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Regional geochemical study of the felsic plutonic rocks in the Nuqrah quadrangle, sheet 25E, Kingdom of Saudi Arabia

by

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REGIONAL GEOCHEMICAL STUDY OF THE FELSIC PLUTONIC ROCKS IN THE NUQRAH QUADRANGLE, SHEET 25E, KINGDOM OF SAUDI ARABIA

BY

Wayne E. Hall[1/], David Dellinger[1/], and Gary I. Selner[2/]

ABSTRACT

A regional geochemical investigation of the felsic plutonic rocks of the Nuqrah quadrangle, sheet 25 E, Kingdom of Saudi Arabia, in which pan concentrates of 384 wadi samples, and 145 rock samples, were collected, defined two separate and distinct anomalous areas. One area contains Jabal Tuwalah and Jabal Awja, and the other is at the north end of Jabal Safad. Both pan concentrates and the rock samples in the Jabal Tuwalah and Jabal Awja areas contain high concentrations of Be, F, La, Mo, Nb, Pb, Th, U, Sn, Y, and Zr, and the plutons underlying those areas are characterized by high total-count radioactivity.

These elements are sited in highly evolved alkalic granites and have not been concentrated into a potentially metalliferous deposit related to a hydrothermal ore system. They may be a potential metal source of the future.

Pan-concentration samples collected from wadis draining the north end of Jabal Safad contain anomalous Sn, Mo, Pb, and La. Four samples contain 250 to 1,000 ppm of tin. The tin anomaly is associated with a small aplitic pluton intrusive into the Jabal Safad alkalic granite complex. A brief reconnaissance of the area did not reveal any greisen or cassiterite mineralization. However, further exploration work in the area is recommended.

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INTRODUCTION

Location and access

The Nuqrah quadrangle, sheet 25 E, is bounded by lats 25° 00' N. and 26°00'N., and by longs 40030'E. and 42°00'E (fig. 1). It is located about 500 km northeasterly from Jiddah, and access is by way of the sealed highway from Al Madina to Buraydah.

Previous work

The geology and ore deposits of the quadrangle were studied by Delfour (1976). Stoeser and Elliott (1979) completed a reconnaissance study of the peralkalic rocks and related mineralization in the area. Stuckless and others (in press) studied the uranium and thorium favorability of the postorogenic granites. Their work shows that, although no metal deposits are known to be associated with the postorogenic granites, numerous geochemical anomalies exist, including anomalous abundance of beryllium (Be), niobium (Nb), thorium (Th), tin (Sn), tungsten (W), uranium (U), zircon (Zr), and the rare earth elements. Recent discoveries of substantial tin and tungsten concentration associated with the peraluminous granites at Baid al Jimalah (Cole and others, 1981) and Jabal Silsilah (du Bray, 1984) have intensified interest in the mineral potential of the felsic plutonic rocks of the northeastern Arabian Shield.

Further exploration work was recommended, better to define the mineral resource potential of the felsic plutonic rocks underlying the quadrangle. This report describes and summarizes a regional geochemical survey of the postorogenic felsic granitoid rocks of the quadrangle, the methods of reviewing the geochemical results achieved, and their interpretation.

The classification of the felsic plutonic rocks used in this report follows the recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Plutonic Rocks (Streckeisen, 1973). The classification of Shand (1951) on the degree of alumina saturation is used to define peralkalic granite (molar ratio Al/(Na + K) <1), metaluminous granite (molar ratio Al/(Na + Ca) <1), and peraluminous granite (molar ratio Al/(Na + Ca) >1).

