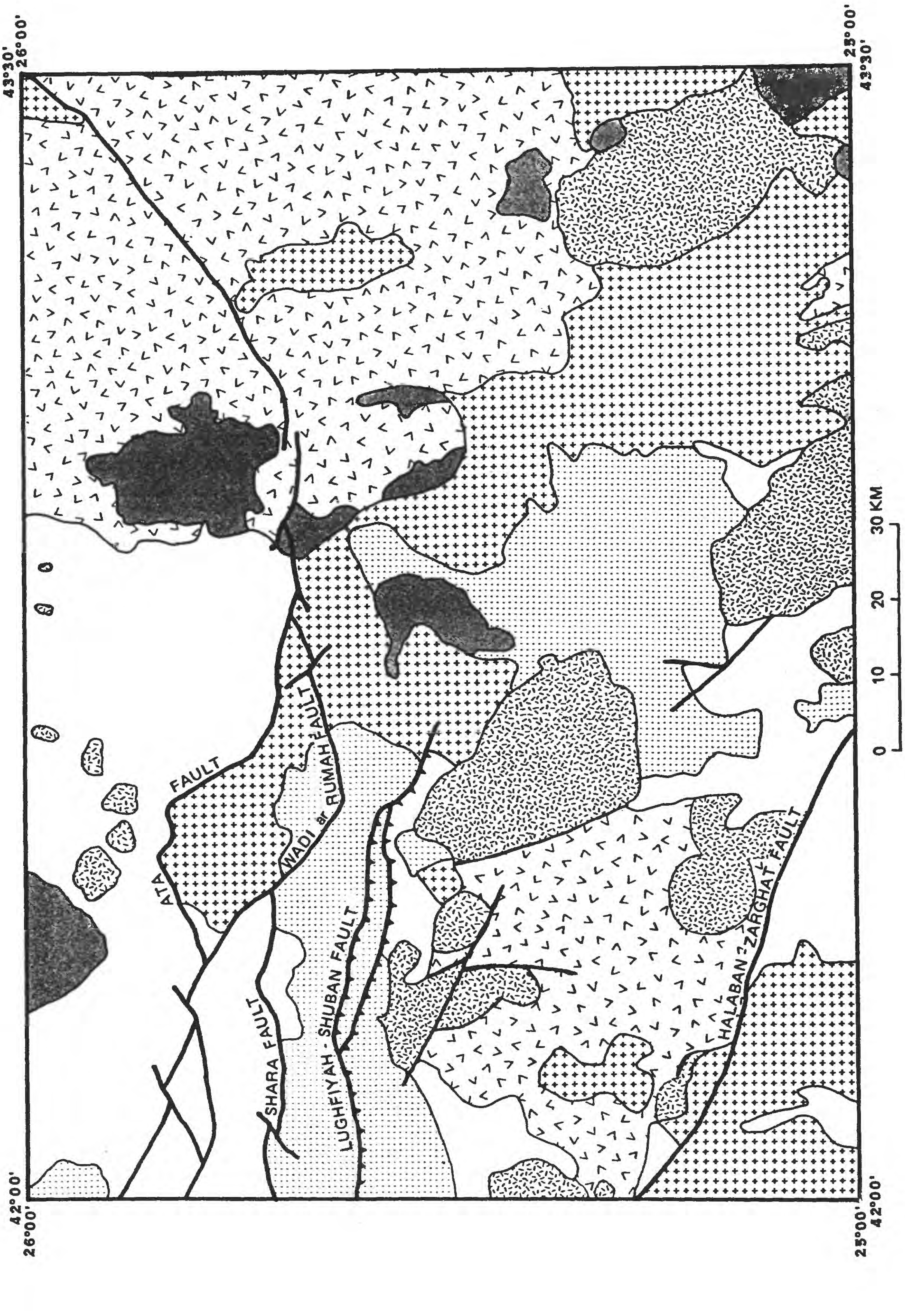
MURDAMA GROUP--Fine-grained, well-bedded, feldspathic sandstone; local basal conglomerate and limestone. Submarine deposition, regionally folded. Not metamorphosed

DHIRAN-SUWAJ TERRANE--Regionally metamorphosed layered and intrusive rock. Layered rock includes meta-andesite, immature metasediments, and sodic-felsic volcanic rock; intrusive rock includes diorite and tonalite. Discontinuously exposed in fault-bounded blocks

FAULT--Dip-slip, strike-slip, and structures with complex history of movement

HIGH-ANGLE REVERSE FAULT

Figure 3.--Generalized geologic map of the Aban al Ahmar quadrangle. Modified from Cole (1986).


43°30'
26°00'
25°00'
43°30'
42°00'
26°00'
25°00'
42°00'
ATA FAULT
WADI ar RUMAH FAULT
SHARA FAULT
LUGHFIYAH - SHUBAN FAULT
HALABAN - ZARGHAT FAULT
0
10
20
30 KM

The peraluminous granites appear to have originated from more hydrous magmas and contain two feldspars. Many are porphyritic and contain phenocrysts of albite and orthoclase (microcline). These granites are enriched in tin, lithium, boron, and tungsten. The peraluminous granite of Jibal Qitan is typical of those found in the quadrangle.

The Humaliyah formation and the Samra rhyolite extrusive rocks have been interpreted by Cole (1985a, 1986) to be cogenitic with the Abanat suite.

MAJOR STRUCTURES

The major structures present in the Aban al Ahmar quadrangle consist of several west- to northwest-trending faults (fig. 3).

The Halaban-Zarghat fault crosses the southwest part of the quadrangle. Cole and Hedge (1985) believe that this fault formed prior to 670 Ma, displacing Dhiran-Suwaj terrane rocks about 40 km. This fault was reactivated (65 km of left-lateral displacement) after Murdama deposition. Lateral displacement had ceased by about 615 Ma and was followed by only minor dip-slip movement.

The Lughfiyah-Shuhban faults are located in the northwestern part of the quadrangle. These faults have displaced Murdama-group rocks northward over Jurdhawiyah-group rocks by a few kilometers. This fault system was active during the final episode of Jurdhawiyah deposition.

The Shara fault is located approximately eight km north of the Lughfiyah-Shuhban fault system. Cole (1986) reports that this steeply dipping fault was active during Jurdhawiyah deposition.

The Ata fault, located in the northwestern part of the quadrangle, was described by Cole (1985a, 1986) as having differential slip at various times during the late Proterozoic. Cole (1985a) also reports the presence of altered ultramafic rocks (listwanite) associated with the Ata fault system, suggesting deep penetration of the fault.

The Wadi ar Rumah fault has been inferred to be beneath the Wadi ar Rumah drainage by Cole (1985a, 1986) in the northern half of the quadrangle; Cole (1985a, 1986) reports that this was an active rotational fault during the late stages of Jurdhawiyah sedimentation. Parts of this fault formed boundaries for the Murdama and Jurdhawiyah depositional basins.

REGIONAL GEOCHEMICAL SURVEY

TECHNIQUES

During 1981 and 1982, R. M. Samater conducted a geochemical survey using wadi-concentrate samples in the Aban al Ahmar quadrangle as part of a regional geochemical survey of the northern Arabian Shield. The samples were sieved at minus-10 mesh to remove grains larger than 2 mm and then was hand-panned to obtain a heavy-mineral concentrate. Magnetite was removed from the concentrate with a hand magnet. The remaining sample was then pulverized to less than 0.064 mm and analyzed by the DGMR-USGS chemical laboratory in Jeddah for 30 elements using a direct-current arc emission spectrograph. The results of the analyses are reported within a framework consisting of six steps per order of magnitude (1, 0.7, 0.5, 0.3, 0.2, 0.15, or multiples of 10 of these numbers) and represent approximate geometric midpoints of the range of concentration. The precision is within one adjoining reporting interval on each side of the reported value 83 percent of the time, and within two adjoining intervals 96 percent of the time (Motooka and Grimes, 1976). The results of the chemical analyses for these samples were interpreted and used as preliminary information for the selection of areas for follow-up geochemical investigations.

The effectiveness of the wadi-concentrate survey is dependent on the presence of a mature drainage system and the consistent application of the sampling and analytical techniques used. The drainage development within the Aban al Ahmar quadrangle is generally either immature or buried by eolian material; therefore, areas of the quadrangle underlain by deeply eroded felsic- to intermediate-composition plutons and sand seas were either not covered or not covered adequately by the geochemical survey, and so the extent of mineralization is not known.

The sample-preparation techniques were not always consistently applied. The collection and preparation of samples were carried out separately on each of the 1:100,000-scale quadrangles within the quadrangle. There is evidence that magnetite in samples from two 1:100,000-scale quadrangles was not completely removed. Magnetite is an iron spinel that can incorporate into it's structure (or scavenge) elements such as Ni, Co, V, and Cu during crystalization (Deer and others, 1966; Overstreet, 1978; Overstreet and Day, 1985). Plots of the distribution of Fe, Ni, Co, V, and Cu in panned concentrates are shown on figs. 4, 5, 6, 7, and 8[1/]. Most of the anomalous concentrations of for these elements fall within quadrangles 25/42A and 25/42B, and many of the Fe concentrations are greater then 20 percent, indicating the presence of magnetite. The effect on the results of the geochemical survey is to give elevated and spurious values for these elements in the two 1:100,000-scale quadrangles.

GENERATION OF THE MAPS

Computer-generated point-plot maps showing distribution of elements for the heavy-mineral concentrates were prepared using the mapping programs within the USGS-STATPAC system (Vantrump and Miesch, 1977). Approximately 10 percent of the samples were classified as anomalous and were divided into four classes at approximately the 99, 97.5, 95, and 90th percentile. An additional class was added at the 75th percentile in order to show samples with elevated concentrations. This procedure has the advantage of approximately doubling the number of samples for each class, going from the most anomalous to the least anomalous.

1/ Figures 4-19 are at the end of the chapter. See page 22.

RESULTS

The results of the chemical analyses for the 1207 samples collected from the Aban al Ahmar quadrangle are summarized in table 1. The pathfinder elements for base-metal mineralization include Cu, Pb, Mo, and Sn. The maximum values for Cu, Pb, and Mo are generally low, and the range or contrast between maximum and minimum values is generally small. Reasons for this are the dilution of wadi sediments by eolian material and the chemical leaching of shield rocks during the long period of time that the shield was subjected to weathering. Plots showing the distributions of Cu, Pb, and Mo are shown on figures 8, 9, and 10.

Elements commonly enriched in evolved granites include Be, La, Nb, Sn, and Y. The maximum values and contrast between maximum and minimum concentrations of these elements is generally greater than that of the base metals (table 1). This is probably caused by the active erosion of abundant, relatively young, highly evolved plutons of Abanat-suite rocks exposed in the quadrangle.

Copper

Most of the anomalous concentrations of copper are found in the northern part of the quadrangle (fig. 8). Some of these anomalies were caused by incomplete removal of magnetite during sample preparation. Magnetite can contain copper, as was discussed earlier in this report. Other anomalous concentrations are present in Murdama sandstone and Dhiran meta-andesite near the Ata fault system. During the follow-up survey, malachite was observed at several locations along this fault system, particularly on northwest-trending branches (Smith and Samater, 1985). These small amounts of copper mineralization, which were probably originally copper sulfides, are present within the fault zone and postdate the inception of faulting. One wadi-concentrate sample collected south of Jabal Akkash contained 100 ppm copper and 100 ppm lead. This sample was collected from a wadi draining an Idah-suite pluton within Murdama sediments and probably reflects mineralization associated with or similar to the ancient workings at Jabal Akkash (MODS 3114). The mineralization along these faults and the large copper anomaly within the Murdama group are probably related to emplacement of small Idah-suite granodiorite plutons that are associated with most of the quartz-vein gold occurrences in the quadrangle (Boyle and Howes, 1983; Cole, 1986; Smith and Samater, 1985).

Lead

Anomalous concentrations of lead (fig. 9) are present within the rocks of the Murdama group in the northern part of the quadrangle. Weak anomalies located along the northern margin of the Aban al Ahmar quadrangle are associated with peralkaline granite of the Ahmar complex. A stronger anomaly located along the east and southeast side of Aban al Asmar is associated with alkalic granitic rocks of the Asmar complex (Cole, 1986).

The highest concentrations of lead in the quadrangle are associated with the Baid al Jimalah East lead-zinc-silver prospect (MODS 2659; Samater, 1982; Lofts, 1982). The minerals present consist of pyrite, sphalerite, galena, chalcopyrtite, and arsenopyrite in hematitic quartz veins within Jurdhawiyah-group sandstone (Cole, 1986). The mineralization is genetically related to the emplacement of albite-microcline granite porphyry of the Abanat suite at Baid al Jimalah West tungsten prospect (MODS 2661) and is discussed in Cole and others (1981).

Table 1.--Summary of statistical information from 1207 wadi concentrates, Aban al Ahmar quadrangle.

[Fe, Mg, Ca, and Ti are in percent, all others are in parts per million. Au, As, Cd, and Sb not detected.]

Variables	Number of samples above detection limit	Minimum	Maximum	Geometric mean	Geometric deveation
Fe	1207	0.7	>20	7.43	5.00
Mg	1207	.03	7.0	1.02	.731
Ca	1207	.07	10	2.65	1.84
Ti	1207	.07	>1.0	1.20	.331
Mn	1207	150	>5000	1413	1057
Ag	2	<.5	7	----	----
B	573	<10	200	11.4	10.7
Ba	1207	70	2000	441	267
Be	784	<1.0	30	1.52	1.63
Bi	1	<10	10	----	----
Co	1142	<5	700	10.9	29.0
Cr	1207	15	5000	555	351
Cu	1090	<5	200	21.6	24.0
La	1143	<20	>1000	62.6	118
Mo	297	<5	15	3.81	2.17
Nb	676	<20	300	26.5	25.7
Ni	1196	<5	200	32.1	25.8
Pb	702	<10	700	16.5	26.8
Sc	1119	<5	50	10.4	6.72
Sn	622	<10	>1000	35.6	101
Sr	1130	<100	1000	293	143
V	1207	10	700	134	73.3
W	4	<70	1000	----	----
Y	1207	10	1000	53.4	54.7
Zn	3	<300	1500	----	----
Zr	1207	100	>1000	1093	380

Molybdenum

The range of molybdenum concentration is small and the maximum values are low (only 15 ppm), probably because the exposed rocks have been leached of much of their molybdenum, which is relatively mobile during chemical weathering. Greater concentrations of molybdenum would normally be expected because of the presence of large areas of highly evolved granites. The highest concentrations are found in the north-central part of the quadrangle within the Murdama sandstone, and northeast of Aban al Asmar within the Khishaybi-suite monzogranite near northeast-trending faults (fig. 10).

Bismuth, Silver, Tungsten, and Zinc

Only one sample contained detectable bismuth (10 ppm). This concentration is at the detection limit and is only slightly anomalous. The sample was collected from Suwaj-suite tonalite west of Wadi ad Dath (fig. 11). This site was resampled during the follow-up survey and produced no detectable bismuth; therefore, little significance is given to the occurrence.

Two samples contained detectable concentrations of silver (fig. 11): one sample collected from Idah-suite granodiorite in the west-central part of the quadrangle contains 5 ppm silver; and the other sample, collected in volcaniclastic conglomerate of the Jurdhawiyan Group in south-central part of the quadrangle, contains 7 ppm silver.

Four wadi-concentrate samples contained detectable tungsten (fig. 11). One sample collected in the west-central part of the quadrangle within the Idah-suite granodiorite contains 70 ppm tungsten. The pluton has been eroded to a flat surface, exposing numerous felsic dikes that were probably formed during late-stage emplacement of the pluton. The tungsten anomaly is probably a result of minor mineralization associated with one of the dikes. Single-sample anomalies, particularly those consisting of only weakly anomalous tungsten, are of little significance when calculating mineral resource potential[1/]. One sample collected from Idah-suite rocks in the eastern part of the quadrangle west of Wadi ad Dath (fig. 11), in a situation similar to the sample mentioned above, contained 100 ppm tungsten. This type of occurrence is discussed in Smith and others (1984). Samples with the highest concentration of tungsten (300 and 1000 ppm) were collected at the Baid al Jimalah West prospect (MODS 2661).

1/ This paper follows the mineral resource terminology recommended by Goudarzi (1984). Mineral resouce potential is defined as the likelihood of the presence of mineral resources in a defined area; it is not a measure of the amount of resources or their profitibility. Low mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment where the existence of resources is unlikely. Moderate mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable chance for resource accumulation... . High mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resources, where interpretations of data indicate a reasonable chance for resource accumulation... . This paper, of course, only considers the geochemical data and, to a lesser extent, the geologic data.

Three wadi-concentrate samples contained detectable concentrations of zinc (fig. 11): one sample collected on the west side of Aban al Asmar contained 300 ppm zinc; another sample collected on the southeast side of Aban al Asmar contained 1500 ppm zinc. Both anomlies are associated with the hornblende perthite granite member of the Asmar complex (Cole, 1986).

One sample collected within the Murdama sandstone in the north-central part of the quadrangle contained 300 ppm zinc. This site was resampled during the follow-up survey, but no zinc was detected in the sample, and so this occurrence in not considered to be significant.

Tin

Anomalous concentrations of tin are generally associated with granites of the Abanat suite, such as those at Aban al Asmar, north of Jibal Minyah, south of Jibal Qitan, and Baid al Jimalah East and West (fig. 12). Tin anomalies are also present in areas underlain by the Khishaybi-suite monzogranite northeast of Aban al Asmar, in Murdama-group rocks in the northern part of the quadrangle, and in Idah-suite rocks north of Jibal Suwaj (fig. 12). These older rocks are probably not the source of the anomalies because they do not normally have geochemical signatures consisting of anomalous concentrations of tin and associated elements. These areas may be associated with buried Abanat-suite plutons.

Beryllium

Anomalous concentrations of beryllium are generally associated with the granite of the Abanat suite at Aban al Asmar, Jibal Qitan, and Aban al Ahmar. Anomalous concentrations of beryllium are also present in the Hamar monzogranite of the Khishaybi suite. The monzogranite is probably not the source of the anomalies because wadi concentrates of this unit do not normally contain elevated concentrations of beryllium (fig. 13).

Lanthanum, Niobium, and Yttrium

Anomalous concentrations of lanthanum, niobium, and yttrium (figs. 14-16) are generally associated with the Abanat-suite granites at Aban al Asmar, Aban al Ahmar, and Jibal Qitan, and the area northeast of Aban al Asmar within Khishaybi-suite Hamar monzogranite. Concentrates from wadis draining the monzogranite do not normally contain elevated concentrations of La, Nb, and Y (table 2). Anomalous concentrations of niobium and lanthanum are present east of Aban al Asmar near the Nubayha area within the Dilaymiyah syenogranite of the Khishaybi suite. Lanthanum anomalies are present along the eastern edge of the southern part of the quadrangle within Idah-suite granodiorite and Nafi schist.

FACTOR ANALYSIS

So much data was generated as a result of chemical analyses of the wadi concentrates that a multivariate numerical method was required to reduce the data to a limited number of groups that could be more readily interpreted. The technique used is R-mode factor analysis, which is a mathematical technique that identifies natural groupings of elements within a data set. The method attempts

Table 2.--Comparison of average values for La, Nb, and Y in wadi concentrates from areas draining Abanat suite and Khishaybi-suite rocks, Aban al Ahmar quadrangle.

[Chemical analyses by emission spectrography.]

Khishaybi Suite (n=10)		Abanat Suite (n=8)	
La	34 ppm	La	600 ppm
Nb	35 ppm	Nb	118 ppm
Y	53 ppm	Y	219 ppm

to explain variation among a smaller number of relations or factors. End-member compositions (or factors) are calculated that approximately describe the variations within the multielement data. Each factor represents a geochemical control or process. Individual samples can then be described in terms of components of these factors or loadings. Once a factor has been interpreted as reflecting a certain process, each sample can then be evaluated with respect to this factor and the process it represents. The degree to which any given sample relates to each factor is called a factor score. The distribution of these factor scores, particularly for factors interpreted as reflecting geochemical processes related to mineralization, can in turn be plotted on maps and considered with respect to selecting areas for follow-up studies.

Factor analysis demonstrates these factors, but does not interpret them. The interpretation of these components and the geological significance of the resulting patterns or plots are subjective and depend upon the user's knowledge of the local geological and geochemical environment. Results similar to those based on interpretation of factor analysis can be obtained qualitatively from observation of single-element distributions, but at an investment of more time and without the quantitative estimates of the importances of each element in an association. Once a model is selected by factor analysis, it is helpful to use the single-element distributions to demonstrate the model. Background information on factor analysis can be found in Davis (1973).

R-MODE FACTOR ANALYSIS OF DATA FROM THE ABAN AL AHMAR QUADRANGLE

R-mode factor analysis of data from the Aban Al Ahmar quadrangle was done by computer using the USGS-STATPAC library system (Van Trump and Miesch, 1977). The basic algorithms for the program were developed following procedures from Rummel (1970). The program extracted principal components which were then rotated according to a varimax solution.

An eight-factor model was selected that would account for 80 percent of the variation in the geochemical data. The factor loadings are shown on table 3. Factors beyond an eight-factor model were mainly single-element factors and do not add to the interpretation beyond the single-element plots. Factors 1, 2, and 8 have a direct bearing on the interpretation and will be discussed later. Of the remaining five factors, factors 3 and 4 are interpreted as reflecting intermediate-composition rocks (primarily Suwaj-suite rocks, as well as minor Jurdhawiyah and Murdama-group rocks), factor 5 as reflecting evaporative concentration processes (mainly associated with playa lakes), and factor 6 as reflecting contamination from crushing and pulverizing during sample preparation. Factor 7 is a single-element factor composed of B. These factors do not have a direct bearing on the interpretation of mineral resource potential and therefore are not discussed.

Computer-generated point-plot maps showing the distributions of anomalous concentrations for factor scores were prepared similarly to that of the element plots. Ten percent of the samples are classified as anomalous and were divided into four classes at the 99, 97.5, 95, and 90th percentile. An additional class was added at the 75th percentile in order to show samples with elevated factor scores. This procedure has the advantage of approximately doubling the number of samples for each class from the most anomalous to least anomalous.

Table 3.--Varimax loadings for an eight factor model, Aban al Ahmar quadrangle.

[Significant loadings are underlined.]

