RECONNAISSANCE GEOCHEMICAL SURVEY OF THE AT TAIF-AL BAHAH REGION, SOUTHERN HIJAZ, KINGDOM OF SAUDI ARABIA

by

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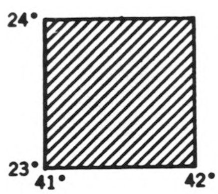
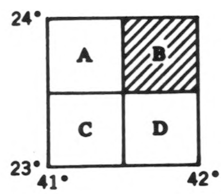


23/41

1-degree
quadrangle



23/41 B

30-minute
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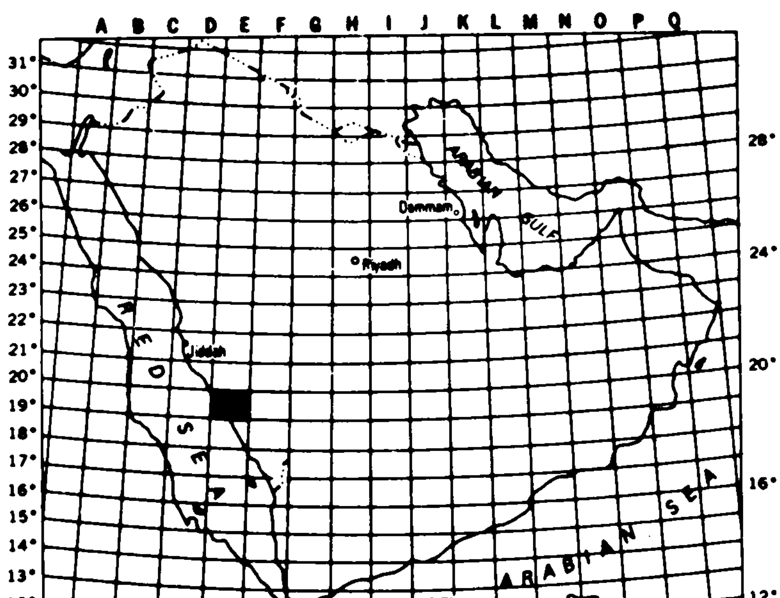

19E

1x1½-degree
quadrangle

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ABSTRACT

Pan concentrates were prepared from 265 wadi sediment samples collected during a geochemical reconnaissance conducted between At Taif and Al Bahah to further assess previously identified tungsten anomalies and to locate additional mineralized rock. The samples were analyzed by semiquantitative spectrographic methods for 30 elements, and tungsten was determined by colorimetry. All determinations in excess of two standard deviations greater than the population mean are considered anomalous, although any detectable amount of tin or tungsten (detection limits 10 and 50 parts per million, respectively) is defined as anomalous.

An area south of At Taif containing significant tungsten was confirmed and found to be larger than initially determined. A possible porphyry copper pluton was discovered 50 km south-southeast of At Taif. Thirty kilometers south of At Taif, a low-grade tin anomaly associated with an S-type granite was identified. In addition, the sampling identified seven anomalous areas attributable to rock geochemically atypical of the study region. Finally, although samples from the Al Lith-Hajrah area collected for an earlier study were found to contain anomalous concentrations of tungsten, samples collected there during this study do not support those findings.

INTRODUCTION

In the mid-1960's, Kouther (1966) and Goldsmith (1971) conducted geochemical reconnaissance surveys in the At Taif region, the northern part of the study area (fig. 1). Pan concentrates of wadi sediment contained tungsten concentrations between 20 and 1,600 parts per million (ppm). Powellite ($Ca(Mo,W)O_4$) and scheelite ($CaWO_4$) were identified as the tungsten-bearing minerals in the concentrates. These minerals were also found disseminated in pegmatites and feldspathic masses in granite, as well as in mineralized quartz veins (Kouther, 1966).

Analyses of pan concentrates collected by Goldsmith (1971) in the Al Lith-Hajrah region, the southern part of the study area (fig. 1), indicate many tungsten-anomalous localities. Tungsten-rich pan concentrates, containing from 20 to more than 150 ppm tungsten, were collected near the contact between granite and amphibolite and amphibolite schist. Again, powellite and scheelite were identified as the tungsten-bearing minerals.

However, studies of other major tungsten anomalies in the Arabian Shield, for example, the quartz-vein stockwork systems at Al Kushaymiya (Whitlow, 1966; Theobald, 1970) and Baid al Jimalah (Cole and others, 1981), showed wolframite ((Fe, Mn) WO_4) as the principal tungsten mineral.

A geochemical reconnaissance of the At Taif-Al Bahah region designed to better define the anomalies identified by Kouther (1966) and Goldsmith (1971) and to locate additional mineralized areas was conducted between July 15 and 30, 1980. An area of approximately 10,000 km^2, from lat 20°00' to 21°15' N. and between long 40°15' and 41°00' E., was traversed by helicopter. Wadi sediment samples were collected at 265 stations in an attempt to identify mineralized areas. Particular emphasis was placed on identification of tungsten mineralization.

The region between the two known tungsten anomalies was thoroughly sampled to test their possible continuity, and the two anomalous areas were sampled sufficiently to evaluate the sampling of Kouther (1966) and Goldsmith (1971). The previously identified anomalies and those found during this study will be more thoroughly studied in a followup investigation designed to identify and evaluate the tungsten sources.

GEOLOGIC SETTING

The study area is predominantly underlain by late Proterozoic metamorphic and plutonic rocks above and below the Red Sea escarpment (Brown and others, 1963). Metadiorite, metagabbro, amphibolite, and felsic tuffaceous schist are the principal metamorphic lithologies. However, northeast-trending chlorite, sericite, and amphibolite schist crop out on the northern, eastern, and southern margins of the region. Fifty to sixty percent of the region is underlain by plutonic rocks, principally monzogranite, but including lesser amounts of granodiorite, diorite, quartz diorite, and gabbro.

Rhyolitic, diabasic, and andesitic dikes are found in the region, and two major dike swarms are present. Aplite and pegmatite dikes are also present. At Hajrah and immediately to the west, dikes cut northwest across the trend of the