	1	2	3	4	5	6	7	8
Fe	.82	.23	.13	-.04	.16	-.09	-.04	.12
Mg	.42	-.15	-.02	.11	.78	-.09	.01	-.06
Ca	.44	-.08	.09	-.20	.73	-.09	.05	.16
Ti	.37	.06	.71	.06	.26	-.04	.03	-.15
Mn	.43	.27	.33	.59	.27	-.05	.10	-.07
B	.32	.10	.06	.11	.20	.16	.80	.07
Ba	-.25	-.34	.06	.47	.64	.06	.01	-.03
Be	-.69	.23	.13	.20	-.08	-.03	.02	.44
Co	.79	-.02	.10	-.17	.11	.18	.00	.10
Cr	.34	.14	.35	.29	.32	.24	-.45	-.02
Cu	.79	-.02	.07	.06	.16	.02	.19	.36
La	-.09	.91	-.02	.00	-.07	.07	.05	-.01
Mo	.06	.16	-.05	-.03	-.08	.94	.08	.07
Nb	-.03	.83	.16	-.00	-.21	.08	.01	.12
Ni	.85	.10	.14	.01	.15	.17	.13	.13
Pb	.39	.40	-.11	-.12	-.06	.12	.07	.70
Sc	.32	.39	.06	-.73	.19	.06	-.05	-.01
Sn	.38	.48	.18	-.03	-.24	.22	.06	.44
Sr	.18	-.39	.07	-.09	.73	.01	.10	-.17
V	.81	.01	.26	.10	.27	-.08	.08	-.07
Y	.13	.82	.17	-.17	-.20	.07	-.01	.21
Zr	-.06	.17	.90	.01	-.06	-.03	-.02	.10

Factor 1

Factor 1 accounts for 29 percent of the total variation and is represented by significant loadings (listed in order of importance) for Ni, Fe, V, Cu, and Co (table 3). Factor 1 (fig. 17) is interpreted as reflecting incomplete removal of magnetite during sample preparation. Within the magnetite crystal structure, V can partially substitute for Fe^{3+} and Ni and Co can partially substitute for Fe^{2+} (Deer and others, 1966). Also magnetite can incorporate in its structure or act as a scavenger for Cu (Overstreet, 1978; Overstreet and Day, 1985). The association of these elements with magnetite explains the presence of these elements in the factor loadings. Distributions of Fe concentrations (fig. 4) show that samples with anomalous values (10 percent or greater) were all collected in the north-central and northeastern quadrangles (25/42 A and 25/42 B). In addition, the anomalous Fe concentrations (10 percent or more) are higher than what would normally be expected if the magnetite had been completely removed for this type of sample, further indicating the presence of magnetite. Distributions of anomalous Ni, Co, V, and Cu also generally fall within these two quadrangles (figs. 5, 6, 7, and 8). Evidence is overwhelming that samples from these two quadrangles have been contaminated by incomplete removal of magnetite; therefore, any interpretation of the data must take this into account.

Factor 2

Factor 2 accounts for 21 percent of the total variation and is represented by significant loadings for La, Nb, and Y, and less significant but high loadings for Sn, Pb, and Sc (table 3). These elements are commonly associated with evolved rocks, such as the granite of the Abanat suite, and the distribution of factor-2 scores shows close correlation with these rocks (fig. 18). Anomalous scores for factor 2 are associated with Abanat-suite rocks at Jibal Qitan, Aban al Asmar, particularly along the east and southeast contacts, and along the margin of the northern half of Aban al Ahmar. Factor 2 is interpreted as reflecting the Abanat-suite lithology. These rocks are highly evolved granites and therefore have a good potential for tin and tungsten mineralization.

In addition, anomalous scores for factor 2 occur within the Khishaybi-suite Hamar monzogranite, northeast of Aban al Asmar in the Nubayha area and within the Khishaybi-suite Dilaymiyah syenogranite, east of Aban al Asmar (fig. 18). Wadi concentrates collected from these two areas contain anomalous concentrations of La, Nb, and Y, similar to wadis draining Abanat-suite rocks. Concentrate samples collected from wadis draining areas underlain by the Hamar monzogranite and the Dilaymiyah syenogranite normally do not contain anomalous concentrations of La, Nb, and Y, in contrast to areas containing Abanat-suite rocks (table 2). This suggests that Abanat-suite rocks have intruded into the older rocks.

D. B. Stoeser (personal comm.) reports that Abanat-suite rocks are intruded into the older Hamar monzogranite northeast of Aban al Asmar in the vicinity of the site of anomalous factor-2 scores, but the younger rocks are difficult to recognize within the monzogranite due to the low relief. These young granites have a good potential for tin and tungsten mineralization, particularly since they represent the upper parts (or cupolas) of underlying plutons. There is an anomalous occurrence of 1000 ppm Sn (fig. 12) within this area, further evidence of high resource potential for tin.

Factor 8

Factor 8 accounts for three percent of the total variation and is represented by significant loadings for Pb, Be, Sn, and Cu (table 3). Factor 8 is interpreted as reflecting a late-stage episode of hydrothermal fluids associated with the emplacement of plutons. While factor 2 is interpreted as reflecting the lithology of evolved plutons, factor 8 reflects late-stage hydrothermal processes. Factor 8 does not seem to discriminate between mineralization associated with emplacement of Abanat-suite and Idah-suite plutons.

Anomalous scores for factor 8 occur within the Murdama sandstone in the northern and west-central parts of the quadrangle (fig. 19) and are probably associated with the emplacement of small Idah-suite granodiorite plutons. These anomalous scores usually occur near small granodiorite bodies, but also occur in the northern part of the quadrangle near a fault and small fractures which may have acted as conduits for hydrothermal fluids from underlying plutons. These areas have moderate resource potential for precious- and base-metal mineralization.

Anomalous scores for factor 8 are also associated with Abanat-suite granite along the eastern margin of Aban al Asmar, along the northern margin of Aban al Ahmar, at Jibal Minyah, at Jibal Qitan, and at Baid al Jimalah West tungsten prospect. Factor 8 is also interpreted as reflecting hydrothermal fluids associated with late-stage magmatic processes during the emplacement of the Abanat-suite rocks of these plutons.

Most of the plutons are exposed at the plutonic level, and the most significant mineralization, if any, has been eroded. But this is not the case for the surrounding country rocks which may host mineralization and satellite bodies associated with these plutonic complexes. The area near Baid al Jimalah West, which is the upper part of an Abanat-suite plutonic complex, has been shown to have high resource potential for W and Sn (Cole and others, 1981; Lofts, 1982). Similar areas may exist in other parts of the quadrangle.

DISCUSSION AND SUMMARY

Areas were selected for follow-up work on the basis of the results of the regional geochemical data of wadi concentrates and plots showing the distribution of anomalous concentrations for selected elements and factor scores. Areas with poor drainage development and sand seas were not tested for mineral resource potential.

Two main types of mineralization are recognized within the quadrangle. The first type is precious- and base-metal mineralization associated with the emplacement of small bodies of Idah-suite granodiorite, particularly within Murdama sandstone in the northern part of the quadrangle. Most of the ancient gold and copper mines in this region are associated with small granodiorite bodies (Kleinkopf and Cole, 1982; Boyle and Howes, 1983; Cole, 1986). The small size of the granodiorite bodies indicates that the mineralization is associated with the upper part or cupolas where hydrothermal fluids would tend to concentrate. Large granodiorite bodies that are exposed at the plutonic level seem to have low potential for mineralization. Mineralization (particularly copper mineralization) occurred along branches of the Ata fault system and was probably caused by leakage of hydrothermal fluids associated with the emplacement of Idah granodiorite bodies. This first type of mineralization is reflected primarily by anomalous Pb and Cu in the wadi concentrates and anomalous factor-8 scores.

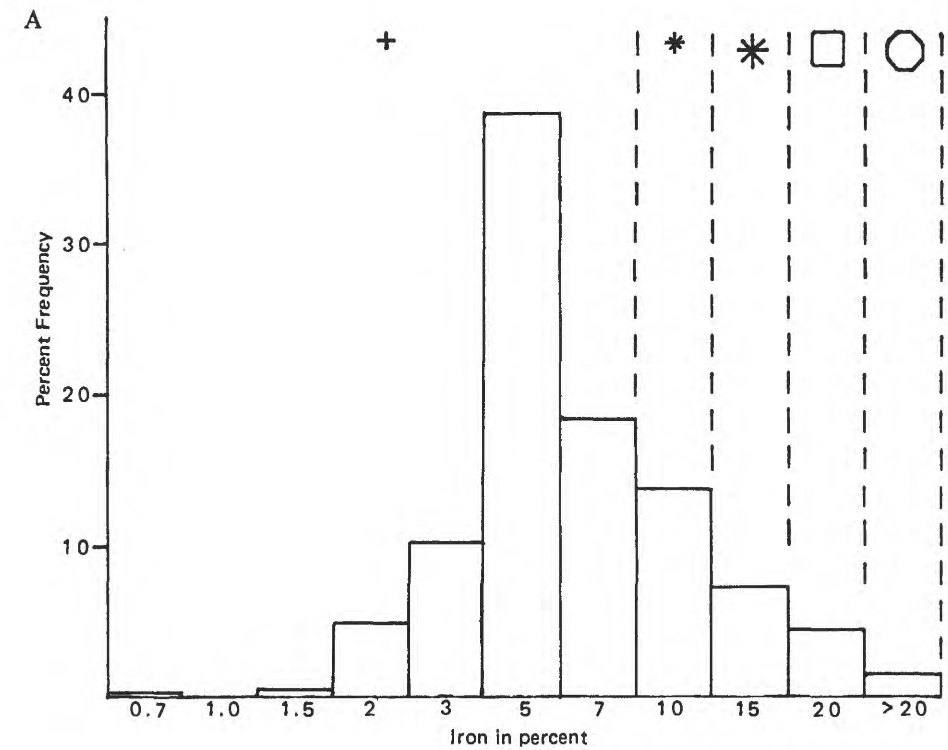
The second type of mineralization is tin, tungsten, and related base metals associated with late-stage emplacement of Abanat-suite plutons. This type of mineralization is indicated by anomalous factor-8 scores and the presence of Sn, Be, and, to a lesser extent, Pb and Cu in wadi concentrates. Most of these intrusive complexes have been eroded to the depth of the original pluton, and so most mineralization, if any ever existed, has been eroded away. Consequently, the most areas of highest resource potential for this type of mineralization are located within the surrounding country rocks that may host mineralization associated with the main pluton or satellite bodies of the main pluton. The area north of Jibal Minyah may be an example of this.

Anomalous factor-2 scores and the presence of La, Nb, Y, and, to a lesser extent, Sn, Pb, and Sc in wadi-concentrate samples reflect the lithology of the Abanat-suite granites. Wadi concentrates from two areas east of Aban al Asmar within Khishaybi-suite rocks contain anomalous concentrations of these elements and anomalous factor-2 scores, geochemical characteristics similar to those of Abanat-suite rocks. Cole and Bohannon (1985) describe an elliptical-foliation arch in the Hamar monzogranite located in the area of the anomaly, which suggests the presence of a Abanat-suite pluton in the subsurface.

Lanthanum and yttrium can be transported in hydrothermal alkaline solutions as carbonate, fluoride, or sulfate complexes. An example is $NaYF_4$, which is stable at 500-550^{o} C (Mineyev and others, 1966). Niobium is enriched with tin in later stages of magma evolution and can be transported in pneumatolytic or hydrothermal solutions; therefore, the possibility exists that Abanat-type granite may underlie the Hamar monzogranite and the Dilaymiyah syenogranite in the area of the anomalous factor-2 scores (fig. 18). The younger rocks may crop out and not been recognized as yet, or hydrothermal solutions carrying anomalous concentrations of Nb, La, and Y may have invaded the older overlying rocks, particularly along faults and fractures, and so outcrops of the younger rocks are not present. A similar situation may exist to the north in the Jibal Habashi quadrangle (sheet 26F) where Allen and others (1984) found anomalous concentrations of Y, Nb, and La within graywacke.

These two areas may have been intruded by Abanat-suite plutons and have moderate resource potential for tin and tungsten in greisen deposits associated with the cupolas of underlying plutons.

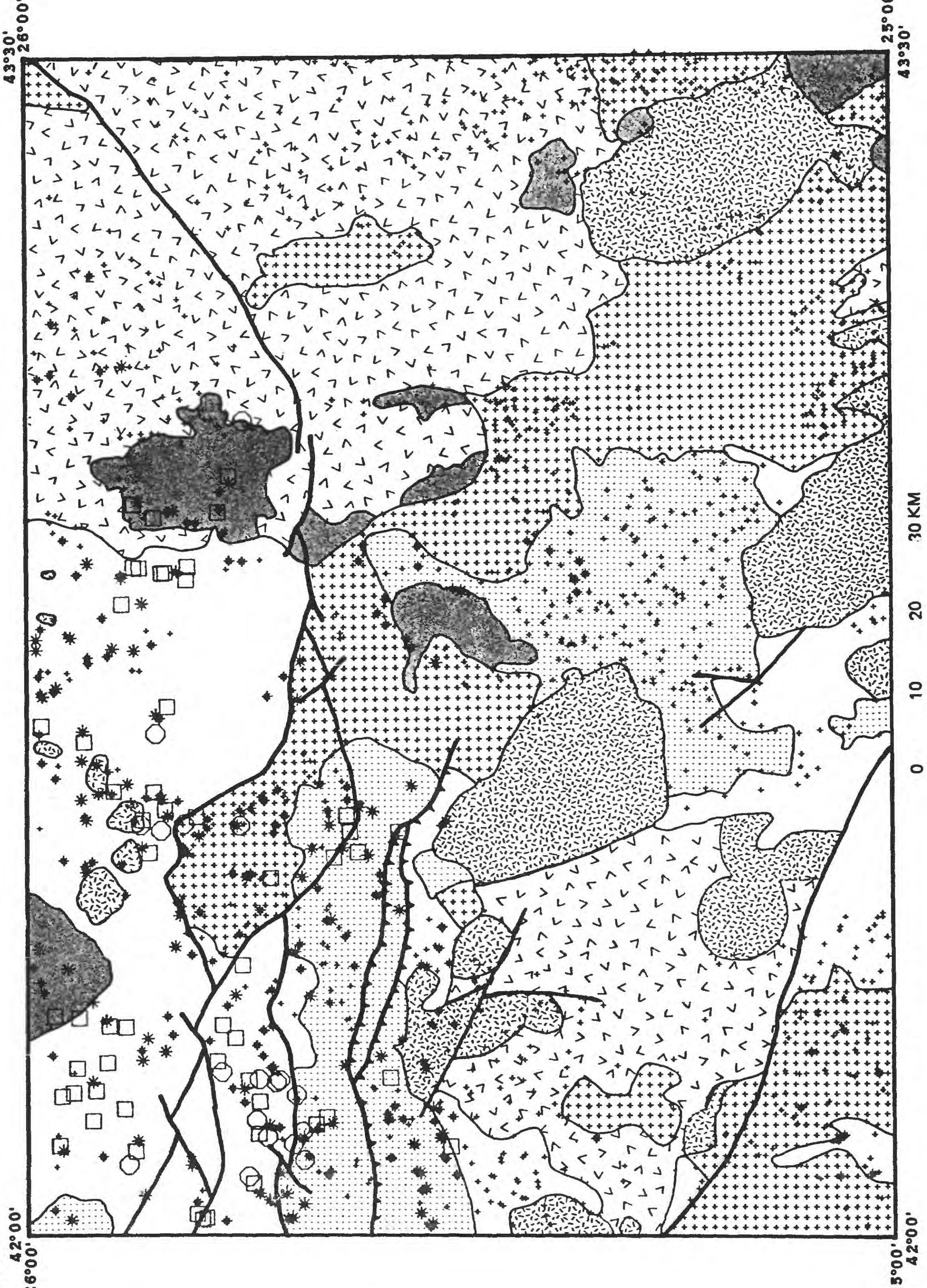
page 22 follows



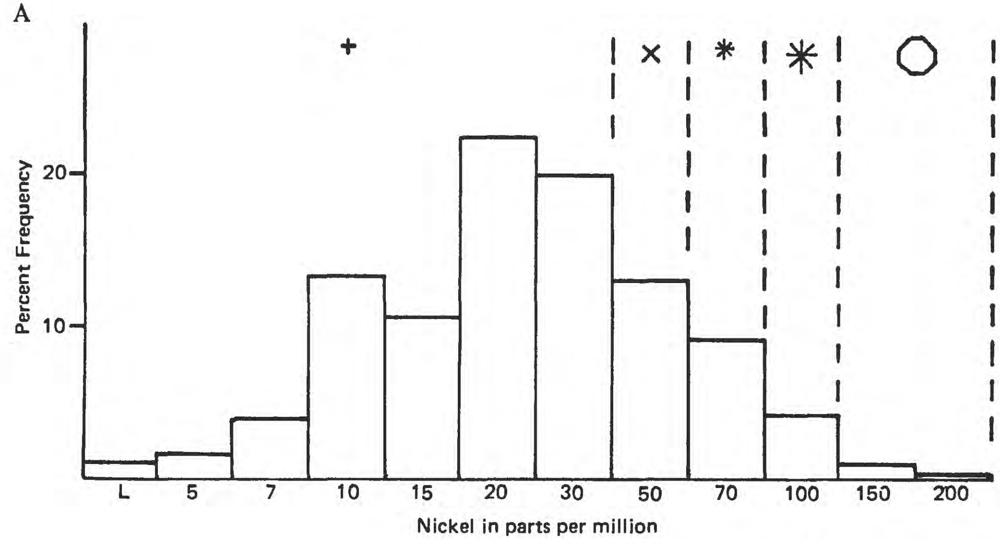
Note: Element-value symbols are shown in red on part B of this figure.

Figure 4.--Histogram (*A*) and distribution (*B*) of iron in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.

B



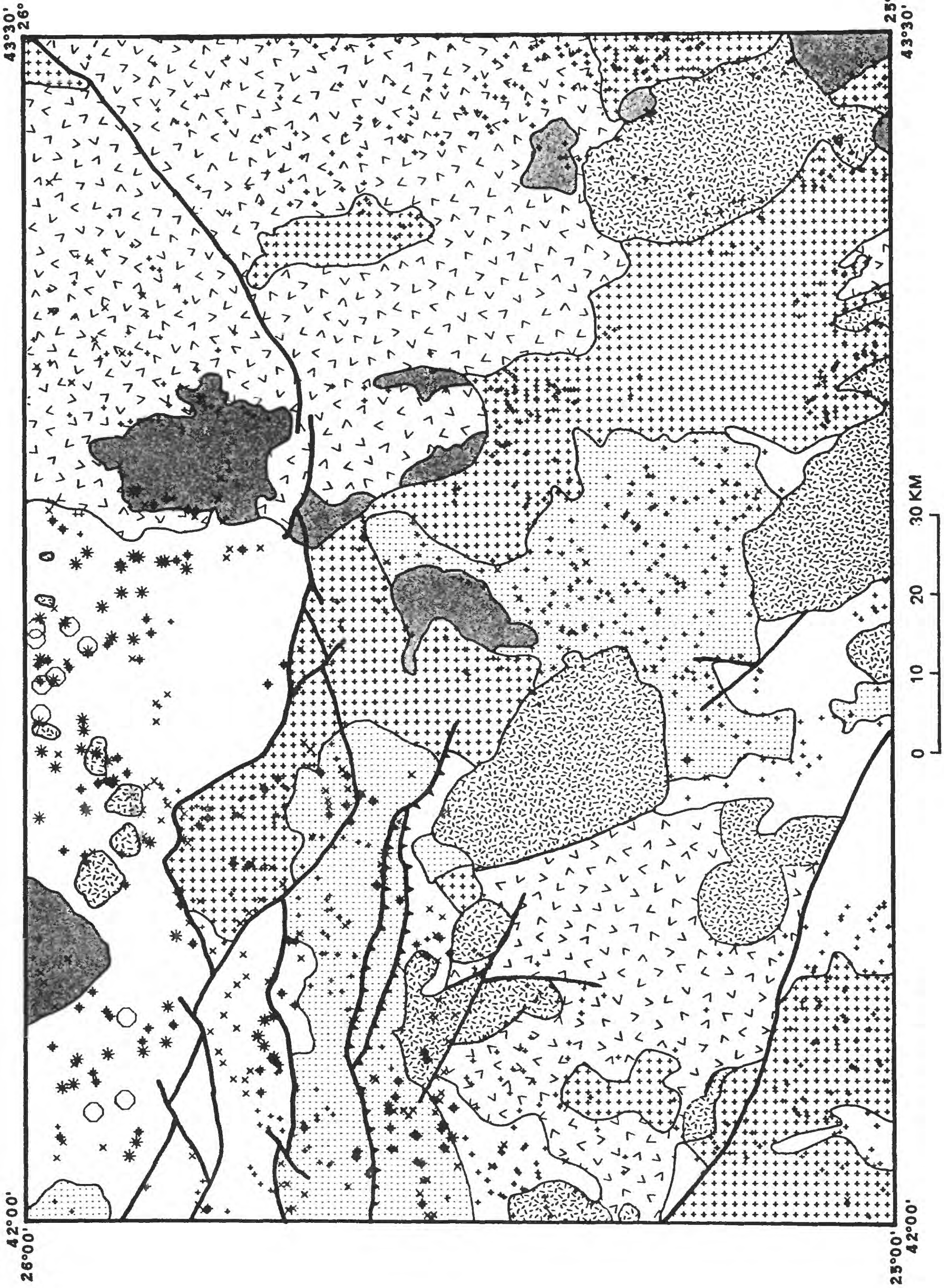
A

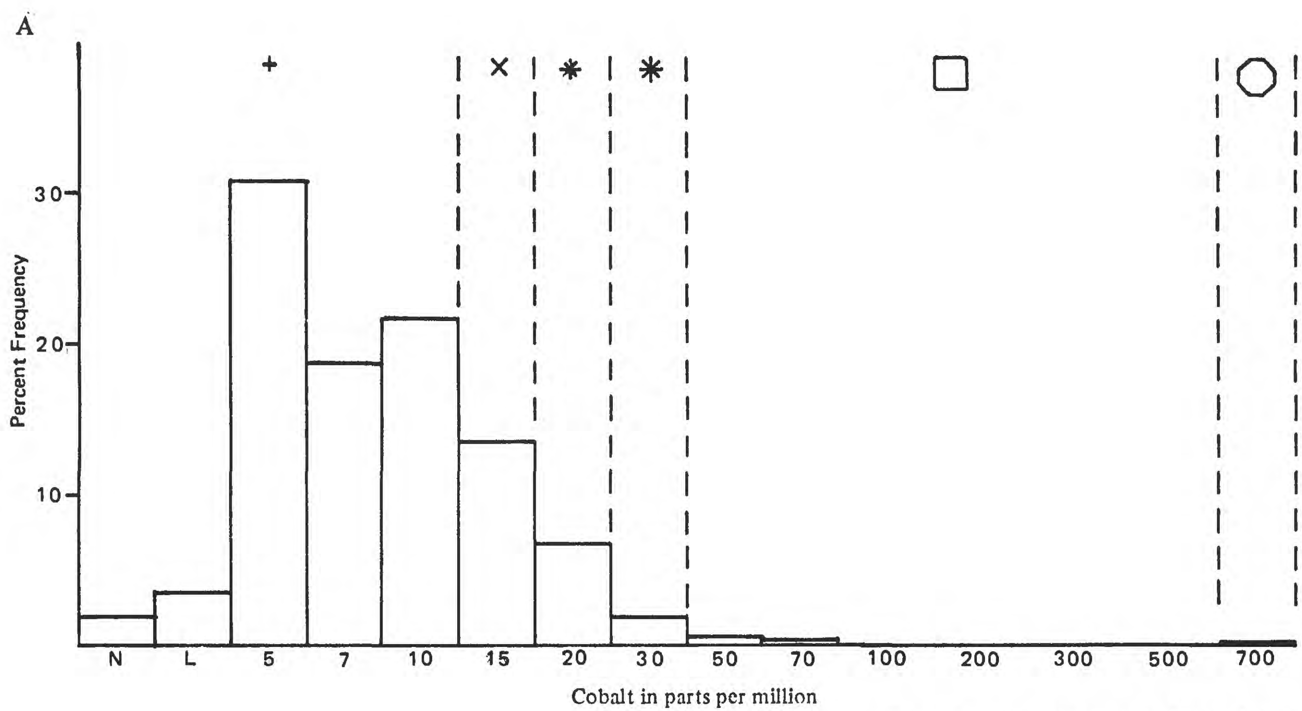


Note: Element-value symbols are shown in red on part B of this figure.