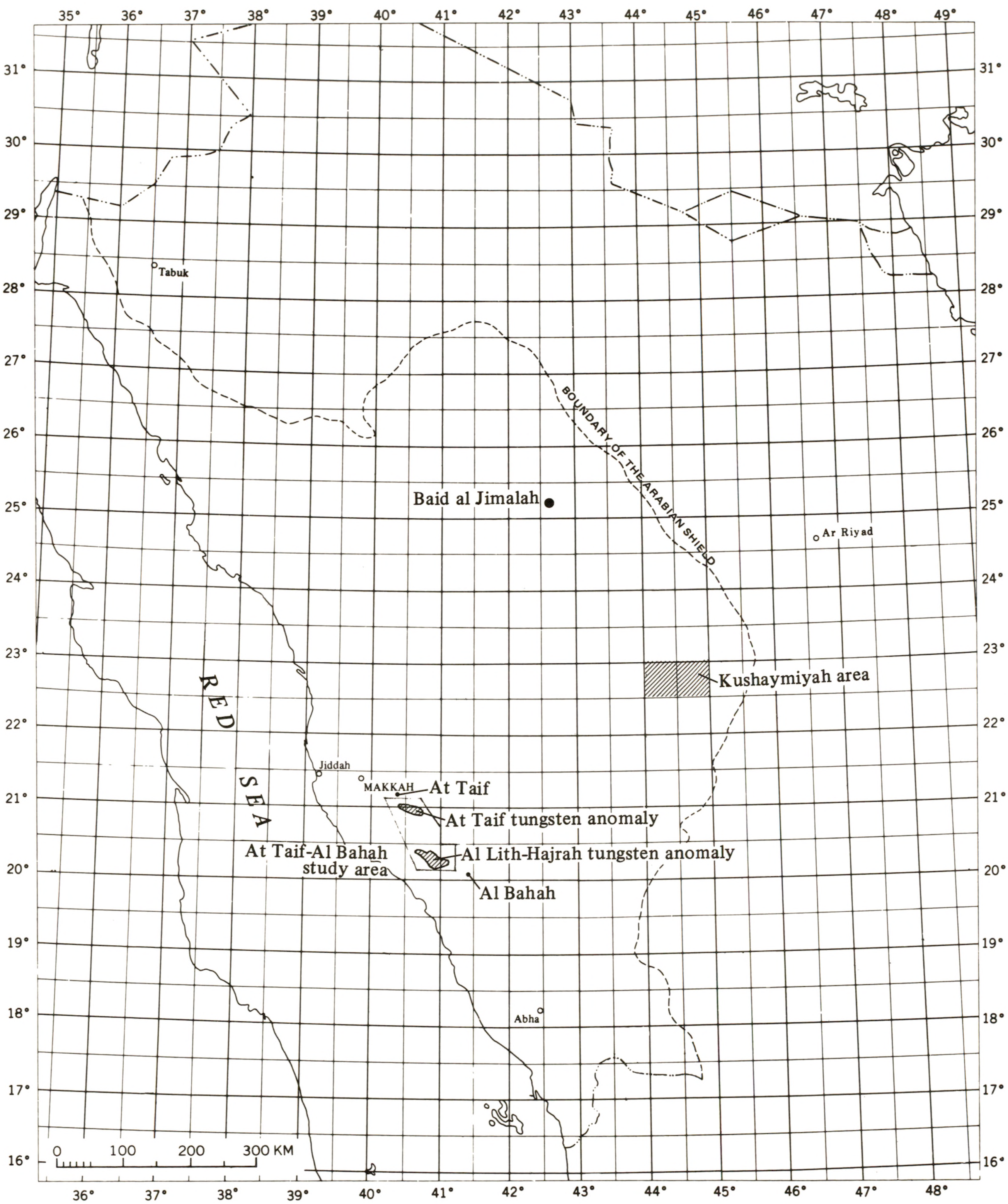

Figure 1.–Index map of the western part of Saudi Arabia showing the location of the At Taif-Al Bahah tungsten study area. Two previously identified tungsten anomalies (Kouther, 1966; Goldsmith, 1971) are plotted.

country rock. North of Al Lith, dikes follow the northeast trend of the country rock and appear to extend to an area 50 km east of At Taif (Brown and others, 1963).

Faults are common in most of the region, but they are most abundant in the southern and west-central sections. An area of intense faulting, which forms a northeast-northwest crosscutting network, is found at Jabal Afaf, and several northwest-trending faults extend from Jabal Afaf to Wadi al Lith. A fault, along which offset is considerable, trends northeast in the Jabal Judah area (Brown and others, 1963).

Alluvial material is primarily restricted to wadis, but a considerable amount is present on the coastal plain in the southwestern corner of the study area. Wadis below the escarpment are larger than wadis above the escarpment and contain comparatively coarser material, including boulders as much as 2 m in diameter. Wadis above the escarpment are smaller, less steep, and contain finer material. Many wadis are cultivated, especially in areas containing natural spring water.

The following 1:100,000-scale geologic maps provide more detailed geologic information concerning this region: At Taif 21/40 C (Smith, 1980), Jabal 'In 21/41 C (Gonzalez, 1973), Wadi Sadiyah 20/40 A (Wier and Hadley, 1975), Wadi Salibah 20/40 B (Cater, 1977), Al Lith 20/40 C (Hadley and Fleck, 1980a), Jabal Afaf 20/40 D (Hadley and Fleck, 1980b), and Jabal Ibrahim 20/41 C (Greenwood, 1975). The geologic map (scale 1:250,000) of Johnson, Morfett, and Bowden (1980) is a useful regional compilation.

The work on which this report is based was performed in accordance with a cooperative agreement between the U.S. Geological Survey (USGS) and the Ministry of Petroleum and Mineral Resources, Kingdom of Saudi Arabia.

GEOCHEMICAL SAMPLING

Wadi sediment samples were collected at 265 stations (pl. 1). In most cases, sampling was downstream of pluton margins and dikes, and, where possible, medium- to coarse-grained sand was collected to avoid windblown material.

Approximately 10 kg of sediment was collected at each station. Each sample was split approximately into a 2.5-kg fraction and a 7.5-kg fraction. The former was archived for future reference, and the latter was panned until a heavy-mineral concentrate with a color index of about 50 was obtained. The pan-concentrate sample medium was employed because other work (du Bray, 1981) has demonstrated that panning enhances element concentrations relative to lower detection limits, so that geochemical anomalies are more readily separable from background values. These samples were submitted to the DGMR (Directorate General of Mineral Resources)-USGS chemical laboratory, Jiddah, Saudi Arabia, for 30-element semiquantitative spectrographic analysis and for tungsten analysis by colorimetry.

ANALYSIS FOR SCHEELITE

Each night, pan concentrates prepared that day were tested for scheelite with a short-wavelength ultraviolet lamp. Tabulation of the number of scheelite grains observed in each of the 265 samples suggested that those containing 10 or more grains should be considered anomalous. Thirty of the 265 samples were found to be anomalous, some containing as many as 20 scheelite grains. Three areas containing numerous anomalous samples were identified. Two areas are those previously mentioned, the At Taif and Al Lith-Hajrah areas. In the At Taif area (1,250 km^2), 8 of 29 samples are anomalous; in the Al Lith-Hajrah area (1,250 km^2) 5 of 24 samples are anomalous. A more diffuse tungsten anomaly was identified in the Jabal al Ahmar-Wadi Sadiyah area (1,300 km^2). There 9 of 84 samples are anomalous.

RESULTS AND DISCUSSION

Semiquantitative spectrographic data for 265 pan concentrates are presented in frequency-distribution histograms (fig. 2), and tungsten concentrations are plotted on plate 1. All spectrographic data for tin are plotted on this plate because any detectable tin, especially if spatially associated with tungsten, is noteworthy (Tischendorf, 1977). All geochemical data for the 265 pan concentrates are archived in the DGMR-USGS Rock Analysis Storage System (RASS) computerized data bank master file titled DUBRAY2.MAS and in USGS Saudi Arabian Mission base data file USGS-DF-01-2. Inquiries regarding these data should be made to the U.S. Geological Survey, Jiddah, Saudi Arabia. The data are included in DGMR-USGS chemical laboratory jobs numbered 01050, 01051, and 01053.

Arithmetic mean and standard deviation were computed and compiled (table 1) for each element using all data not qualified by either L (less than) or G (greater than). Data values more than two standard deviations greater than the computed mean are considered anomalous and are plotted on plate 1. Data values three or more standard deviations greater than the population mean are specially noted. Iron, titanium, and zirconium are not plotted because many data values for these elements exceed the maximum detection limit