Figure 5.--Histogram (*A*) and distribution (*B*) of nickel in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.

B

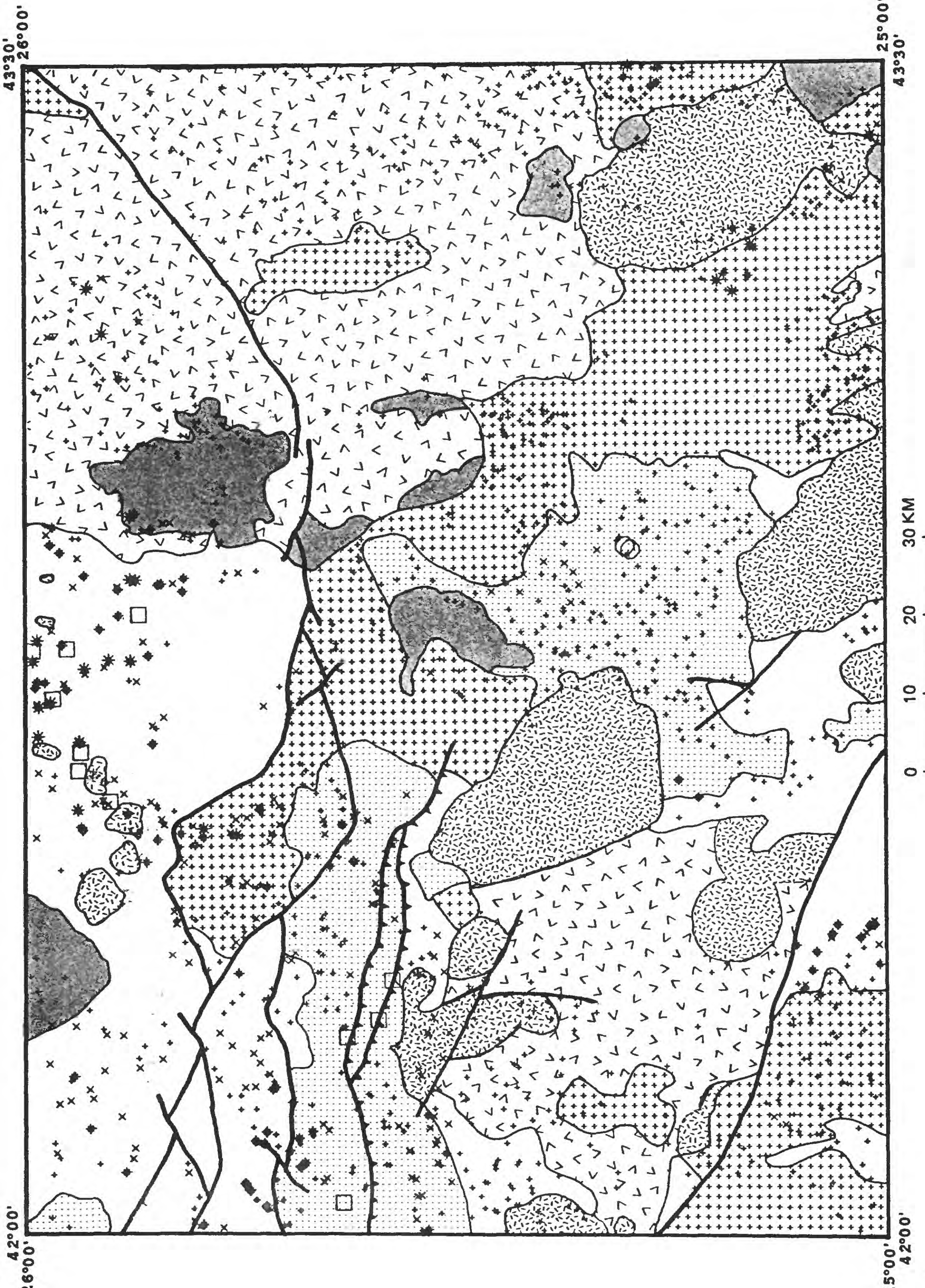




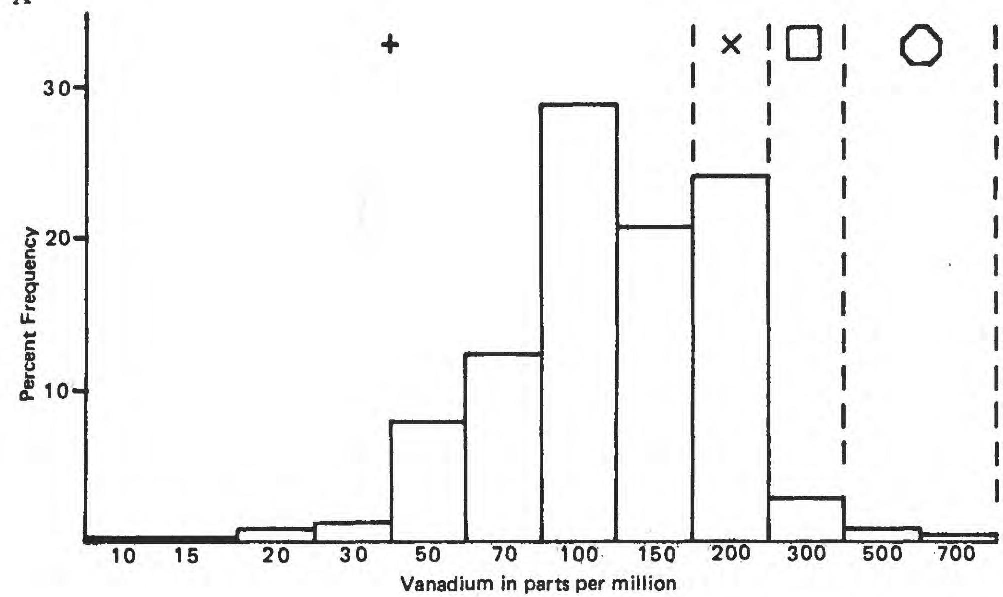
Note: Element-value symbols are shown in red on part B of this figure.

Figure 6.--Histogram (*A*) and distribution (*B*) of cobalt in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.

B



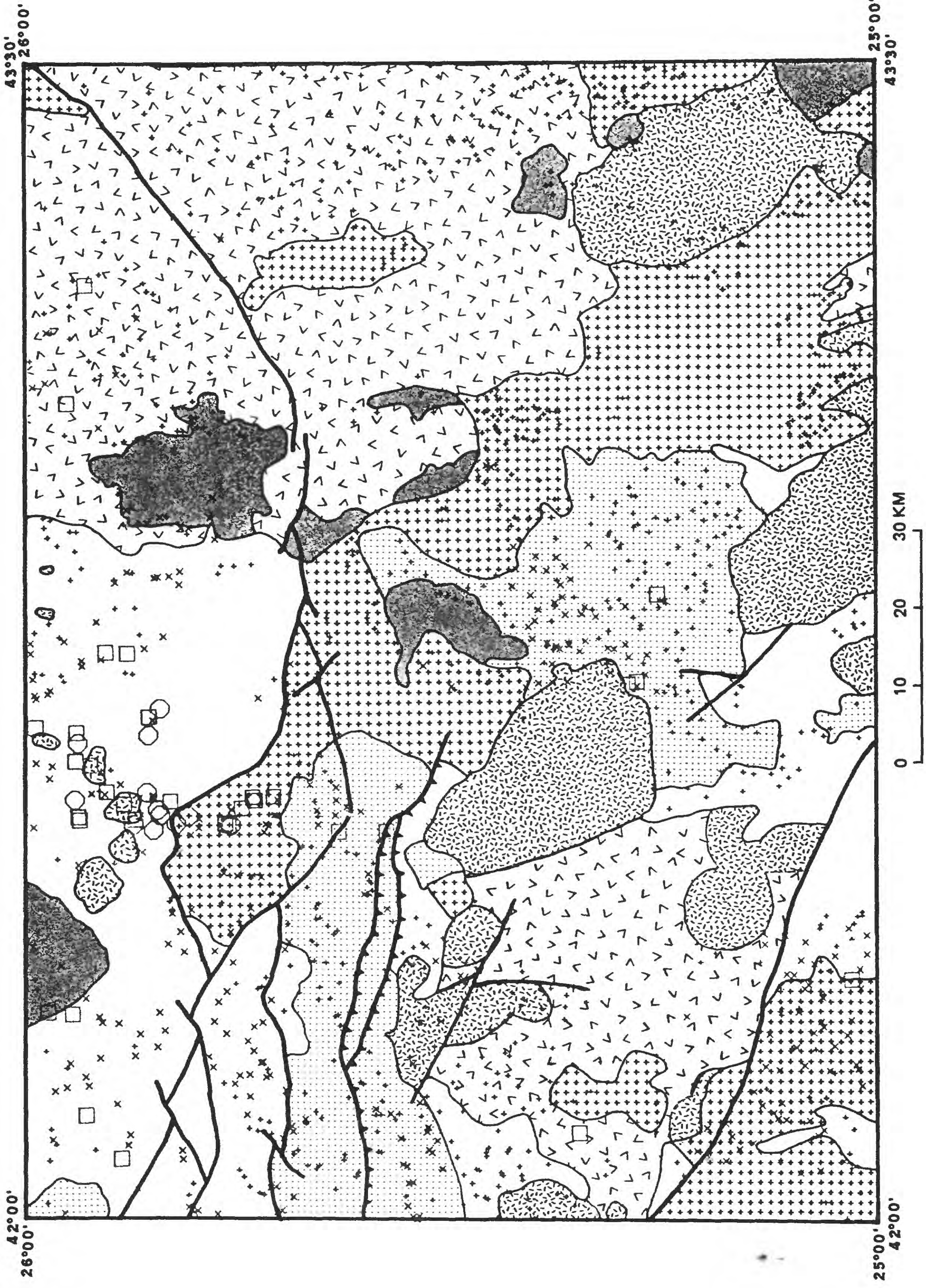
A

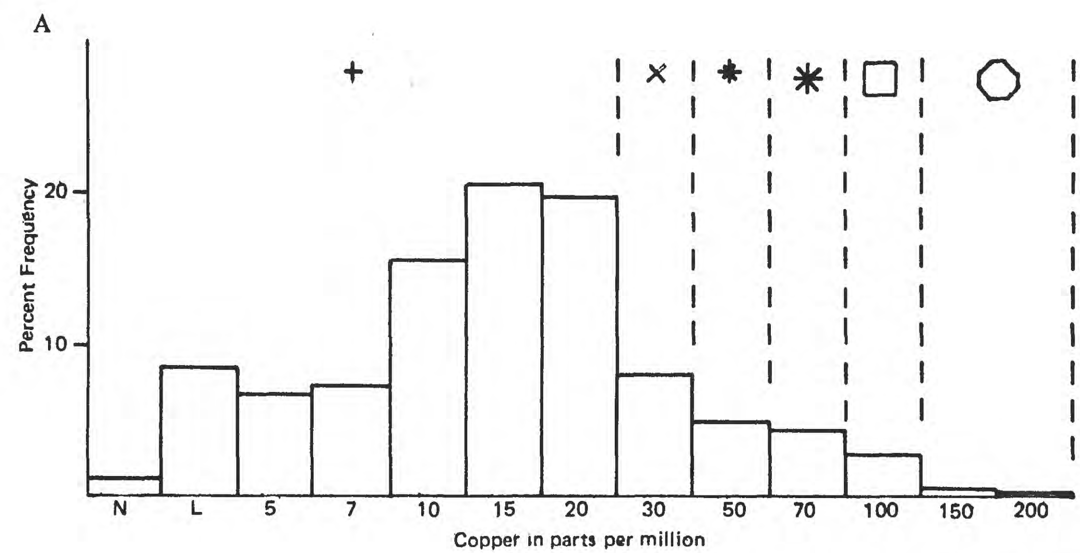


Note: Element-value symbols are shown in red on part B of this figure.

Figure 7.--Histogram (*A*) and distribution (*B*) of vanadium in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.

B

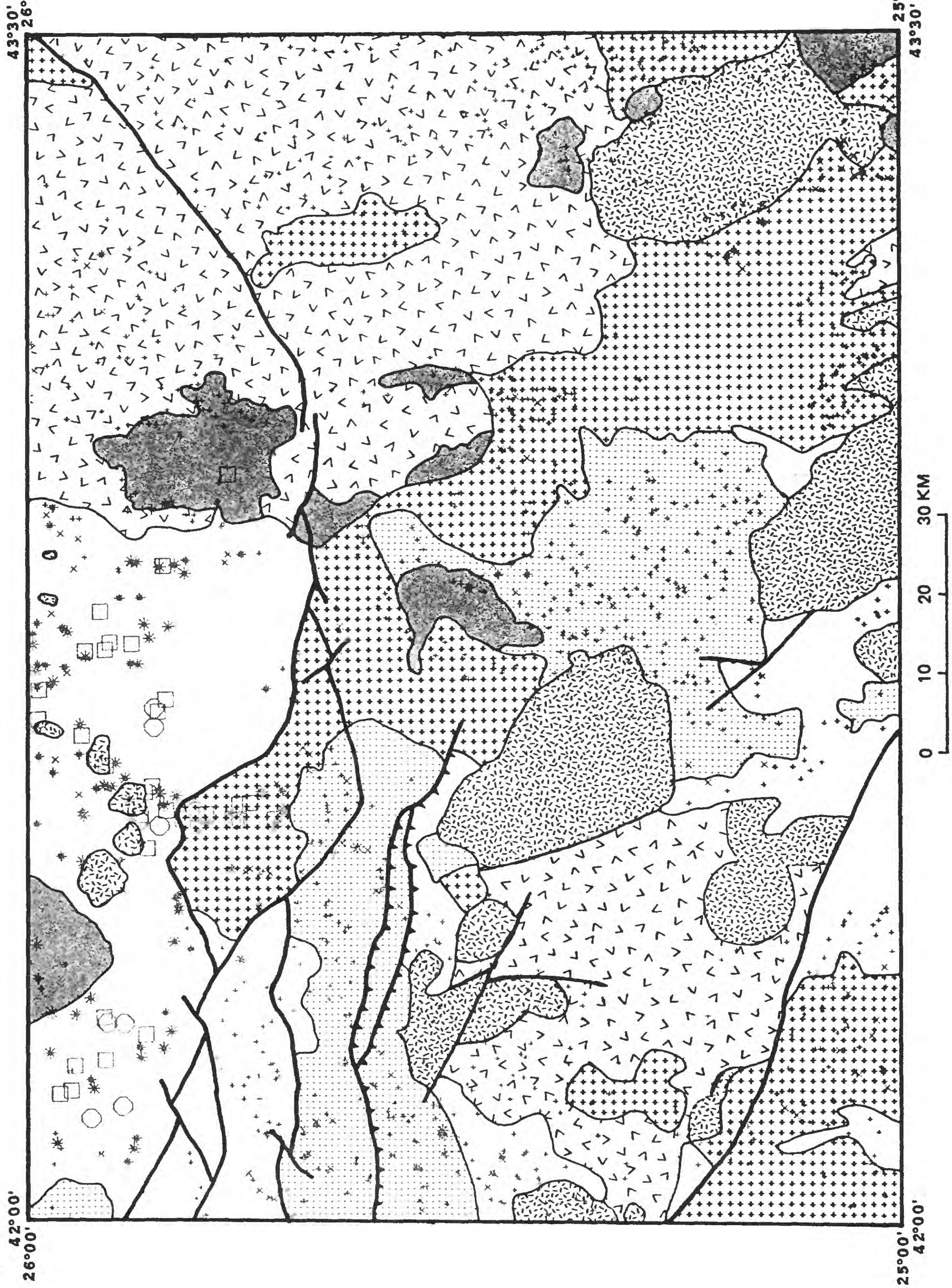




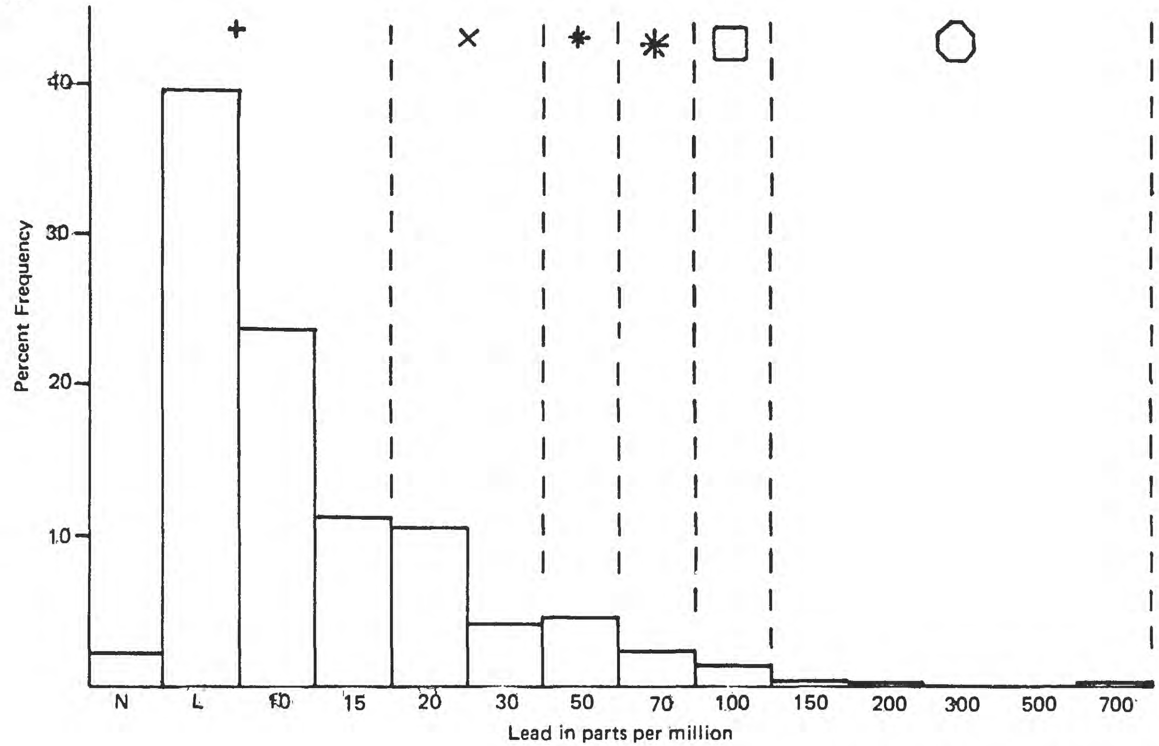
Note: Element-value symbols are shown in red on part B of this figure.

Figure 8.--Histogram (*A*) and distribution (*B*) of copper in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.