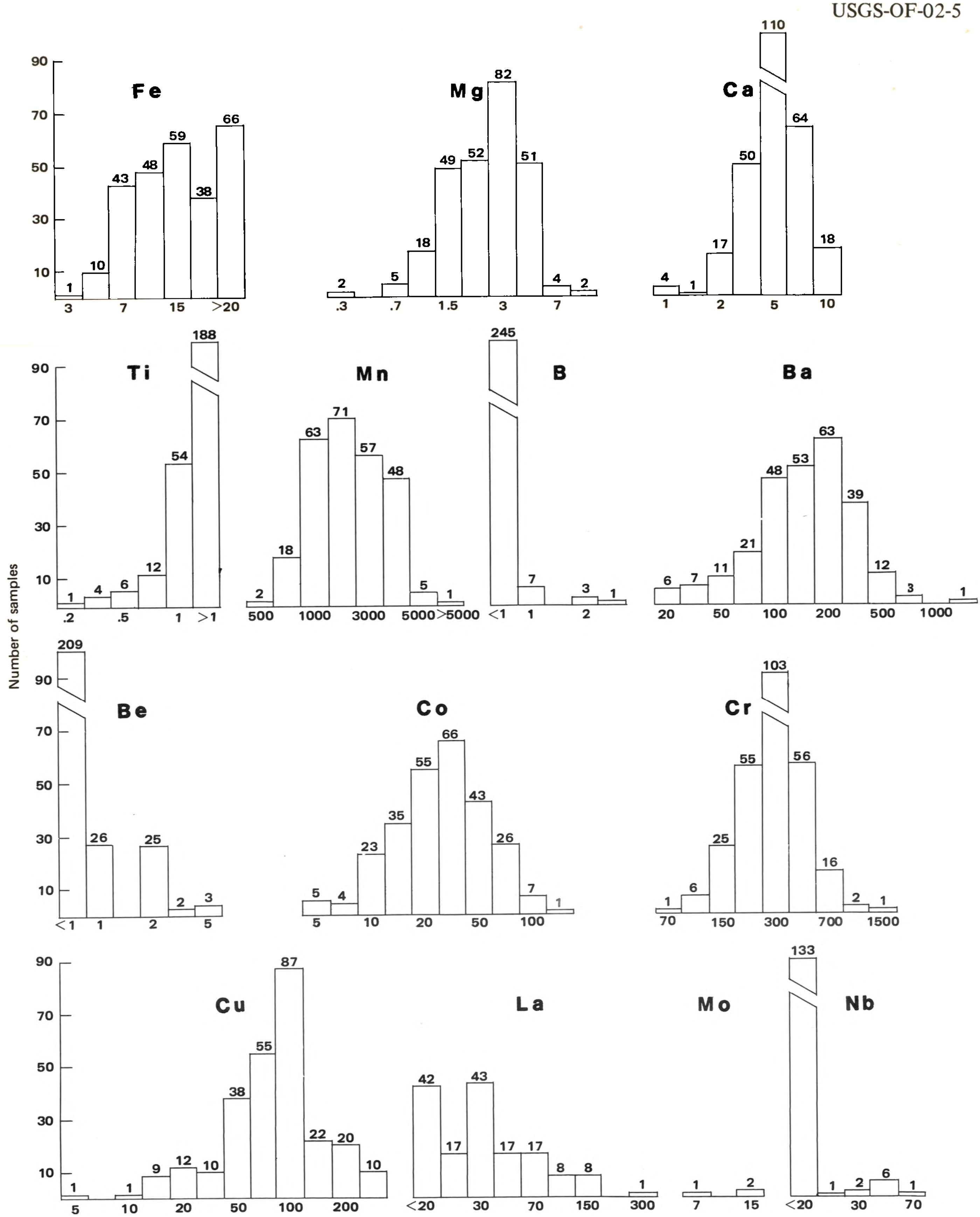

Figure 2.–Frequency distribution of semiquantitative spectrographic analyses of pan concentrates collected in the region between At Taif and Al Bahah, Kingdom of Saudi Arabia. Iron, magnesium, calcium, and titanium concentrations in percent; all others in parts per million. Concentration intervals are in the series 0.1, .15, .2, .3, .5, .7, 1.0, etc.; every other class is labeled.

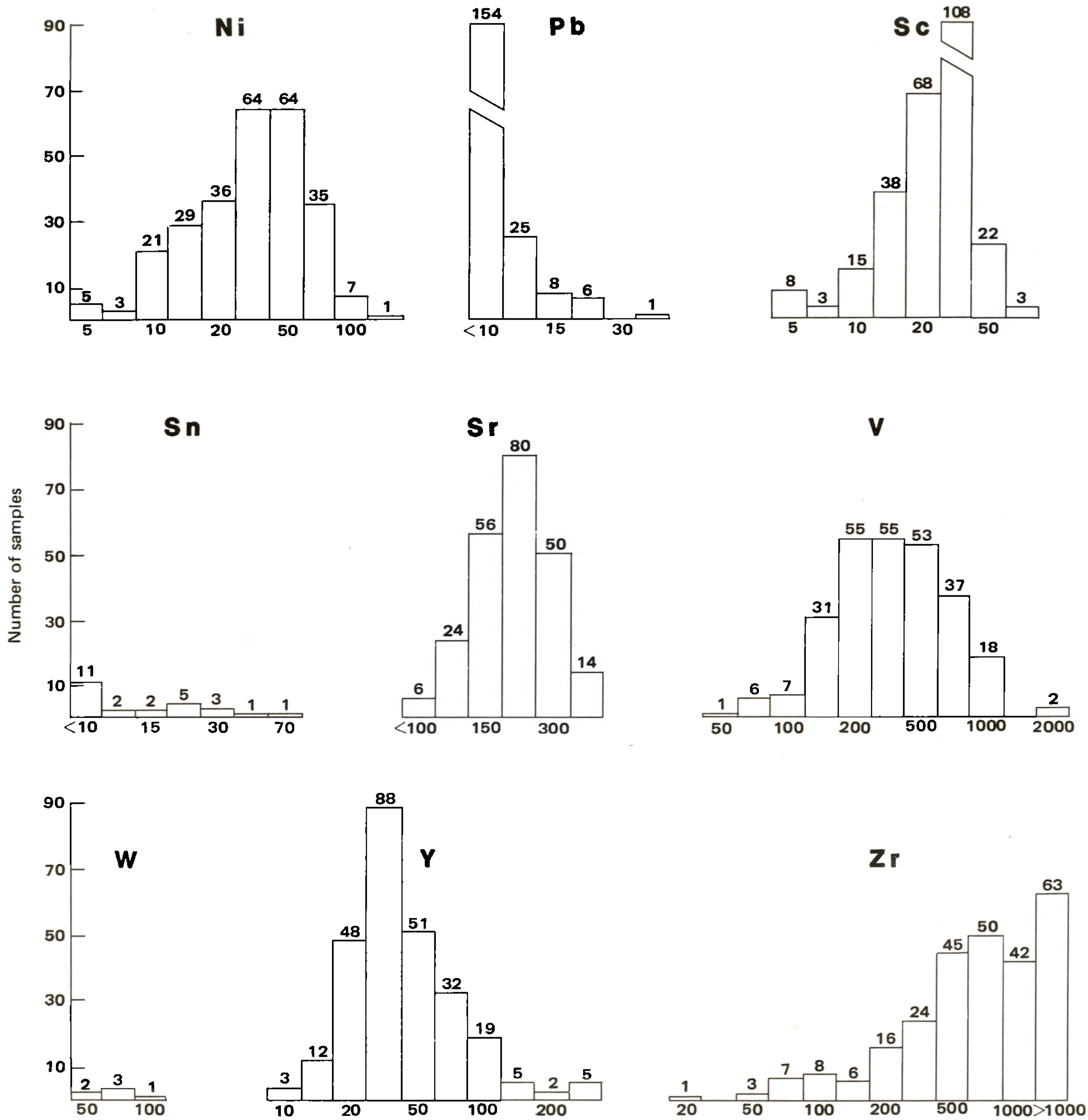

Figure 2.--Continued

Table 1.--*Means and standard deviations, by element, of semiquantitative spectrographic data for 265 pan concentrates collected in the At Taif-Al Bahah region*

[Only data not qualified by either L (less than) or G (greater than) were used in the calculations. Hyphens indicate an element undetected in all samples. Values for Fe, Mg, Ca, and Ti in percent; all others in parts per million]

Element	Mean value	Standard deviation	Number of unqualified values
Fe	12.5	4.9	199
Mg	2.8	1.5	265
Ca	5.2	2.1	265
Ti	0.9	0.2	77
Mn	1766	859	264
Ag	-		0
As	-		0
Au	-		0
B	15	7	11
Ba	186	144	264
Be	1.7	1	56
Bi	15		1
Cd	-		0
Co	33	22	265
Cr	336	177	265
Cu	96	62	265
La	54	43	111
Mo	12	5	3
Nb	45	14	10
Ni	37	23	265
Pb	14	7	40
Sb	-		0
Sc	25	12	205
Sn	26	16	14
Sr	218	96	224
V	406	286	265
W	68	18	6
Y	50	46	265
Zn	-		0
Zr	556	303	202

and because their host minerals are the principal constituents of pan concentrates. In any case, deposits of these elements are not expected in this geologic environment.

Scattered single-station, single-element anomalies were identified at many localities. Because samples from these localities do not include extreme values, the anomalies are considered artifacts of the panning procedure or the result of local geochemical variation and are not considered further. Exceptions include any occurrence of tungsten or tin because these elements are present in amounts less than the minimum detection limits (50 and 10 ppm, respectively) in most rock types and are considered anomalous if detected. Most areas containing a group of samples that are anomalous in a single element are underlain by a rock type geochemically atypical of the region; the areas appear anomalous because of peculiar source-terrain composition, not because of mineralization.

Anomalies 1-6 (pl. 1) are characterized by groups of samples that are anomalous in a single element; these elements include scandium, cobalt, vanadium, chromium, manganese, and magnesium. These anomalies probably are attributable to above average accumulations of iron-oxide and ferromagnesian minerals in their pan concentrates. Mason (1966, p. 135-137) confirmed the correlation between these elements and minerals. The areas are underlain by mafic igneous rocks, including gabbro, diorite, amphibolite, and metabasalt, which are all rich in iron-oxide and ferromagnesian minerals. Therefore anomalies 1-6 are not indicators of mineralized rock but of rock more mafic than the regional norm.

Samples from anomaly 7 (pl. 1) along Wadi Salibah contain anomalous amounts of strontium and barium. Because the lithologies of the area are unlikely to contain barium and strontium deposits, feldspars are the likely host minerals (Mason, 1966; p. 134-135). Feldspars are normally removed during panning, but in this case they probably contain heavy mineral inclusions, which caused them to be retained.