B

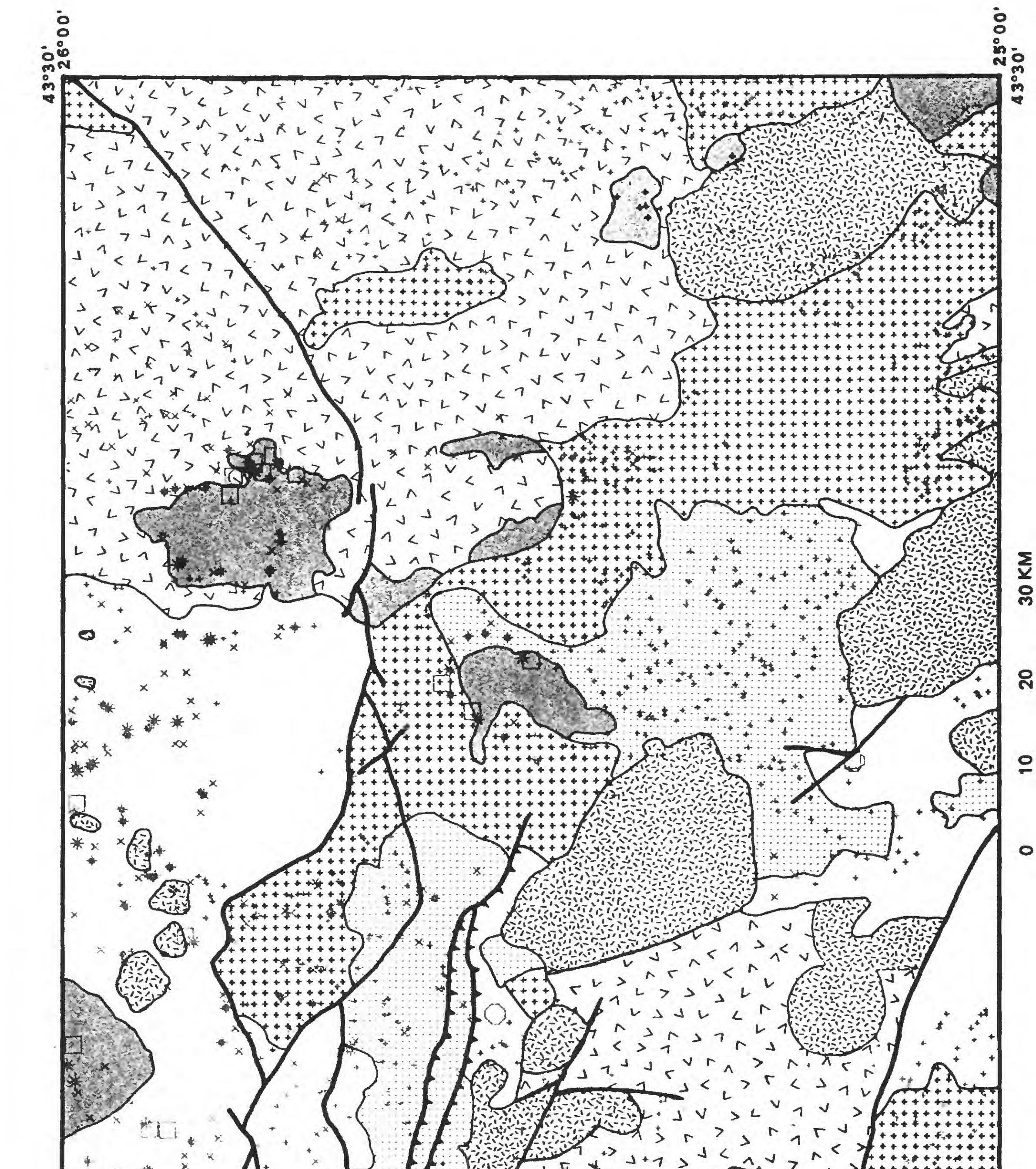


A

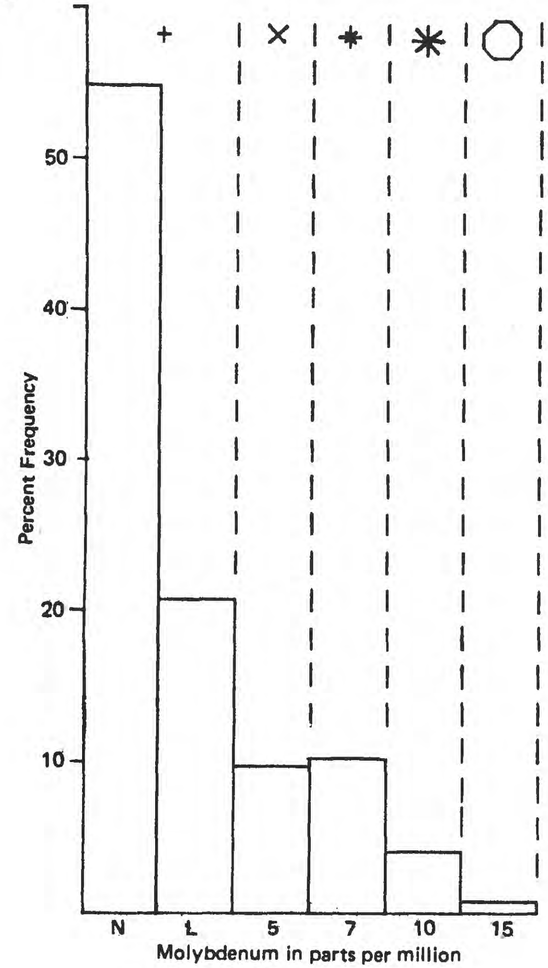


Note: Element-value symbols are shown in red on part B of this figure.

Figure 9.--Histogram (*A*) and distribution (*B*) of lead in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.


B
43°30'
26°00'
25°00'
43°30'
42°00'
26°00'
25°00'
42°00'
0
10
20
30 KM

A



Note: Element-value symbols are shown in red on part B of this figure.

Figure 10.--Histogram (*A*) and distribution (*B*) of molybdenum in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.

B

page 37 follows

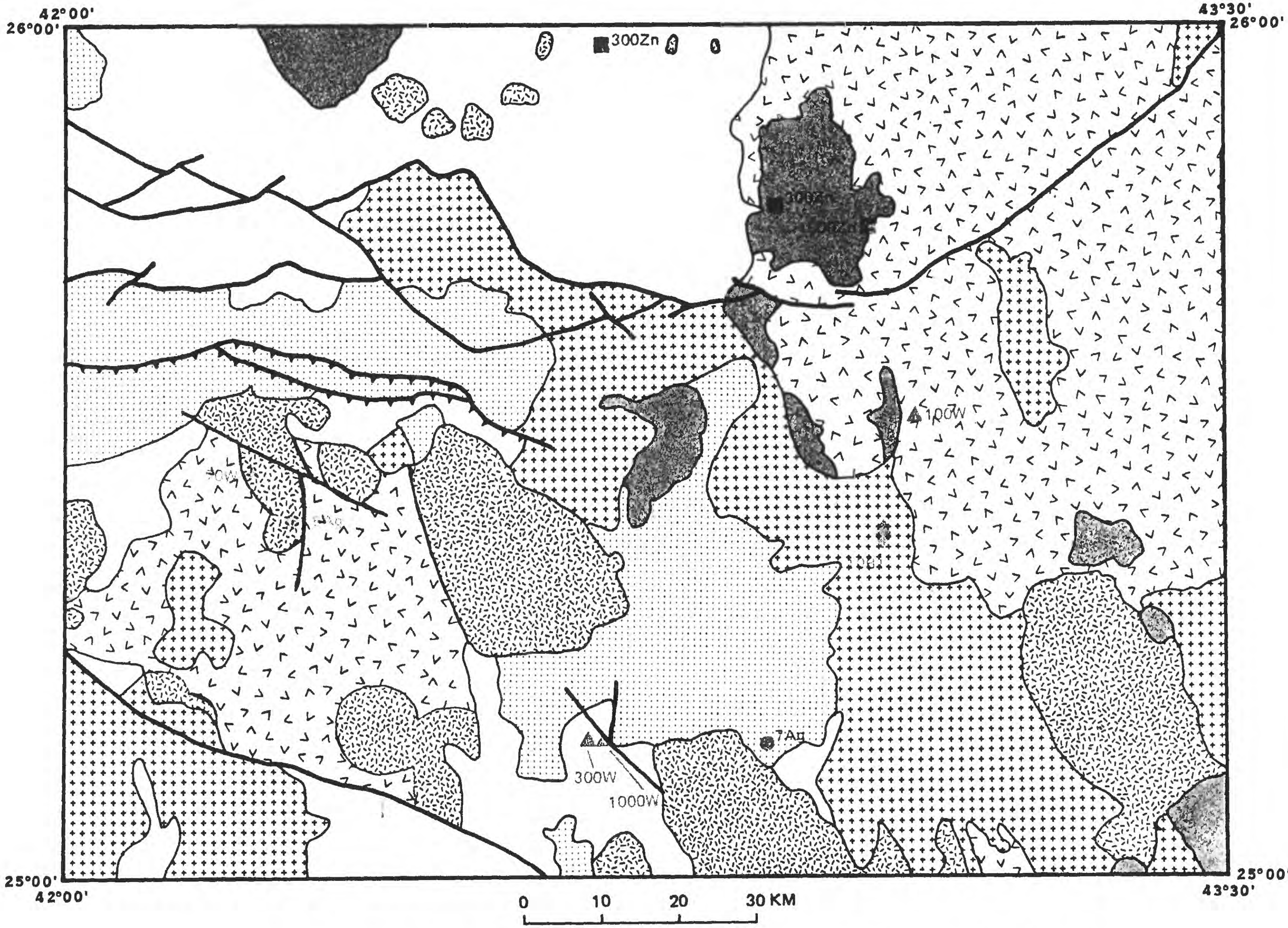
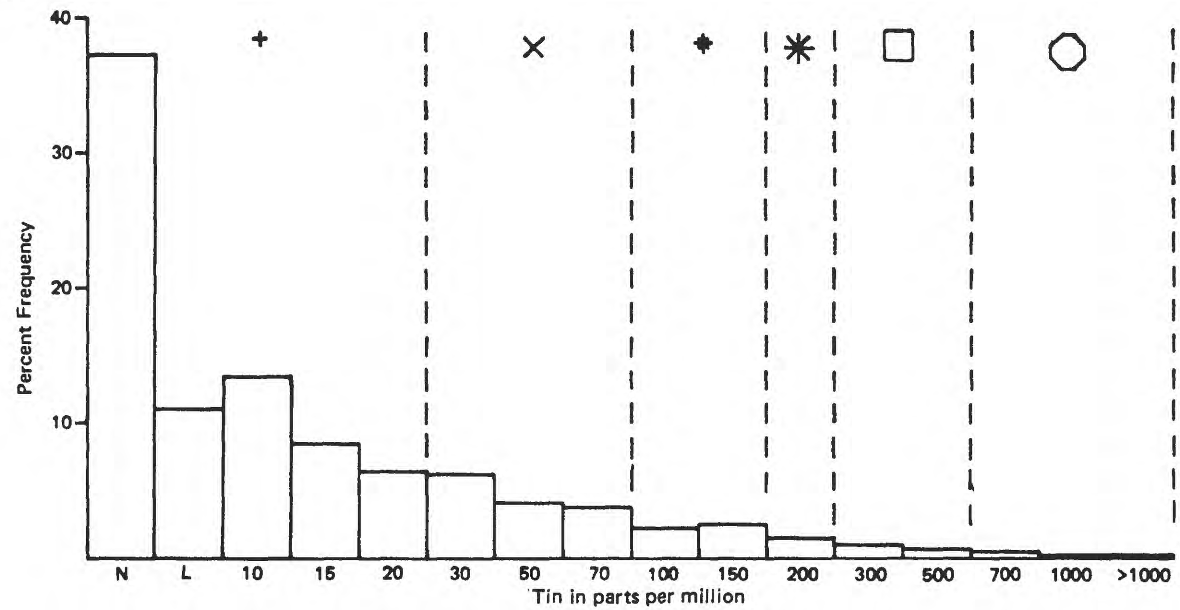


Figure 11.--Distribution of Ag, W, Bi, and Zn in wadi concentrates, Aban al Ahmar quadrangle; number next to sample site symbol indicates concentration in parts per million. Geologic map units same as figure 3.

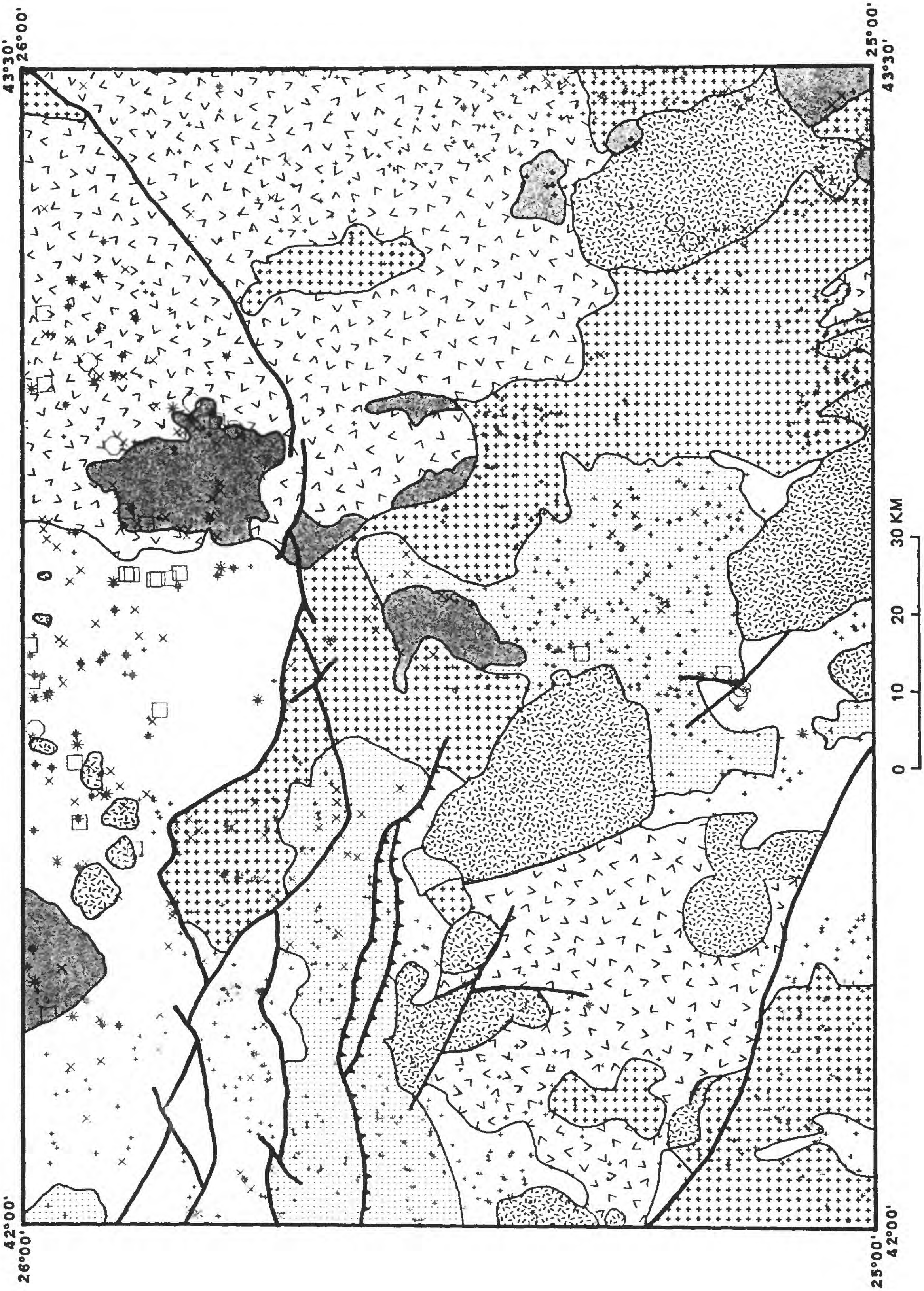
A

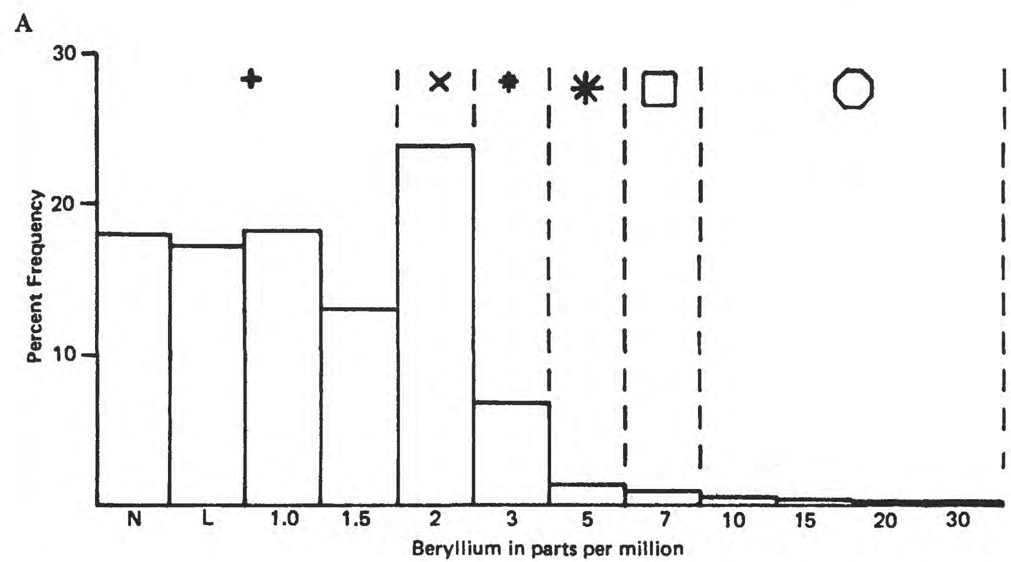


Note: Element-value symbols are shown in red on part B of this figure.

Figure 12.--Histogram (*A*) and distribution (*B*) of tin in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as figure 3.

B

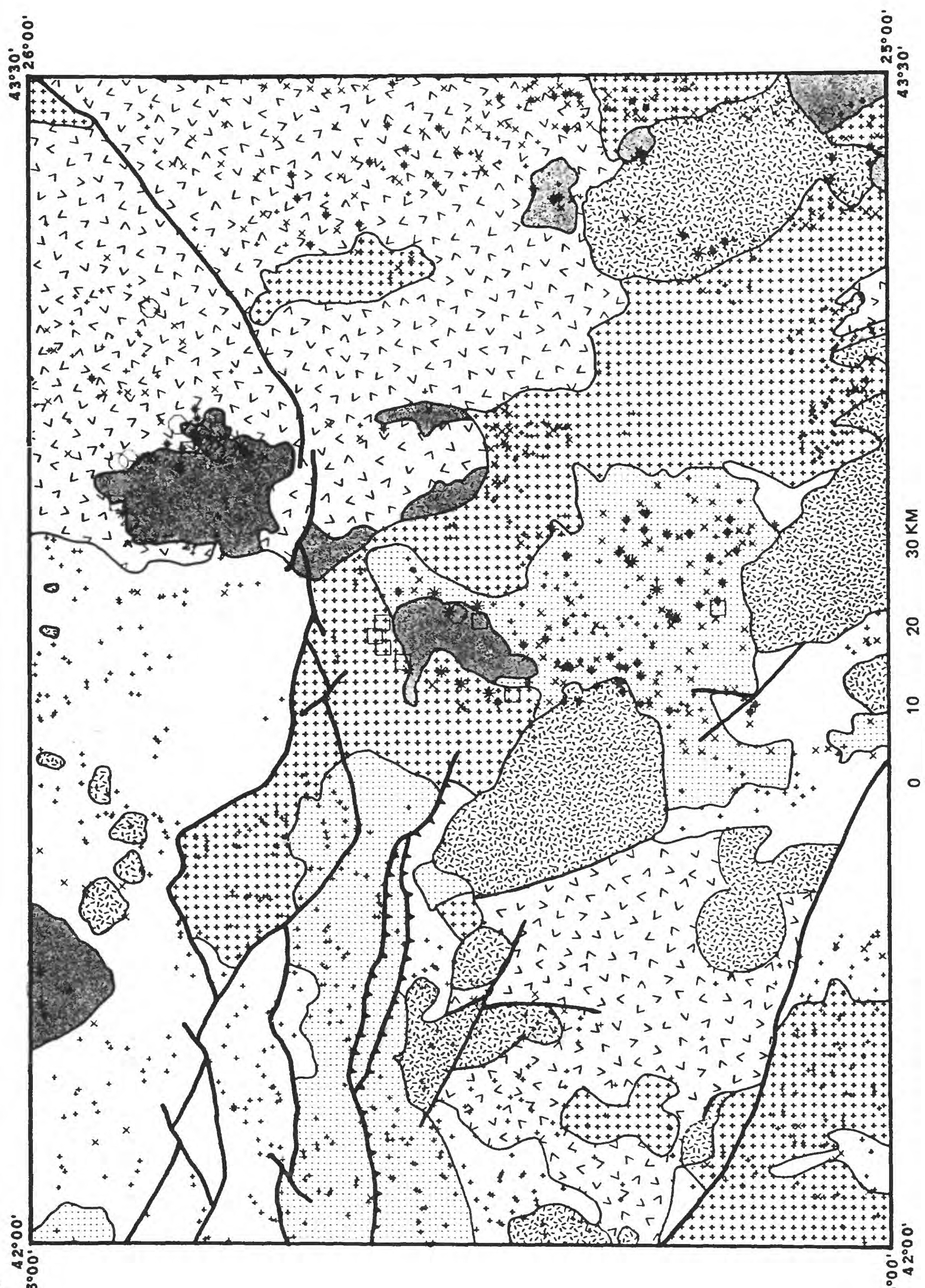


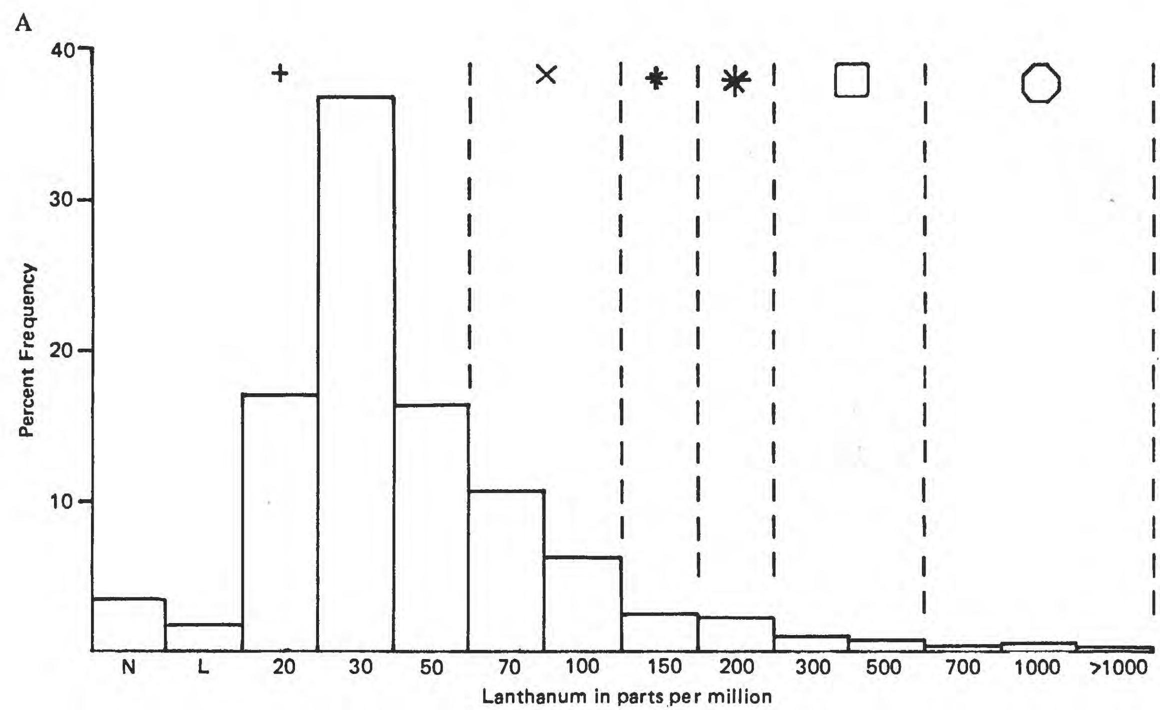


Note: Element-value symbols are shown in red on part B of this figure.

Figure 13.--Histogram (*A*) and distribution (*B*) of beryllium in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.

B

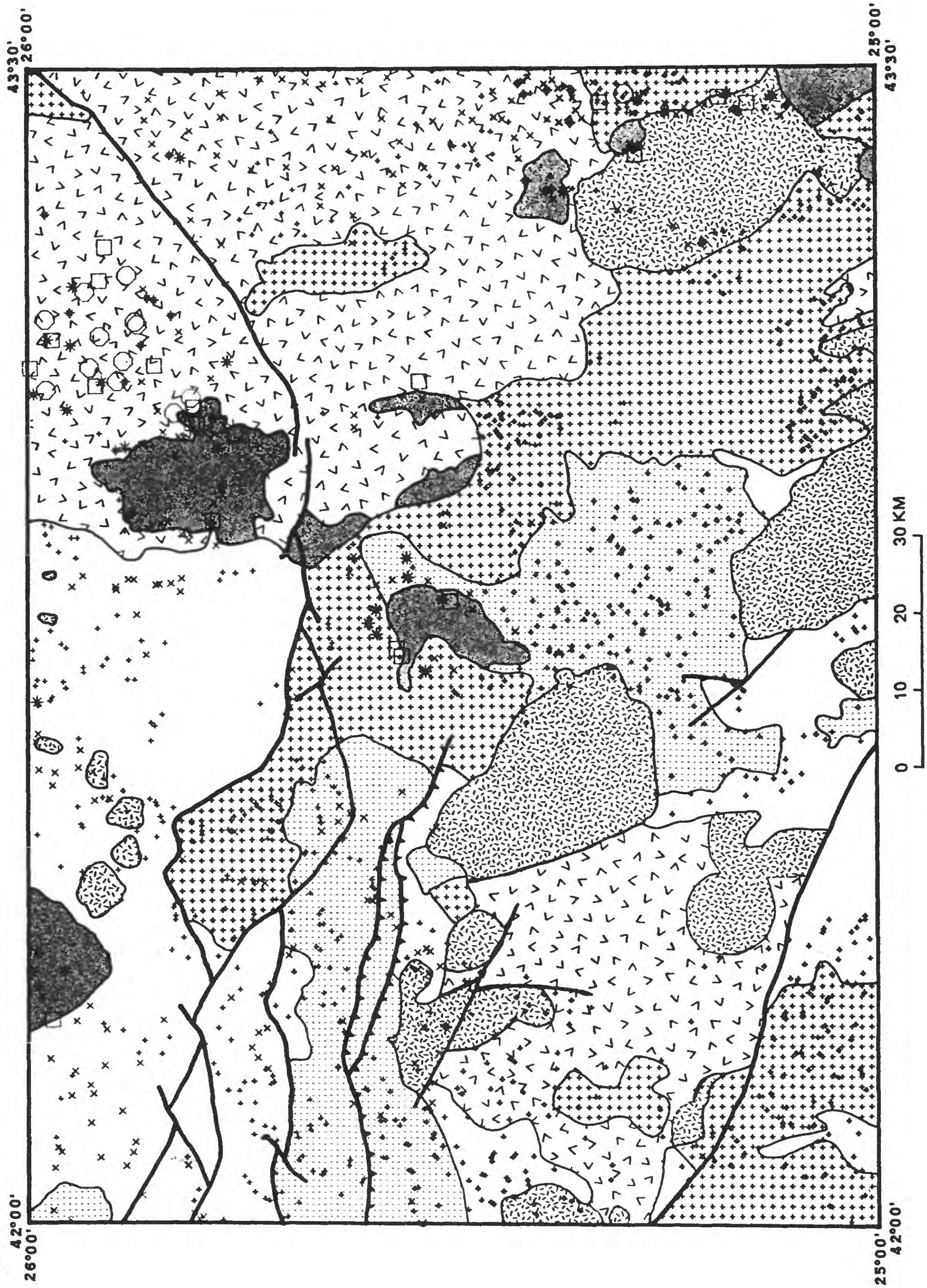




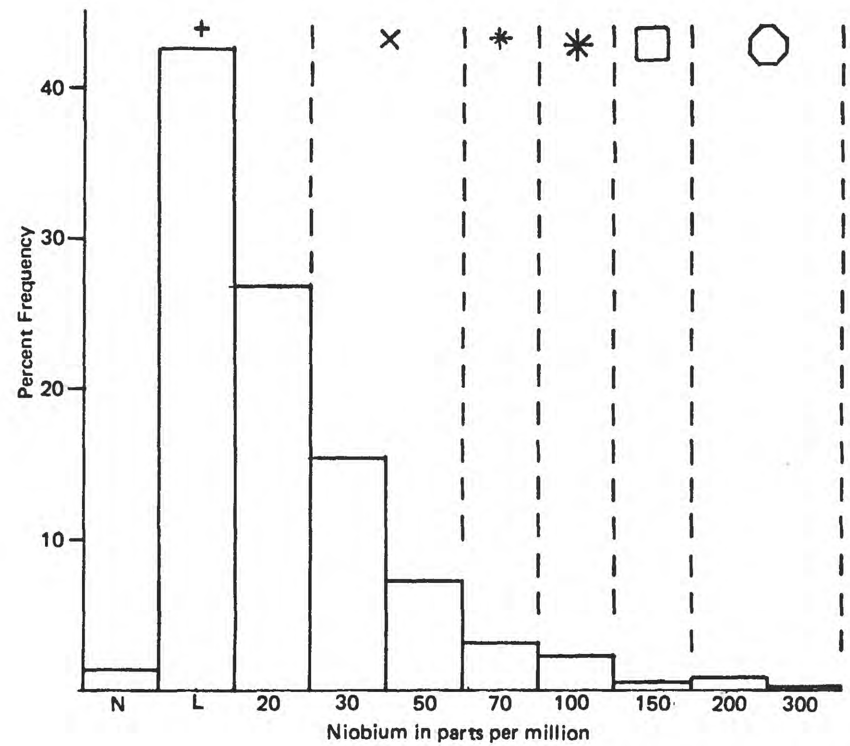
Note: Element-value symbols are shown in red on part B of this figure.

Figure 14.--Histogram (*A*) and distribution (*B*) of lanthanum in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.

B

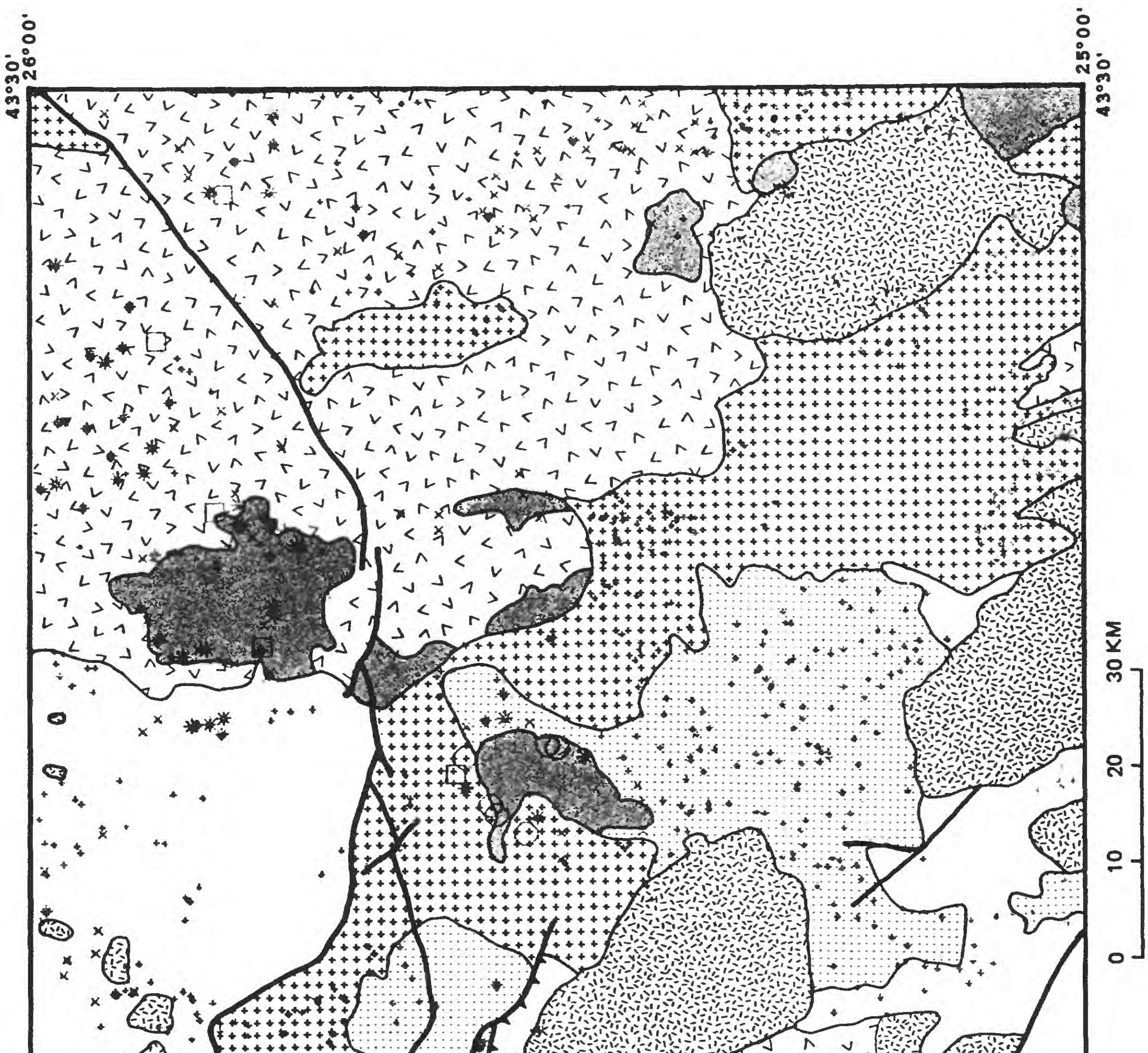


A



Note: Element-value symbols are shown in red on part B of this figure.

Figure 15.--Histogram (*A*) and distribution (*B*) of niobium in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.



B

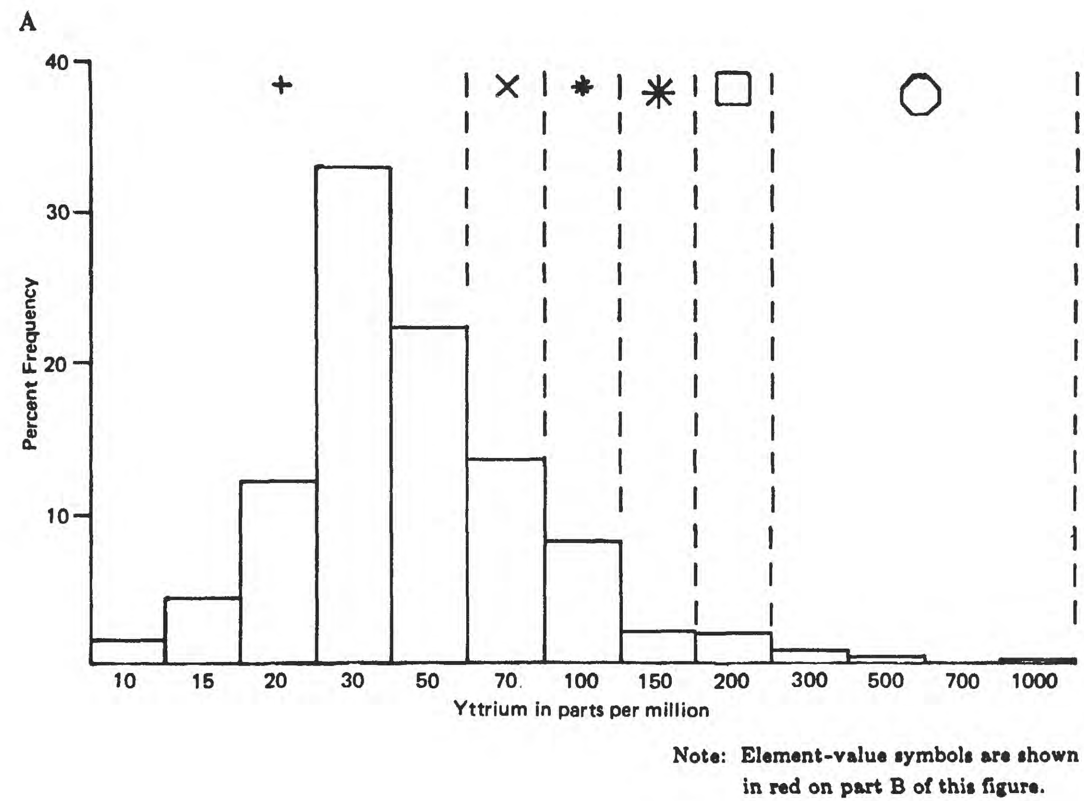
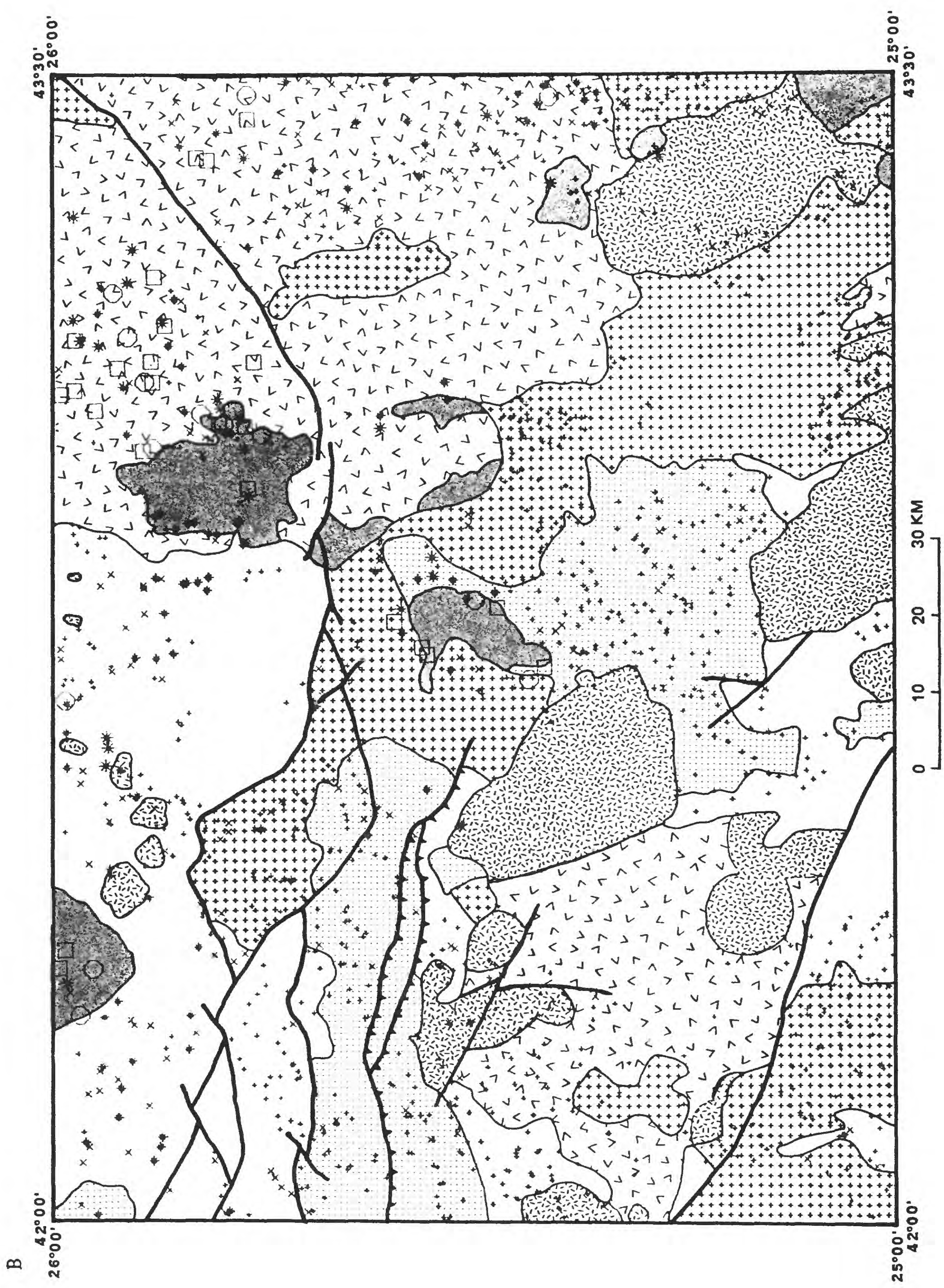
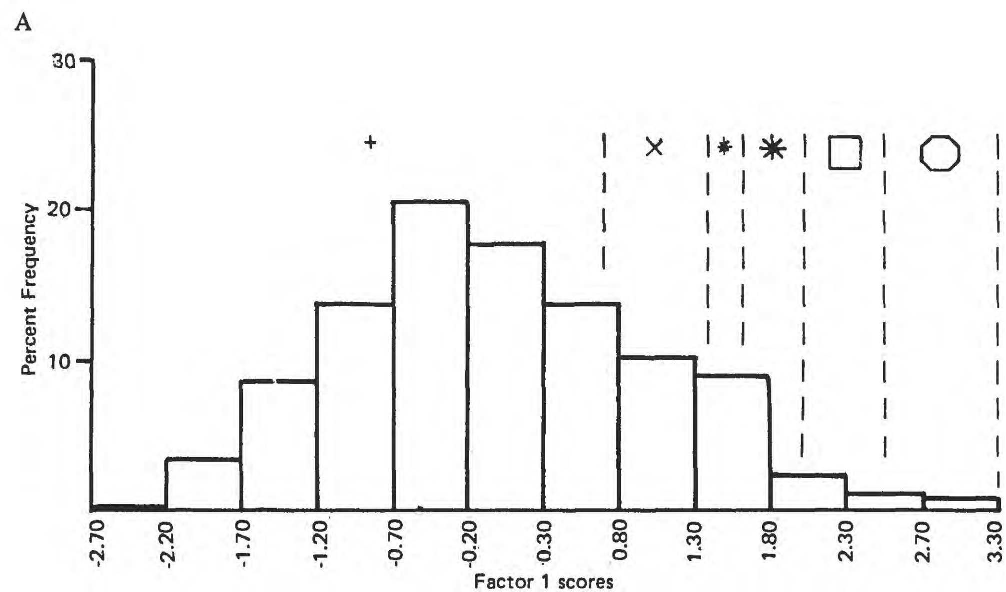


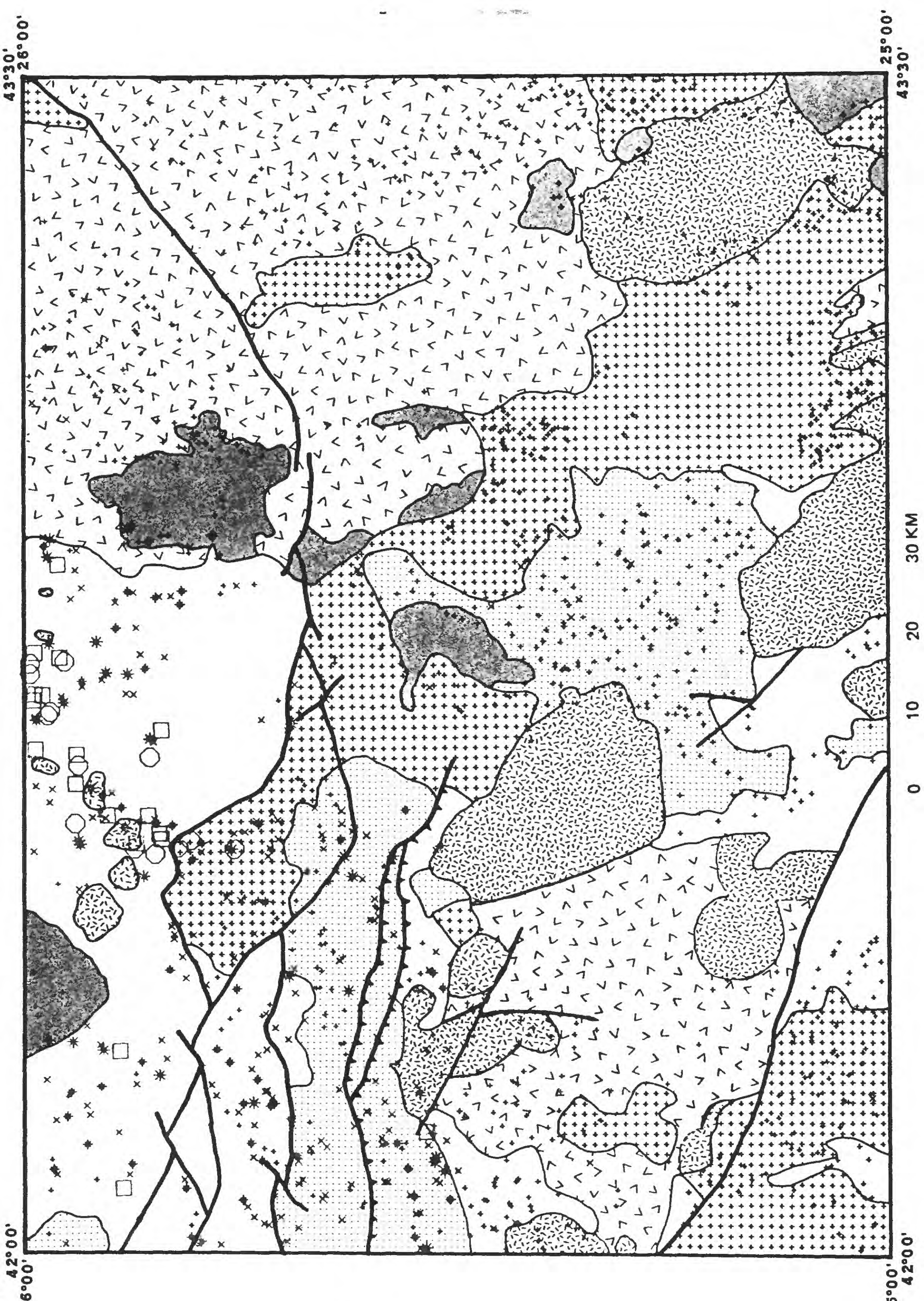
Figure 16.--Histogram (*A*) and distribution (*B*) of yttrium in wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.