Anomaly 8, south of At Taif, is associated with a monzogranite pluton. Some samples from this area contain anomalous amounts of tin, rare earth elements, and beryllium, a suite characteristic of S-type granites (Tischendorf, 1977). S-type granites, as defined by Chappell and White (1974), have the following characteristics:

1. biotite and (or) muscovite the only mafic phases
2. initial strontium ratios greater than 0.708
3. Mol $Al_2O_3/(Na_2O+K_2O+CaO)$ greater than 1.1

4. composition restricted to high SiO_2 magmas
5. irregular variation diagrams
6. greater than 1 percent CIPW normative corundum
7. relatively low sodium, Na_2O normally less than 3.2 percent in rocks with approximately 5 percent K_2O

Other work (Chappel and White, 1974; Tischendorf, 1977) has documented a correlation between S-type granites and tin, tungsten, or molybdenum mineralization; therefore, anomaly 8 warrants further study. Additional work should concentrate on identification of mineralized quartz veins and (or) greisenized zones. Additional wadi sediment sampling should be completed west of the anomalous area to determine its extent.

Anomaly 9 is a multi-element anomalous feature that suggests copper-mineralized rocks. Pan concentrates of samples collected in wadis draining the associated porphyritic monzogranite pluton contain 300 ppm copper. The geochemical data, limited available petrographic data, and compositional and textural information suggest a porphyry copper environment, which should be further investigated. In addition, tin was found associated with the monzogranite, and its distribution should also be studied.

Of the three areas containing anomalous amounts of scheelite identified during this study, only the northern area (At Taif) includes more than one sample containing detectable tungsten. Surprisingly, only one sample (163207) collected for this study in the Al Lith-Hajrah tungsten-anomalous area identified by Goldsmith (1971) contains detectable tungsten. Colorimetric analyses of samples collected there were repeated to insure that the analyses were representative of tungsten content. The two sets of analyses are reconcilable within analytical uncertainty, a relationship that suggests that analyses of samples previously collected for Goldsmith's study in the Al Lith-Hajrah area may have given spurious results.

The diffuse scheelite anomaly identified by the authors in the Jabal al Ahmar-Wadi Sadiyah area is also not anomalous in tungsten. Only one sample in the area contains detectable tungsten, and further work in the area seems unwarranted.

The scheelite-anomalous area south of At Taif, previously identified by both Kouther (1966) and Goldsmith (1971) and confirmed by this study (anomaly 10, pl. 1), includes a number of samples containing anomalous amounts of tungsten. Tungsten concentrations for these pan concentrates in anomaly 10 range from 10 to 160 ppm and indicate that significant potential for tungsten-mineralized rock exists. Kouther

(1966) attributed the tungsten to scheelite in quartz veins cutting the Na'man monzogranite mapped by Smith (1980). Smith's mapping indicates that the tungsten anomaly is associated with a region of complex geology, and the geochemical results presented here do not indicate a good correlation between geology and anomalous-sample localities. Smith's mapping does, however, show marble and calc-silicate rock of the Wij group within the area sampled. Anomalous calcium concentrations in the pan concentrates may be attributable to these rock types and, in light of the tungsten anomaly, suggest the possibility of skarn mineralization.

Detailed mapping and sampling in this area are needed to identify the source and extent of the tungsten anomaly. Additional wadi sediment sampling north and west of the area already sampled should fully define the extent of the anomaly. The area north of lat 21° 00' N. and south of At Taif, between long 40°15' and 41°00' E., contains the greatest potential for mineralized rocks.

CONCLUSIONS AND RECOMMENDATIONS

Geochemical sampling in the region between At Taif and Al Bahah identified 10 anomalous areas. Six of these anomalies are attributable to concentration of iron-oxide and ferromagnesian minerals in drainages underlain by mafic and ultramafic rocks. A weak tin anomaly associated with an S-type monzogranite (anomaly 8, south of At Taif) should be thoroughly sampled and mapped. The principal effort should be toward identification of mineralized quartz veins and (or) greisens. A multi-element anomalous feature (anomaly 9, southeast of At Taif) associated with porphyritic monzogranite, possibly of the porphyry copper type, should be thoroughly sampled and mapped. Finally, the tungsten anomaly south of At Taif (anomaly 10) should be thoroughly examined. Quartz veins and pegmatite dikes should be examined for scheelite content, and all calcareous country rock should be examined for skarn mineralization.

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