B
43°30'
26°00'
25°00'
43°30'
42°00'
26°00'
25°00'
42°00'
0
10
20
30 KM

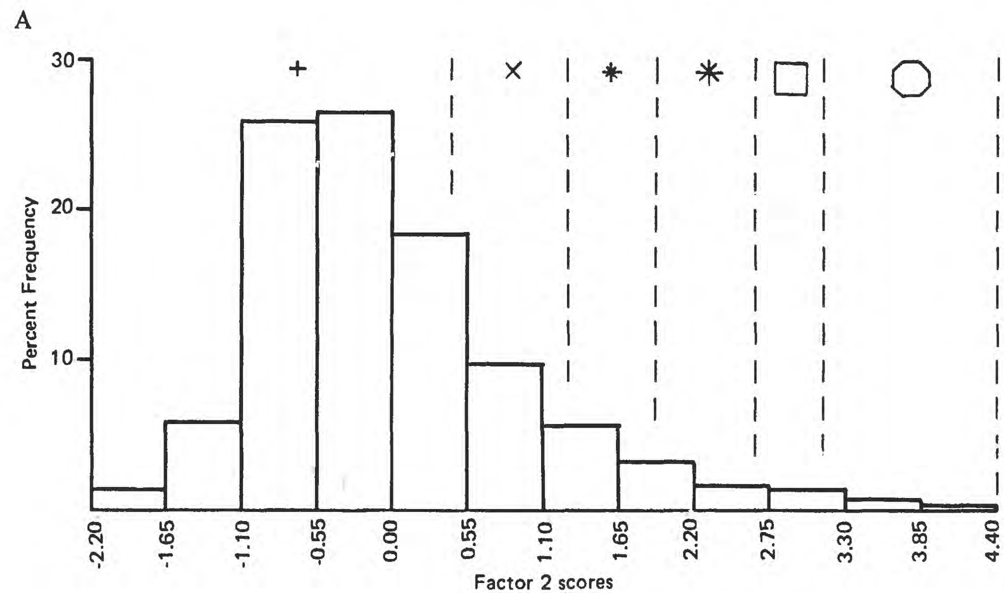


Note: Element-value symbols are shown in red on part B of this figure.

Figure 17.--Histogram (*A*) and distribution (*B*) of factor 1 scores for wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.

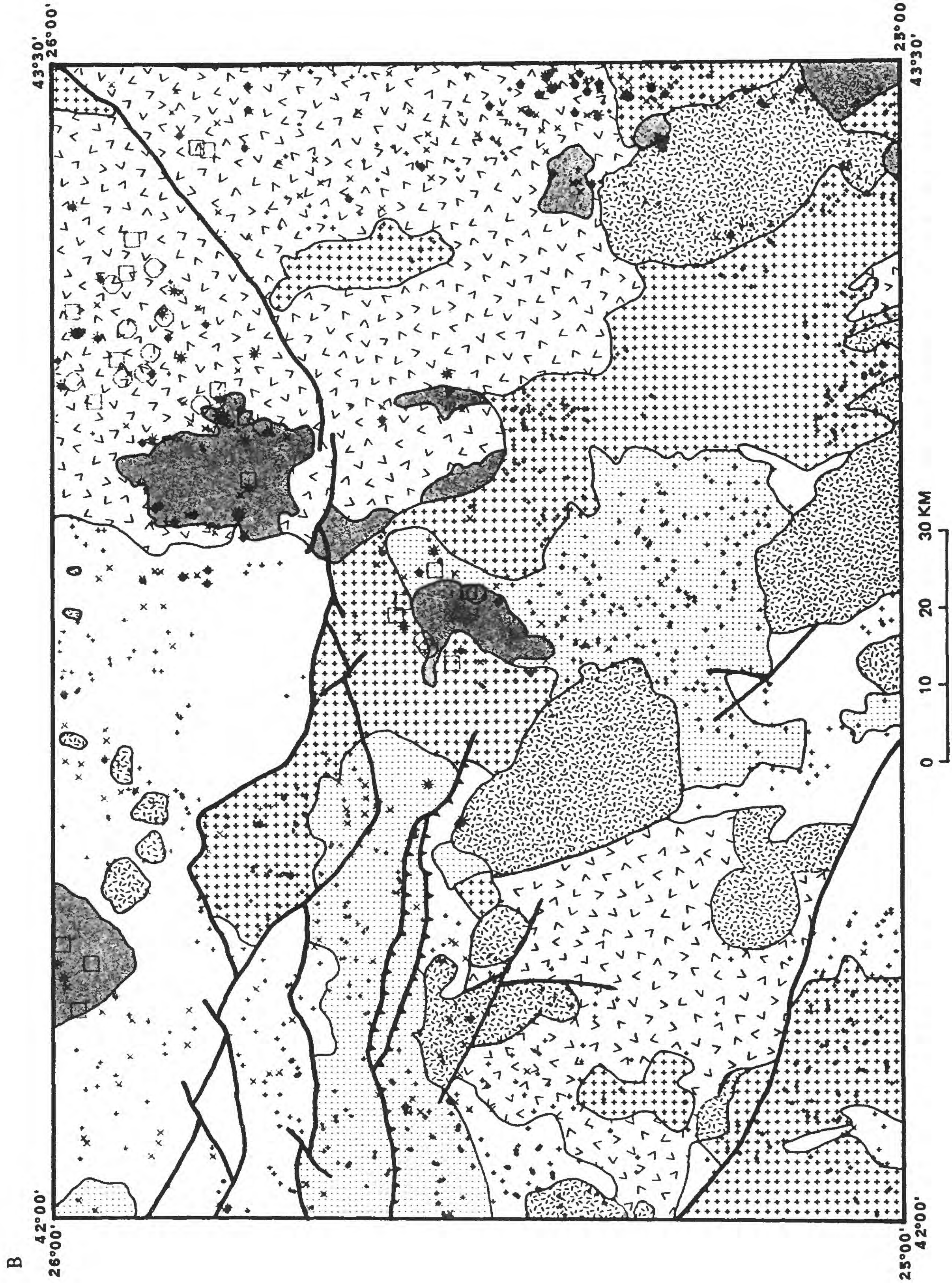


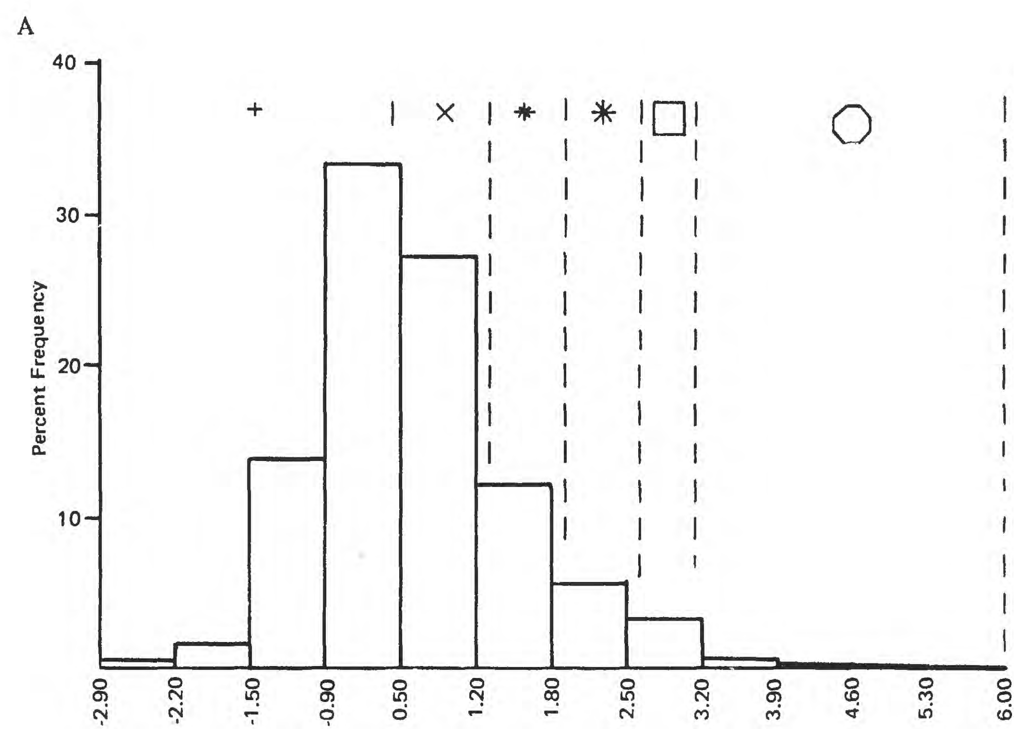
B



Note: Element-value symbols are shown in red on part B of this figure.

Figure 18.--Histogram (*A*) and distribution (*B*) of factor 2 scores for wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.

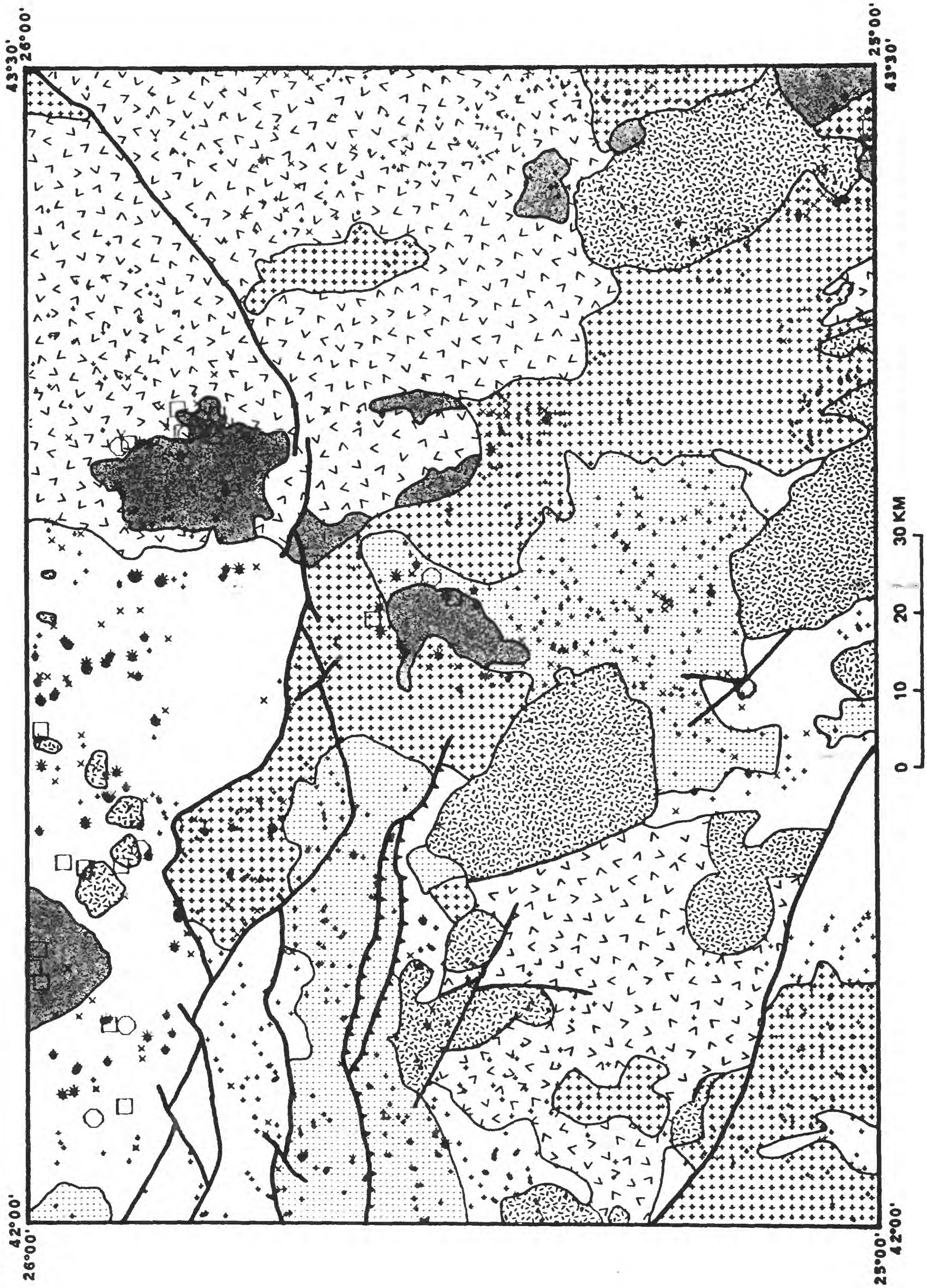

B
43°30'
26°00'
42°00'
26°00'
25°00'
43°30'
25°00'
42°00'
0
10
20
30 KM



Note: Element-value symbols are shown in red on part B of this figure.

Figure 19.--Histogram (*A*) and distribution (*B*) of factor 8 scores for wadi concentrates, Aban al Ahmar quadrangle. Geologic map units same as fig. 3.

B



FOLLOW-UP SURVEY

TECHNIQUES

Wadi samples were prepared for analysis at site locations by sieving approximately 5 kg of sample material through a 2-mm screen. The surface material was first removed before collection of the sample. At the field camp, one fraction of this sample was sieved to obtain the -30-to +80-mesh fraction (0.177 to 0.595 mm). This fraction was analyzed by atomic absorption spectroscopy for As, Au, Sb, Te, and Zn by the DGMR-USGS chemical laboratory in Jeddah.

The second fraction was hand panned at the field camp to obtain the heavy-mineral concentrates. In the laboratory, the panned concentrates from the samples were dried and sieved to -18 mesh (<1.0 mm), and the magnetite removed with a hand magnet. The remaining concentrate was separated run through heavy-liquid separation to obtain a light and a heavy fraction. The light fraction, which contained mainly minerals such as quartz and feldspar, was discarded. The remaining heavy-mineral fraction was separated electro-magnetically by a Frantz isodynamic separator with a forward and side slope of 15 degrees and an ampereage setting of 0.2A. The magnetic fraction (at 0.2 amperes) was discarded and the remaining fraction was further electro-magnetically separated into a nonmagnetic and magnetic fraction at a setting of 0.6A. The discarded magnetic fraction contained iron-rich magnetic minerals such as ilmenite, as well as several amphiboles and pyroxenes. The nonmagnetic fraction (at 0.6A) was hand ground to less than 149 micrometers in an agate mortor. This fraction was then analyzed with a d.c.-arc emission spectrograph for 31 elements by R. T. Hopkins at the USGS laboratory in Denver, Colorado. Mineralogic studies of individual grains from this fraction were conducted using a conventional binocular microscope and an x-ray emission spectrograph with a scanning electron microscope (SEM) at the USGS laboratory in Denver.

Rock samples were obtained by collecting chips from approximately one m^2 areas. Samples of veins were obtained by collecting chips from one to three m along strike. All rock samples were pulverized and split. One split was analyzed with a d.c.-arc emission spectrograph for 31 elements and another split was analyzed by atomic absorption spectrography for As, Au, Sb, Te, and Zn. The samples were analyzed at the DGMR-USGS laboratory in Jeddah and at the USGS laboratory in Denver.

DISCUSSION OF STUDY AREAS

The areas located during the follow-up survey that may be of economic significance are described below. Figure 2 is an index map of the Aban al Ahmar quadrangle showing the locations of these areas.

Wadi al Mahalani Area

Wadi concentrates collected northwest of the village of At Tarfawi in the northwestern corner of the quadrangle during the regional geochemical survey contained anomalous Cu (200 ppm) and Pb (150 ppm). Subsequent field study located a linear trend of discontinuous outcrops of iron-rich siliceous rocks over a length of approximately two km on the west side of Wadi al Mahalani (figs. 2

and 20[1]). The rocks along this trend vary in color from red to limonitic yellow, are strongly silicified, contain fragments of brecciated material, and are more resistant to weathering than the surrounding Murdama sandstone. These rocks trend about N. 65 W., approximately parallel to bedding in the Murdama sandstone. Nine samples of iron-rich silicious rocks collected during the follow-up survey contained low-level concentrations of Co, Cu, Mo, Ni, Pb, Au, Zn, As, and Sb, and high concentrations of Fe (table 4[2]).

The trend of the iron-rich silicious rocks is roughly parallel to the bedding of the Murdama sandstone, suggesting possible strataform deposition by volcanogenic exhalative processes. Williams (1983) reports evidence for minor volcanic activity during Murdama-group deposition, although no rocks of volcanic origin were observed near the iron-rich silicious outcrops. More likely, the iron-rich silicious rocks formed along a small fault or fracture by deposition from hydrothermal fluids, possibly related to emplacement of Idah-suite stocks similar to those northeast of Wadi al Mahalani.

Silicified samples collected from a granodiorite porphyry of the Idah suite located about 6 km northeast of the iron-rich silicious outcrops contained low concentrations of Au and W (table 5). These areas (fig. 26) have moderate resource potential for precious- and base-metals in vein deposits.

Jibal Qitan Skarn Area

During regional mapping of the Uqlat as Suqur quadrangle, sheet 25/42A, Cole (1985a) located a garnetiferous skarn on the southeastern side of Jibal Qitan (figs. 2 and 21). No mineralization was noted during field reconnaissance and the regional geochemical survey. The skarn zone is approximately one km long and occurs between Qitan granite and Murdama limestone. The Qitan complex consists of peraluminous two-mica granite (Stuckless and others, 1982a) and intrudes the Murdama group along a steep, sharp contact. Thin, irregular fine-grained dikes locally intrude the limestone. Garnet and epidote are commonly found along these contacts (Cole, 1985a).

Rock samples collected from the skarn zone in the Murdama limestone during the follow-up survey contained no visible sulfides, and scheelite was not detected under short-wave ultraviolet light. Several samples contained weakly anomalous concentrations of Zn, W, Sn, As, and Sb indicating some mineralization (table 6). The elevated concentrations of Sn and W occurred in samples collected near the contact between the granite and limestone. The possibility exists that more significant skarn mineralization may be present along the contact in the subsurface. This area has moderate resource potential for Sn, W, and base metals in skarn deposits (fig. 26).

Jibal Minyah Tin Area

The area north of Jibal Minyah in the southeastern part of the quadrangle is anomalous on the basis of high concentrations for factor-8 scores from the regional geochemical survey (fig. 19). Follow-up work consisted of sampling rocks and sediments of the smaller drainages in order to determine the source of the anomalous concentrations and to delineate any mineral occurrence in the area. The anomalous area consists of several large felsic porphyritic dikes that intrude

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1/ Figures 20-26 are at the end of the chapter. See page 64.

2/ Tables 4-11 are at the end of the chapter. See page 59.

Idah-suite granodiorite porphyry north of the peraluminous Minyah granite stock (figs. 2 and 22). On the basis of composition, Bohannon (1984) suggests that the dikes may be genetically related to the Minyah granite of the Abanat suite, but rounded inclusions in the granite suggest that these dikes are older (Cole, written commun., 1986).

Wadi-concentrate samples collected during the follow-up survey contained highly anomalous concentrations of Sn and Bi, and moderate to weakly anomalous concentrations of Pb, Mo, and Be (table 7). Petrographic and SEM x-ray studies of grains from wadi concentrates identified cassiterite as the tin-bearing mineral. Rock samples collected from the area contained anomalous concentrations of Sn, Bi, Pb, Cu, and Ag (table 8). Rock samples that contained appreciable amounts of tin (70-500ppm) were collected from dikes. Two types of dikes are present: (1) coarse- grained porphyritic dikes, and (2) fine-grained aplitic dikes, which are the youngest rocks in the area and generally contain the highest concentrations of tin.

The SnO_2 content, determined by SEM semiquantitative analysis of 18 cassiterite grains from wadi-concentrate samples collected from the follow-up area, ranges from 59 to 79 percent. The cassiterite is black, submetallic, highly angular, with some crystal faces still present. The wadi-concentrate samples also contain abundant grains of fluorite and topaz, and sample 209249 contains fragments of attached grains of cassiterite, fluorite, feldspar, quartz, and topaz. The cassiterite in this sample exhibits a high degree of crystalinity and angularity, comparable to the other samples in the area. Wadi concentrates 209404 and 209617 contain large angular cassiterite grains with mineral fragments similar to those found in 209249, but less abundant fluorite. These three samples have morphological and mineralogical characteristics similar to those of wadi-concentrate samples collected by M. S. Allen within 2 km of the tin greisen at Jibal as Silsilah. However, the Silsilah samples did not contain fluorite (M. S. Allen, person. commun.). Small fluorite veins were observed cutting the larger porphyritic dikes near Jibal Minyah.

The mineral association of wadi concentrates (cassiterite, fluorite, and topaz) indicates possible greisen mineralization. It is unlikely that these minerals were derived from the exposed granite at Jibal Minyah, which has been eroded to plutonic level. In addition, most of the sampled wadis do not drain the Minyah pluton. It seems likely that the large, angular cassiterite was derived from a nearby greisen that was covered. No greisenized rock was observed during the follow-up survey, but this may be due to the abundant covering of grus and eolian sand in the flat-lying areas between the more resistant dikes. Cole (1986) reports a minor fluorite-muscovite greisen near the northwest border of Jibal Minyah. It is also possible that the cassiterite may be derived from the felsic dikes, but this seems unlikely. This area north of Jibal Minyah has high resource potential for tin and tungsten in greisen deposits (fig. 26).

Detailed geologic mapping of the area and a rock geochemical survey would be useful in evaluating the resource potential of the area.

Jibal Suwaj Tin Area

Two wadi-concentrate samples collected from the northeast side of Jibal Suwaj during the regional geochemical survey contained 700 ppm tin. Follow-up rock and wadi sampling was conducted in the area of the two wadis that drain isolated outcrops of the Shubaykiyah granite (figs. 2 and 23). During reconnaissance mapping of the Ash Shubaykiyah quadrangle (sheet 25/43C), Bohannon (1984) mapped these isolated outcrops as the youngest intrusives (possibly Abanat-suite rock) in the area.

Six of the seven wadi-concentrate samples collected during the follow-up survey contained more than 2000 ppm tin (table 9). The six samples containing high concentrations of tin were collected from wadis draining flat-lying areas covered with sheet sand and grus in which the Shubaykiyah granite outcrops. The one sample that contained only 150 ppm tin was collected from a small wadi within the center of the largest outcrop of the Shubaykiyah granite, which suggests that the granite outcrop is not the source of the tin anomaly. Petrographic and SEM x-ray studies of grains from the wadi concentrates identified cassiterite to be the tin-bearing mineral. The cassiterite grains found at sites 209068, 209237, 209753, and 209781 are angular, and several samples contain composit grains consisting of cassiterite, quartz, feldspar, and topaz. The angular cassiterite and composite grains are similar in appearance to those found in the Jibal Minyah tin area.

Twenty-six rock samples of the Shubaykiyah granite were collected during the follow-up survey. Only four samples contained detectable tin ranging from 10 to 50 ppm. No greisenized rock of mineralized dikes and veins were located during the follow-up survey. It is possible that the tin is present as disseminated grains within the granite, but the coarse-grained, angular cassiterite is more likely derived from greisenized rock associated with an Abanat-suite pluton that is covered by eolian sand and grus. This area has moderate resource potential for tin and tungsten greisen deposits (fig. 26).

Buqaya al Luaah Gold Area

A large quartz vein, 1-2 m wide, and sparse ancient workings were discovered in this area during a follow-up survey of a remote-sensing anomaly (G. Raines, person. commun.). The area is located in the southeastern part of the quadrangle, approximately 35 km west of Jibal Minyah and is referred to as Buqaya al Luaah (figs 2 and 24). The quartz vein trends discontinuously NNW near an Idah-suite intrusive in a Suwaj-suite foliated quartz diorite.

Five samples of the quartz vein were collected along strike and contain anomalous Bi, Cu, Mo, Pb, and W (table 10). Three of the five samples contained low but detectable concentrations of Au and Te (table 10). Shallow ancient workings are located approximately three km NNE along this same trend. A sample (no. 209428) of the vein material from the ancient workings contained anomalous Au, Te, and Ag (table 10).

The discontinuous quartz veins roughly parallel the trend of a nearby fault and may be structurally controlled. The quartz veins contain hematite and limonite, some crystals of which are after sulfides. The limonitic material is usually present near the contact with the wall rocks. This area has moderate resource potential for precious- and base-metals in vein deposits (fig. 26). More detailed mapping and sampling is needed to accurately evaluate the area.

Aban al Ahmar Area

Based on the interpretation of regional geochemistry, anomalous scores for factor 2 (La, Nb, Y, and Sn) and factor 8 (Pb, Sn, Be, and Cu) occur along the margin of the northern half of Aban al Ahmar (figs. 18 and 19). A follow-up survey was conducted to assess the mineral potential of this area.

Wadi-concentrate samples collected within the Aban al Ahmar peralkaline granite pluton during the follow-up survey contained concentrations of 100-150 ppm tin. Rock samples collected from within the pluton contained less than 10 ppm tin. Peralkaline granites in the Arabian Shield, of which Aban al Ahmar is one, have been described (Elliott, 1983; Cole, 1986; Stuckless and others, 1982a) as typically containing high concentrations of tin. No greisenized rocks were identified in the Aban al Ahmar granite during the follow-up field investigation, although Cole (1986) discusses a quartz-fluorite vein (MODS 2733) with high concentrations of La, Nb, and Sn in the southern part of Aban al Ahmar granite.

If tin mineralization was associated with the emplacement of this pluton, particularly in the upper part of the system, it has probably been eroded away. The extent of the erosion, combined with generally low tin concentrations in wadi concentrates and rocks indicate high resource potential for tin deposits within the Aban al Ahmar pluton. Tin and tungsten mineralization could be associated with satellite bodies of Abanat-suite rocks in the surrounding country rock, peripheral to the main plutonic complex. This area surrounding the pluton has moderate resource potential for tin and tungsten greisen deposits and moderate potential for precious- and base-metal resources in vein deposits (fig. 26).

Aban al Asmar Area

Based on the interpretation of the regional geochemistry, anomalous scores for factor 2 (La, Nb, Y, and Sn) and factor 8 (Pb, Sn, Be, and Cu) occur along the east and southeast margin of Aban al Asmar (fig. 18 and 19). The Aban al Asmar area is located approximately 25 km northeast from Aban al Ahmar. The Asmar complex consists of nested, arcuate intrusions surrounding the central block of Samra rhyolite. The granites range from metaluminous to peraluminous in composition (Stuckless and others, 1982a; Cole, 1985b; Cole and Bohannon, 1985). Samples of wadi concentrates collected during the regional survey contained anomalous concentrations of tin (700 to >1000 ppm) and lead (50 to 200 ppm). These anomalous areas are mainly underlain by biotite-perthite granite, breccia, and hornblend-perthite granite of the Asmar complex (Cole and Bohannon, 1985). A follow-up survey was conducted to assess the mineral resource potential of these areas.

Wadi-concentrate samples containing anomalous concentrations of lead were found to be associated with a hydrothermally altered zone present along the eastern margin of the pluton. This altered area probably resulted from the hydrothermal fluids associated with the late magmatic processes during emplacement of the Asmar pluton and has moderate potential for precious- and base-metal resources in vein deposits (fig. 26).

Thirty-six rock samples collected during the follow-up survey contained 30 ppm or less tin. No greisenized rocks were located, although parts of the Asmar pluton have been eroded, possibly removing mineralization that may have been associated with the upper levels of the pluton. The small amount of erosion of part of the plutonic complex combined with the generally low concentrations of tin in wadi concentrates and rocks indicate only moderate resource potential for tin greisen deposits within the Asmar plutonic complex. Tin and tungsten mineralization could be associated with satellite bodies of Abanat suite rocks in the surrounding country rock, peripheral to the main plutonic complex, or below the Samra rhyolite in the center of the plutonic complex. These areas have moderate resource potential for tin and tungsten in greisen deposits (fig. 26).

Isolated Gold Occurrences

Several quartz veins located throughout the quadrangle (fig. 25) were sampled and shown to contain low concentrations of gold (table 11). These quartz veins are primarily associated with Idah-suite intrusives. Boyle and Howes (1983), Smith and others (1984), Smith and Samater (1985), and Cole (1986) discuss occurrences of this type of mineralization. The low-to-moderate gold content and limited size of these occurrences indicate moderate potential for gold and silver resources in vein deposits.

Table 4.--Chemical analyses of rocks from silicious gossans in the Wadi al Mahalani area.

[Values for Fe are in percent, all other values are in parts per million; N=not detected.]

	-----Emission Spectrography-------							-----Atomic Absorption---			
Sample	Fe	Mn	Ba	Co	Cu	Mo	Pb	Au	Zn	As	Sb
209025	5	150	300	N	10	20	N	<.05	23	N	N
209070	10	500	200	5	20	N	<10	N	72	N	N
209274	5	1500	70	10	10	N	<10	0.1	60	15	N
209540	2	100	300	N	5	N	N	N	9	N	12
209545	5	500	500	N	20	15	N	N	26	N	N
209591	5	1000	100	N	15	N	N	N	16	N	N
209679	20	200	150	20	10	50	<10	N	115	300	N
209920	20	500	500	N	15	10	20	N	20	12	<5
209993	3	70	150	N	7	N	N	<.05	6	12	21

Table 5.--Chemical analyses of silicified rocks within Idah suite granodiorite porphyry.

[Tungsten by emission spectrography, all others by atomic absorption spectrography. All values in parts per million; N=not detected.]

Sample	Discription	Au	As	Sb	W
209133	Silicified zone	N	300	<10	N
209444	Quartz vein	0.08	18	<10	N
209862	Silicified breccia	<.05	110	10	200

Table 6.--Chemical analyses of skarn at Jibal Qitan.

[Values for Fe are in percent, all other values are in parts per million; N=not detected.]

	Emission Spectrography									Atomic Absorption			
Sample	Fe%	Mn	Bi	Cu	Ni	Pb	Sn	W	Zn	Zn	As	Sb	Te
209520	5	1000	N	<5	30	15	150	N	500	317	N	24	N
209530	1	150	N	15	10	30	N	N	N	28	13	N	0.4
209605	5	1000	10	15	50	10	200	50	N	68	13	N	N
209613	3	500	N	30	50	30	20	N	N	135	N	N	N
209652	2	700	N	5	50	10	N	N	N	50	20	N	N
209917	5	500	N	15	70	N	N	N	700	590	11	<5	N

Table 7.--Chemical analyses by emission spectrography of the wadi concentrates from the Jabal Minyah tin area.

[All values are in parts per million; N=not detected.]

Sample	Be	Bi	Cu	Mo	Pb	Sn	W
209249	150	1500	<10	50	300	>2000	N
209404	3	1500	N	20	150	>2000	N
209617	5	1000	<10	30	500	>2000	N
209620	70	150	N	N	300	>2000	N
209764	N	N	N	15	50	>2000	N
209772	2	30	N	N	30	>2000	N
209918	2	N	N	10	50	2000	N
209979	<2	N	20	30	300	>2000	<100

Table 8.--Chemical analyses by emission spectrography of rocks from the Jabal Minyah tin area.

[All values are in parts per million; N=not detected.]

Sample	Discription	Ag	Ba	Be	Bi	Cu	Pb	Sn
209001	Aplite dike	N	50	2	110	<5	30	150
209057	Porphoritic dike	N	100	5	N	<5	10	30
209060	Porphoritic dike	2	2000	10	N	<5	N	30
209093	Porphoritic dike	N	700	2	N	<5	<10	N
209162	Aplite dike	N	50	2	N	10	30	200
209202	Aplite dike	N	100	7	N	<5	20	70
209218	Aplite dike	N	100	3	N	<5	100	200
209262	Quartz vein	N	100	50	N	<5	<10	N
209286	Aplite dike	N	70	2	N	50	70	500
209459	Aplite dike	N	100	7	N	<5	15	70
209544	Porphoritic dike	N	20	7	N	<5	15	100
209549	Quartz vein	2	300	3	N	30	50	30
209584	Porphoritic dike	N	N	20	N	7	50	100
209588	Aplite dike	N	150	2	N	20	70	150
209593	granodiorite	N	700	1	N	15	20	N
209595	Quartz vein	N	100	10	10	700	100	N
209671	Aplite dike	N	200	7	10	<5	20	100
209718	Quartz vein	N	N	1	N	15	N	N
209790	Aplite dike	N	150	15	N	20	10	150
209846	Aplite dike	N	100	10	N	10	30	30
209875	Granodiorite	N	700	N	N	50	10	N
209879	Aplite dike	N	70	3	N	5	50	200
209941	Mica rich dike	N	200	7	N	7	N	30
209955	Quartz vein	N	700	10	N	7	10	30
209960	Granodiorite	N	700	7	N	7	30	30

Table 9.--Chemical analyses by emission spectrography of wadi concentrates from the Jabal Suwaj area.

[All values in parts per million; N=not detected.]

Sample	As	Mo	Pb	Sn	W
209068	500	N	70	>2000	N
209131	N	N	50	150	N
209142	N	N	50	>2000	N
209237	N	10	200	2000	N
209334	N	20	70	>2000	N
209753	<500	N	50	>2000	N
209781	N	10	70	>2000	100

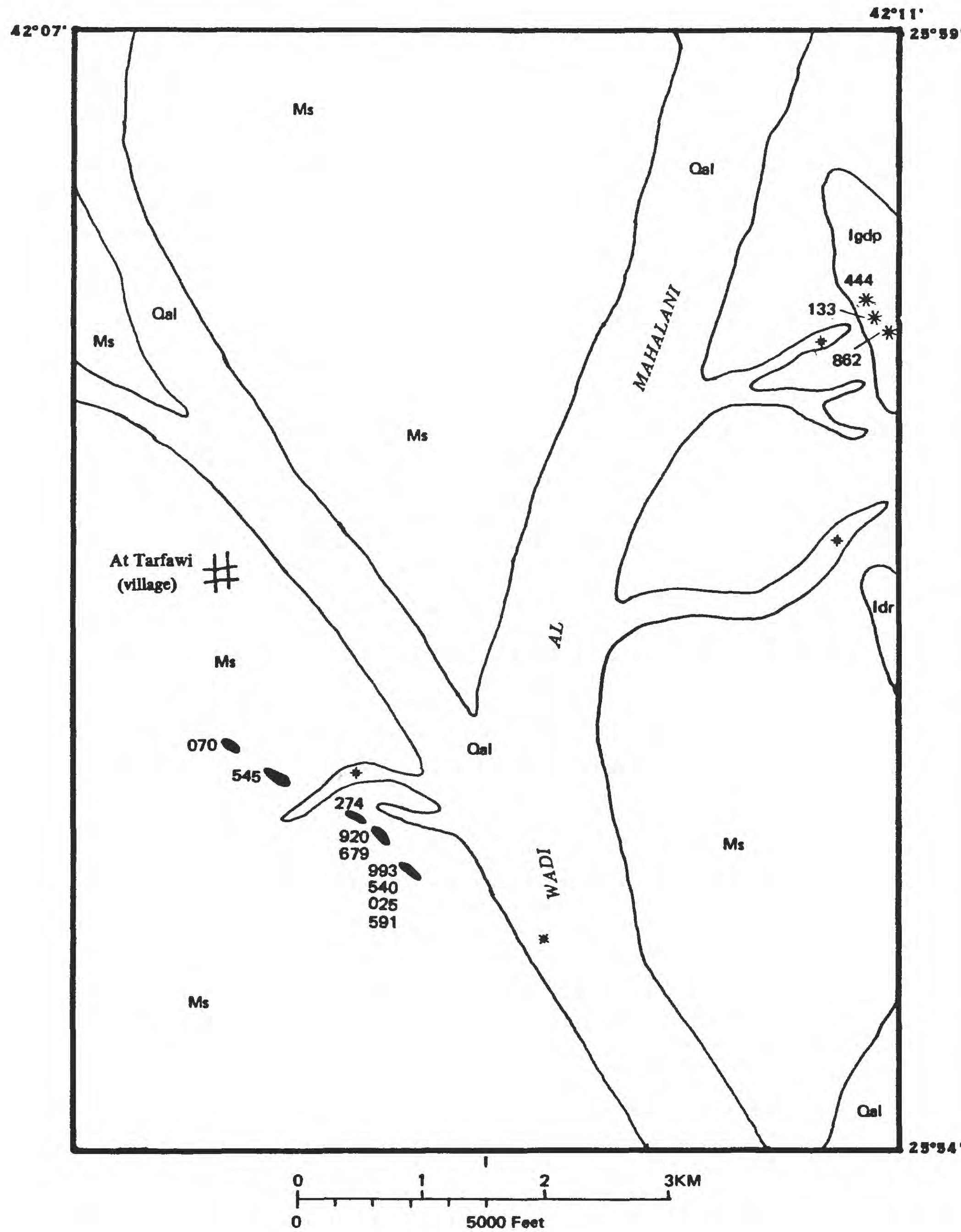
Table 10.--Chemical analyses of rocks from the Buqaya al Luaah gold area.
[All values in parts per million; N=not detected.]

	-----Emission Spectrography-----						------Atomic Absorption-------				
Sample	Ag	Bi	Cu	Mo	Pb	W	Au	Zn	Sb	As	Te
209016	N	500	2000	300	500	100	N	23	N	N	2.0
209164	N	N	50	N	20	N	N	45	<5	25	N
209333	N	N	15	30	N	N	0.1	40	N	N	N
209428	5	50	7	5	700	N	5.2	60	N	12	4.6
209548	N	N	500	1000	N	500	1.5	60	N	13	0.4
209704	1	500	1000	100	200	N	<.05	9	9	N	2.3
209801	N	100	70	70	15	N	N	80	N	55	N
209978	N	N	7	N	N	N	N	N	<5	N	N

Table 11.--Atomic absorption analyses of rocks from isolated gold occurrences in the Aban al Ahmar quadrangle.

[All values in parts per million; N=not detected.]

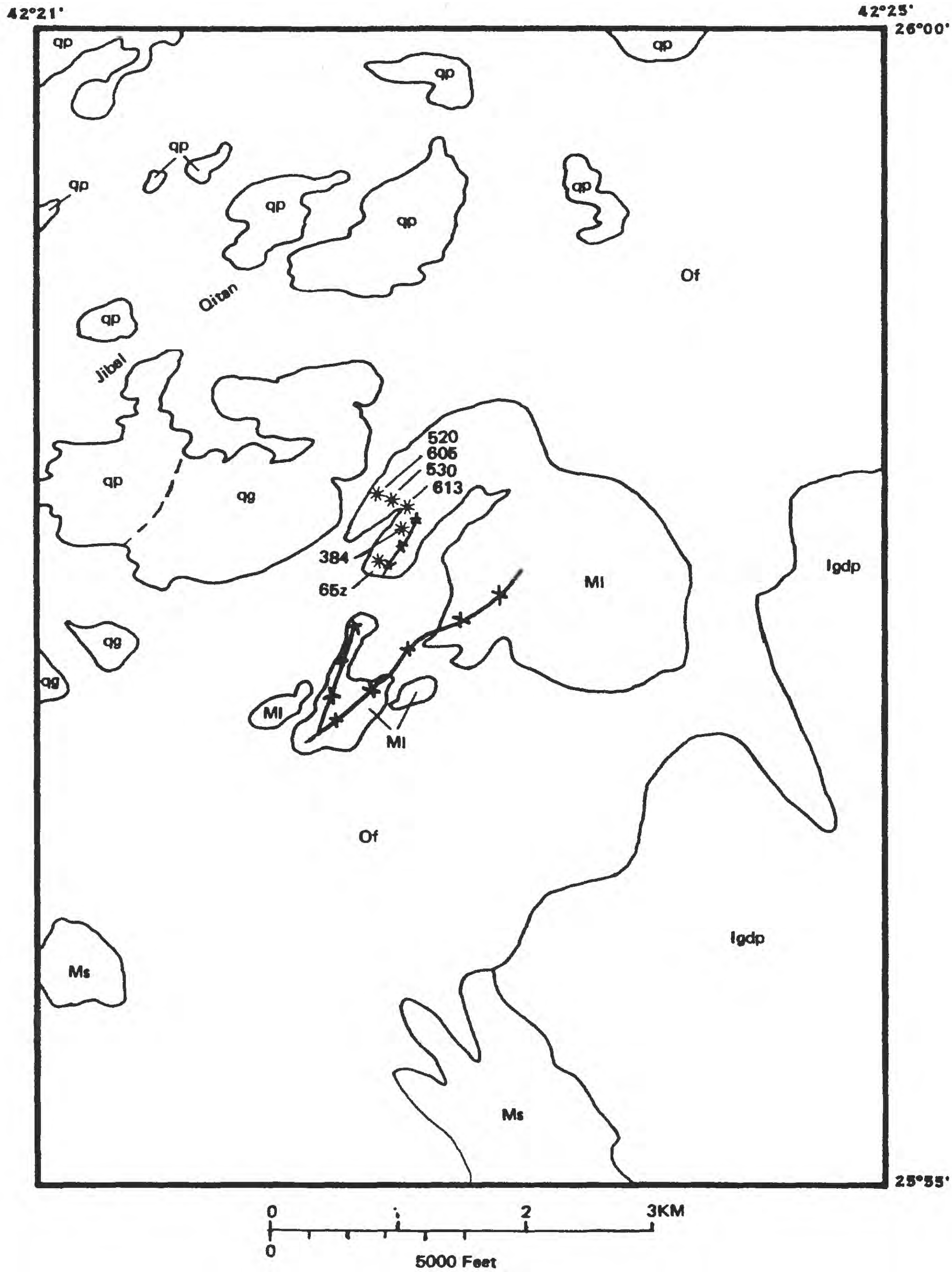
Sample	Au	Zn	As	Sb	Te
209004	.06	10	30	N	N
209022	.06	20	50	<5	0.4
209025	<.05	23	N	N	2.0
209029	5.4	28	10	N	N
209042	.44	5	10	10	N
209058	.12	300	130	12	6.0
209274	0.1	60	15	N	N
209333	0.1	40	N	N	N
209428	5.2	60	12	N	4.6
209444	.08	70	N	N	N
209548	1.5	60	13	N	0.4
209704	<.05	9	N	9	2.3
209706	.06	45	540	<5	0.2
209862	<.05	37	110	10	N
209993	<.05	6	12	21	N



EXPLANATION

Qal	Alluvium	Ms	Murdama sandstone
(black ellipse symbol)	Silicious gossan - - Showing sample number	*	Rock sample with site number
Igdp	Idah suite granodiorite porphyry	*	Wadi sample sites
Idr	Idah suite diorite		

Figure 20.--Geologic map of the Wadi al Mahalani gossan area showing rock sample sites (see tables 4 and 5). Modified from Cole (1985a).



EXPLANATION

Of	Alluvial fan and apron deposits	520 ✳	Rock sample with site numbers
qg | qp	Qitan granite, porphyry, and dikes	——— — —	Contact, dashed where inferred
Igdp	Idah suite granodiorite porphyry	—X—X—	Dike
Ms / Ml	Murdama sandstone and limestone		

Figure 21.--Geologic map of the Jibal Qitan skarn area showing sample sites (see table 6). Modified from Cole (1985a).

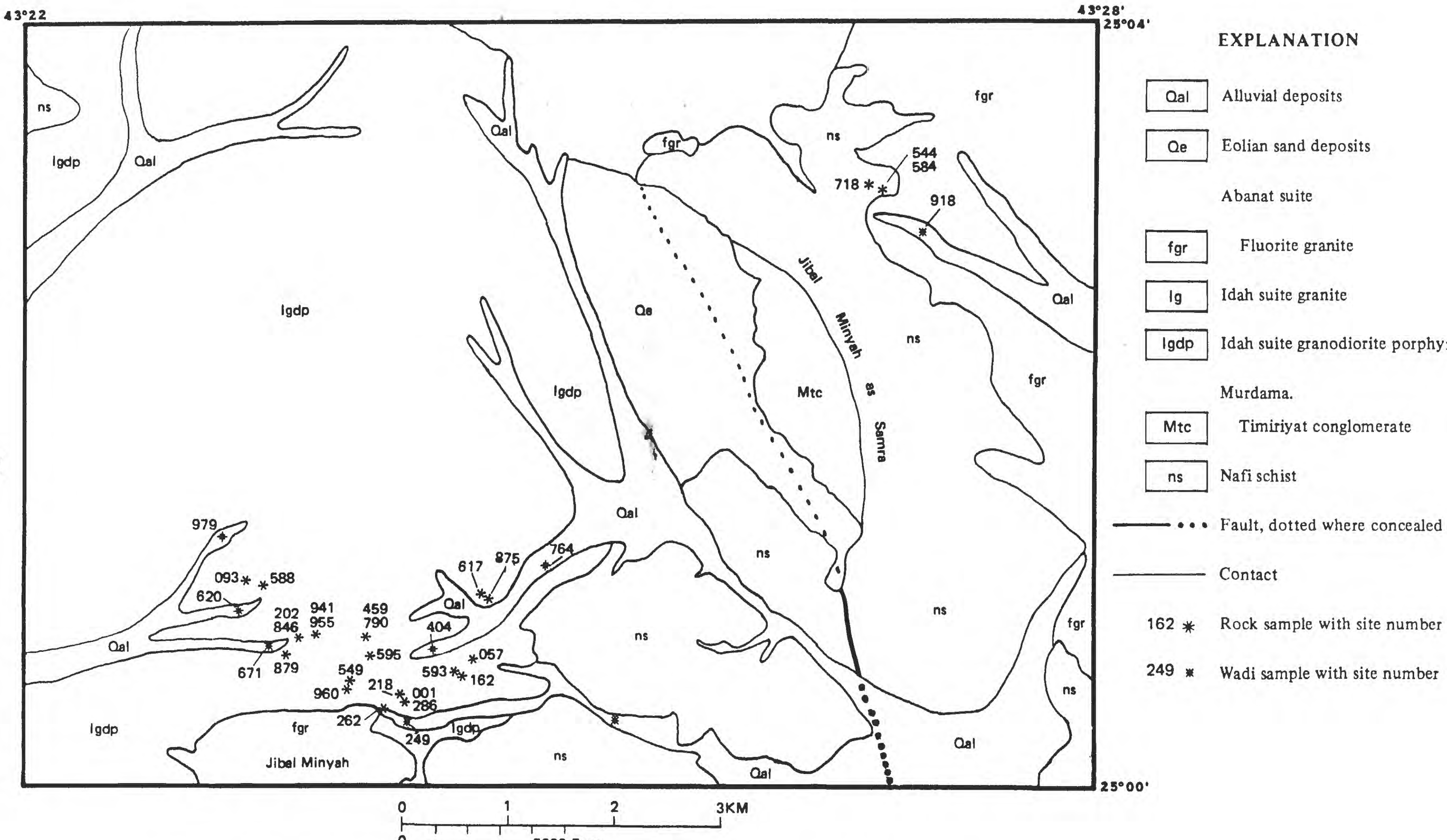
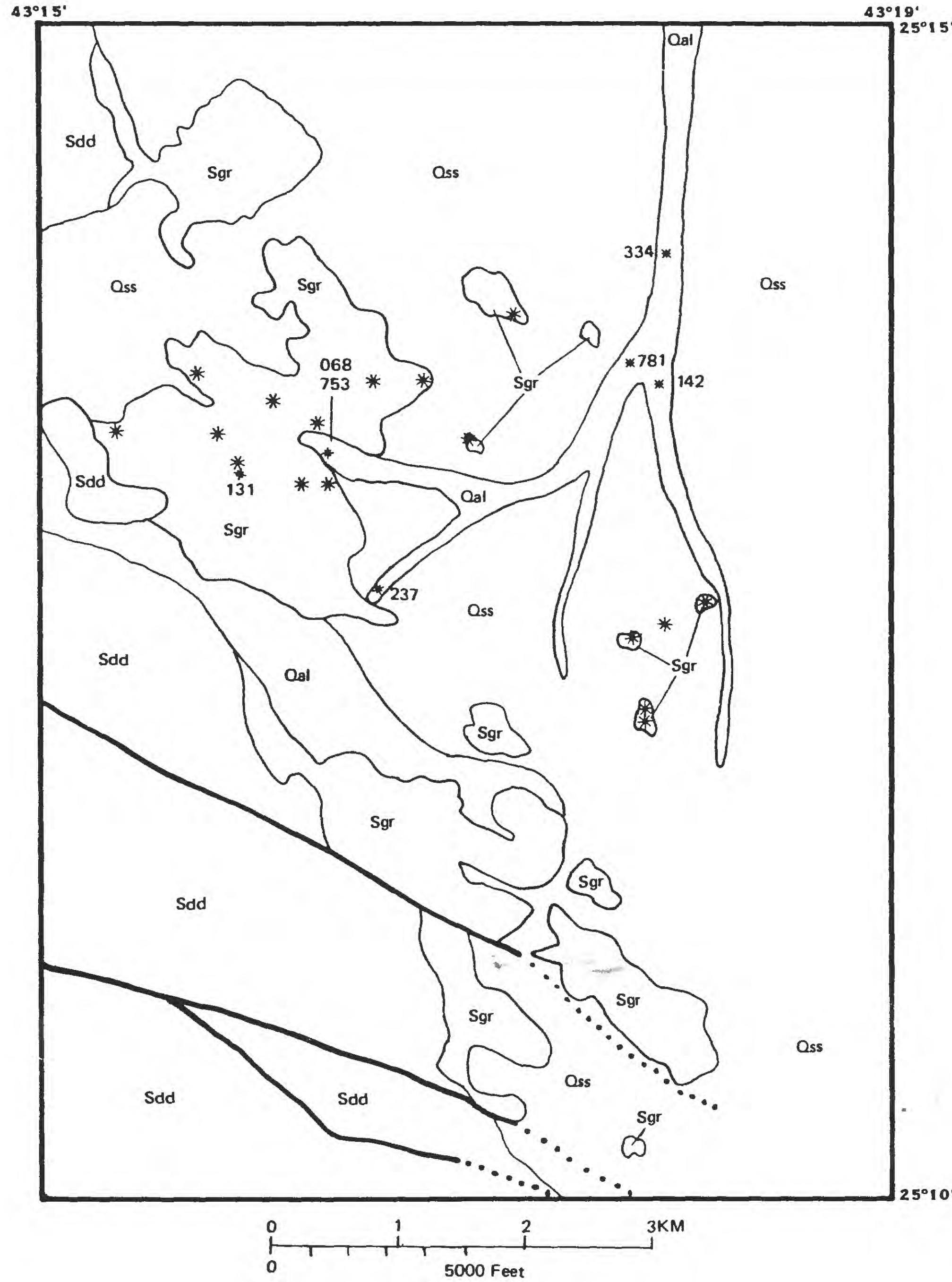


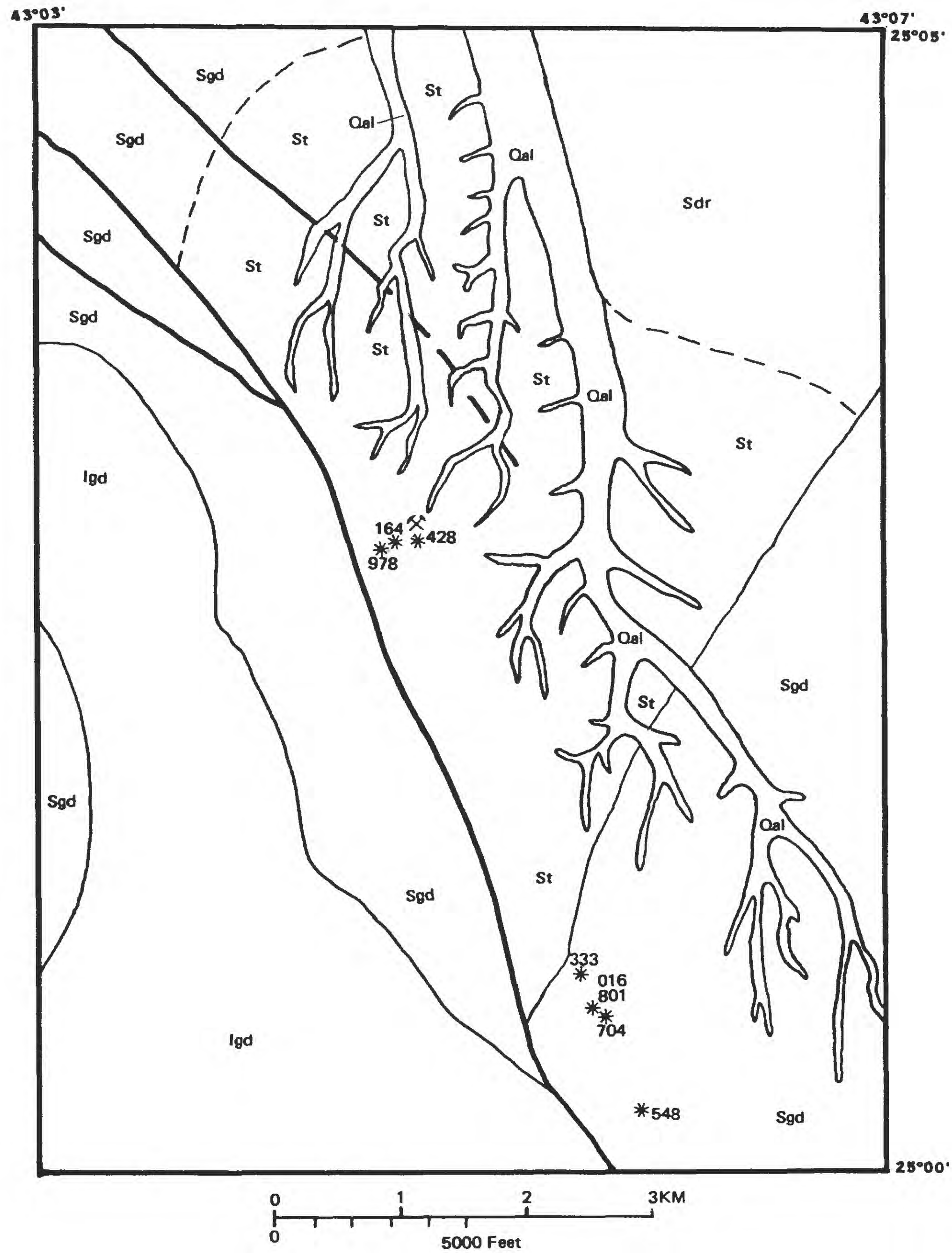
Figure 22.--Geologic map of the Jibal Minyah tin area showing sample sites (see tables 7 and 8). Modified from Cole (1986).



EXPLANATION

Qss / Qal	Sheet sand and alluvial deposits	Faults, dotted where concealed
Sgr	Shubaykiyah granite	Contact
Sdd	Suwaj diorite and quartz diorite	407 Wadi sample with site numbers
		Rock-sample sites

Figure 23.--Geologic map of the Jibal Suwaj tin area showing sample sites (see table 9). Modified from Bohannon (1984).



EXPLANATION

Qal	Alluvial deposits	——— - - -	Faults, dashed where inferred
Igd	Idah suite granodiorite	——— - - -	Contact, dashed where inferred
Sgd	Suwaj granodiorite	428 ✳	Rock sample with site numbers
St / Sdr	Suwaj tonalite and diorite	⚒	Ancient workings

Figure 24.--Geologic map of the Buqaya al Luaah area showing sample sites (see table 10). Modified from Cole (1986).

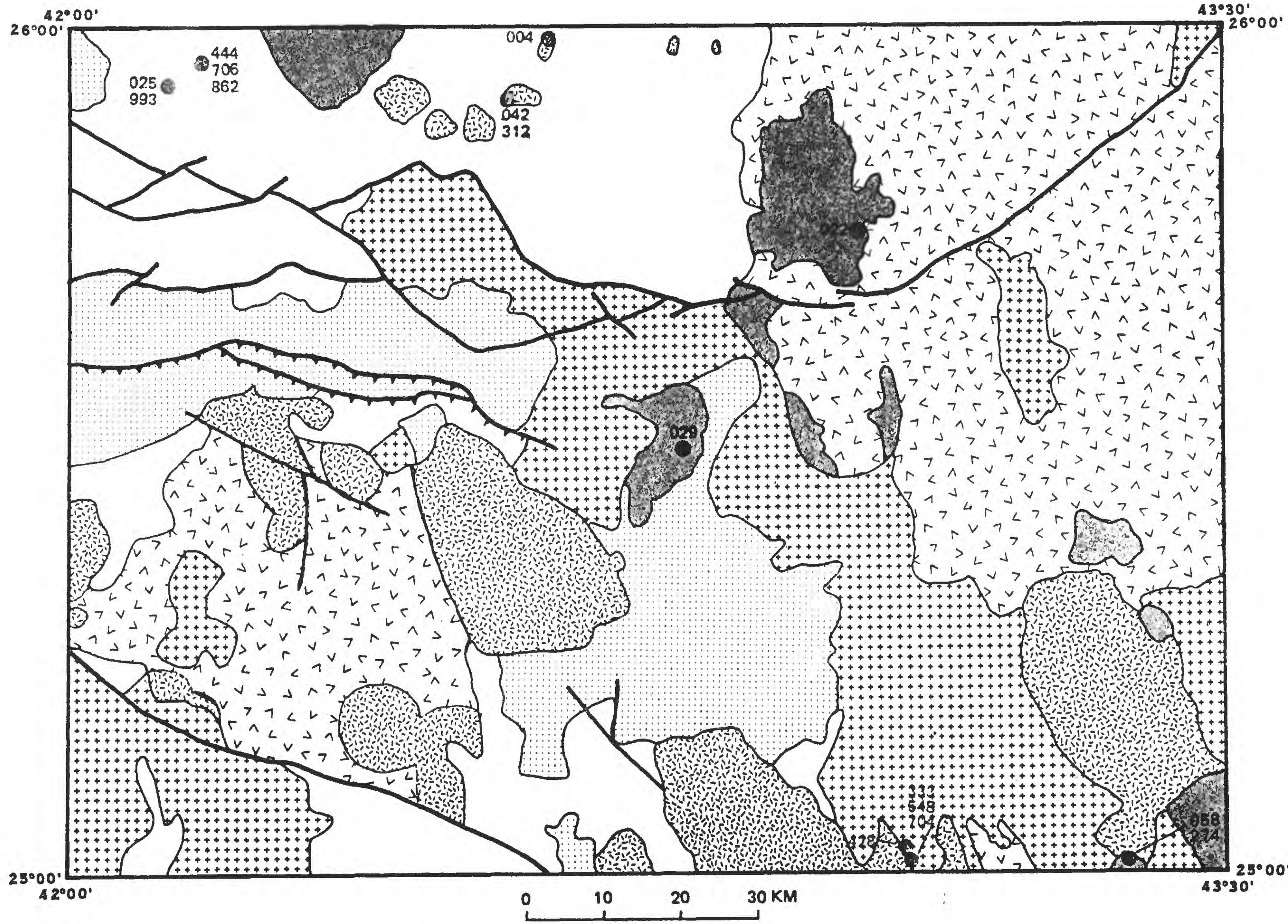


Figure 25.--Generalized geologic map showing locations of isolated gold occurrences, Aban al Ahmar quadrangle (see table 11). Filled circle is rock-sample site, with sample number. Geologic map units same as figure 3.

EXPLANATION

Low to moderate mineral potential for base- and precious-metal resources, associated with emplacement of Idah-suite rocks.

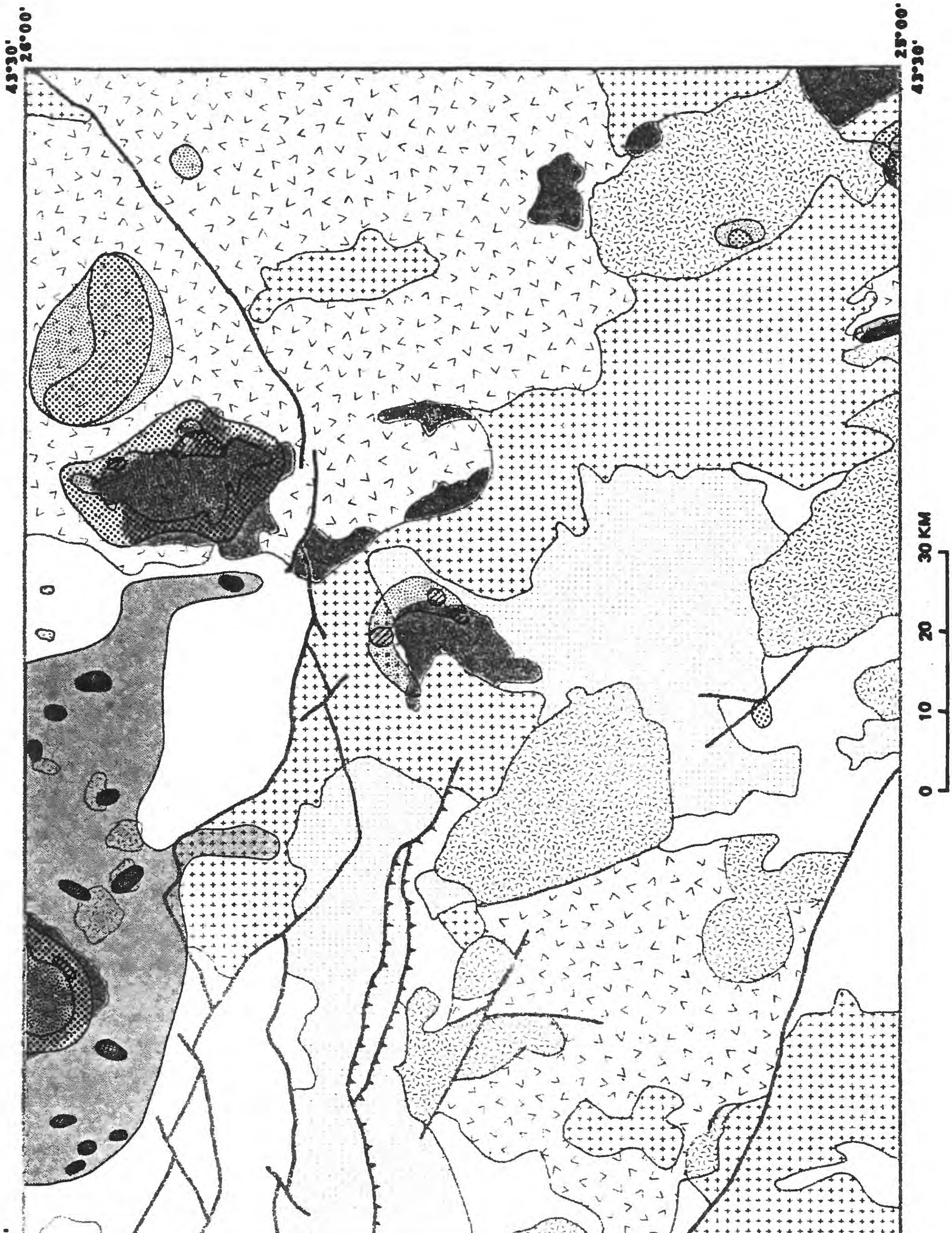
Moderate to high mineral potential for base- and precious-metal resources, associated with emplacement of Idah-suite rocks.

Low to moderate mineral potential for tin and tungsten resources associated with exposed or underlying Abanat-suite plutons.

Moderate to high mineral potential for tin and tungsten resources, within country rocks surrounding exposed Abanat-suite plutons or associated with underlying Abanat-suite plutons.

Moderate mineral potential for base- and precious-metal, tin, and tungsten resources associated with emplacement of Abanat-suite rocks.

Figure 26.--Mineral resource potential map based on regional and follow-up geochemistry, Aban al Ahmar quadrangle. Geologic map units same as figure 3.


43°30'
26°00'
28°00'
43°30'
42°00'
26°00'
28°00'
42°00'
0
10
20
30 KM

SUMMARY AND CONCLUSIONS

Figure 26 shows the types of mineral resources that may exist within the Aban al Ahmar quadrangle, as well as the level of resource potential for each deposit type. Two main igneous/hydrothermal episodes and two main types of mineralization occurred within the quadrangle. The first main episode of mineralization is associated with the emplacement of Idah-suite plutons. Precious- and base-metal mineralization are the most important types of mineralization and are generally associated with small bodies of granodiorite, which are the upper levels, or cupolas, of larger plutons. Plutons that are exposed at deeper levels and, therefore, larger in size, generally have less resource potential for precious- and base-metal deposits. The mineralization consists of free gold and sulfides, such as pyrite, galena, and chalcopyrite, found in quartz veins within the country rock (Cole, 1986). Known occurrences are small consequently, of limited economic value, but moderate potential exists for resources in vein deposits. The most favorable areas are within the Murdama-group rocks in the northern and west-central parts of the quadrangle. The An Najadi-Wuday region, located in the northwestern corner of the quadrangle, is an example of this type of occurrence (Smith and others, 1984).

The second main episode of mineralization is associated with emplacement of Abanat-suite rocks (fig. 26). The most important potential ore deposit type is tin/tungsten greisen. The Baid al Jimalah West tungsten prospect, within the quadrangle, is an example of wolframite and, less commonly, scheelite and cassiterite mineralization in a stockwork and sheeted-vein system associated with an Abanat-suite granite porphyry (Cole, 1986). The Silsilah tin prospect to the north in Jibal Habashi quadrangle (sheet 26F) is an example of cassiterite-bearing greisens associated with the Fawwarah alkali-feldspar granite of the Abanat suite (du Bray, 1984). Additional occurrences of these two types of mineralization may be present in the Aban al Ahmar quadrangle associated with Abanat-suite plutons. Most of the Abanat-suite granites were eroded to the plutonic level and, therefore, mineralization that may have been present in the upper levels of the plutons has been eroded away. The abundant presence of small, well-rounded grains of cassiterite in wadi concentrates throughout the quadrangle suggests that a considerable amount of cassiterite was once present but has been eroded away: therefore, cassiterite placer deposits may be present in some of the paleodrainages, such as the larger wadis within the quadrangle. Additional studies would be needed to evaluate this possibility.

There is moderate-to-high resource potential for tin and tungsten deposits associated with satellite bodies of Abanat-suite rocks in the surrounding country rocks, peripheral to the main plutonic complexes. These areas are also considered to have moderate-to-high potential for precious- and base- metal resources (fig. 26). In addition, there is moderate-to-high potential for tin and tungsten greisen deposits in the country rocks above Abanat suite plutons and within the upper parts of Abanat-suite plutons, that have intruded to near the level of the present surface (fig. 26).

Skarn mineralization is present along the southern margin of Jibal Qitan (fig. 26) and may be present in other parts of the quadrangle. This area has moderate resource potential for skarn deposits.

In summary, the greatest resource potential within the Aban al Ahmar quadrangle is for tin and tungsten greisen deposits within the country rocks surrounding the Abanat-suite plutons or within country rocks that have been intruded by Abanat suite plutons that may or may not be exposed as small bodies at the surface. This may be the case north of Jibal Minyah, northeast of Aban al Asmar in the Nubayha area, and near Jibal Suwaj (fig. 26). In addition, there is moderate-to-high potential for precious- and base-metal resources associated with Idah-suite plutons, particularly within the Murdama group in the northern part of the quadrangle.

DATA STORAGE

DATA FILE

Field and laboratory data contributing to this report are stored in Data File USGS-DF-06-10 in the Jeddah office of the U. S. Geological Survey Mission. The Data File contains:

Field notes
Sample location maps
Analytical results
Single-element and factor plots

MINERAL OCCURRENCE DOCUMENTATION SYSTEM

Data on mineral occurrences in the Aban al Ahmar quadrangle have been updated for the following Mineral Occurrence Documentation System (MODS) numbers:

2659	Baid al Jimalah East	Pb	10/86
2661	Baid al Jimalah West	W, Sn	10/86
3114	Jabal Akkash	Cu, Pb	10/86

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