Acknowledgements

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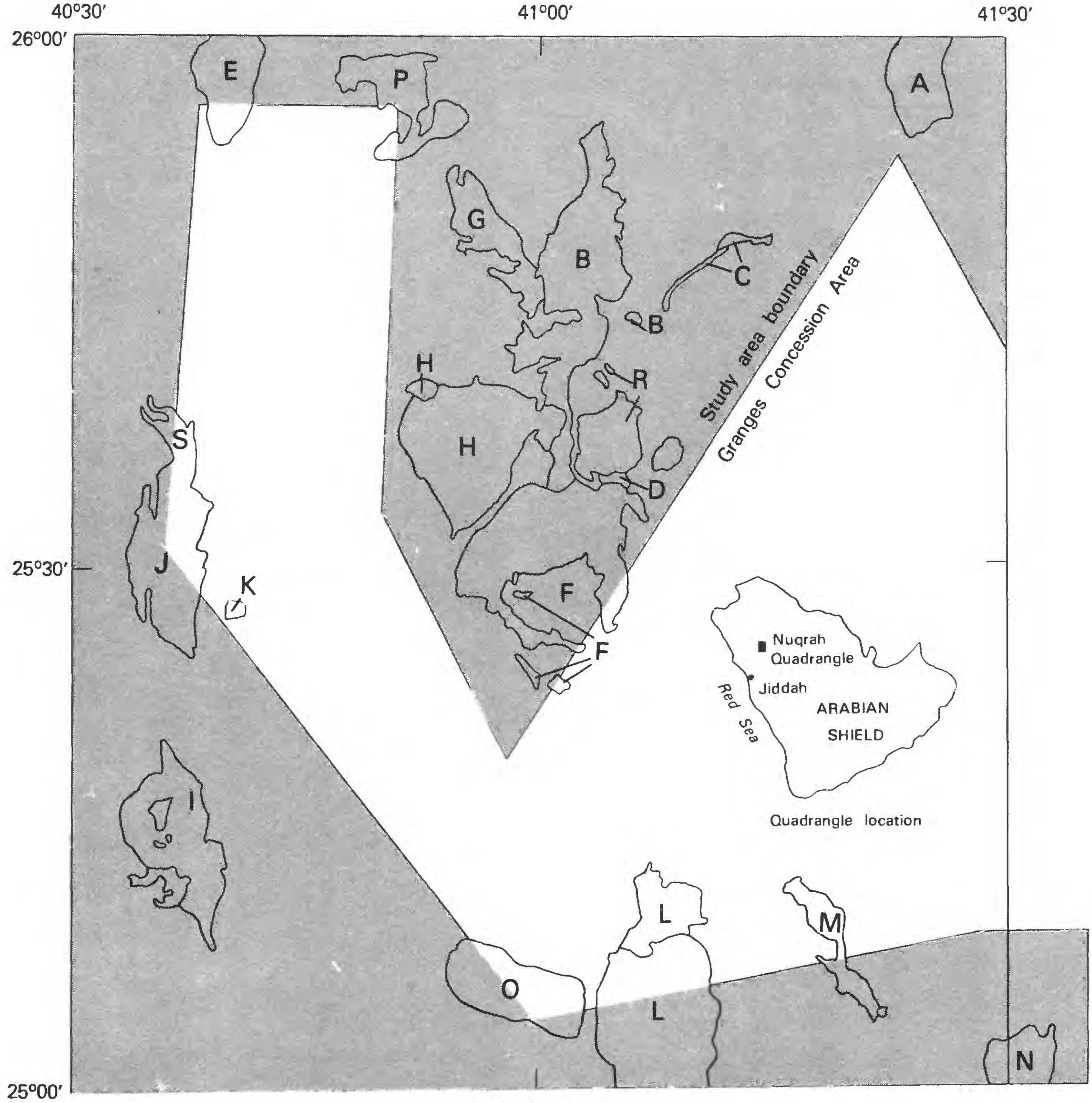


EXPLANATION

A -- Jibal aj Jajah
B -- Jabal Umm 'Abal
C -- Jabal Waiylah
D -- Jabal Isamah
E -- Jabal Shajarah
F -- Jabal Tuwalah
G -- Jabal 'Awaj
H -- Jabal ar Raqab
I -- Jabal al Kurayziyah/Jabal Mirbad
J -- Jabal Safad
K -- Jalab Safad East
L -- Jabal Bidayah/Jabal Ajir
M -- Jabal Idhkayrah/Jabal al Khar
N -- Jabal Anfadhi
O -- Jabal al Mururah
P -- Jabal 'Ibib/Jabal Hamiriyah
R -- an Namar
S -- Jabal Safad North

Figure 1.--Index map showing the location of the Nuqrah quadrangle, sheet 25 E, Kingdom of Saudi Arabia, and the distribution of the felsic plutonic rocks.

GEOLOGIC SETTING

The Nuqrah quadrangle is underlain by a thick sequence of Late Proterozoic mafic, intermediate, and felsic volcanic rocks, interstratified pyroclastic and sedimentary rocks that lie uncomformably on a Middle Proterozoic basement of calc-alkalic granite, gneiss, amphibolite, and two northwest-trending belts of layered gabbro and serpentinized peridote (Delfour, 1977). This metavolcanic, sedimentary, and plutonic orogenic complex evolved from 1165 to 680 Ma (Greenwood and others, 1980; Fleck and others, 1976, 1978, 1980). It was intruded along the western side of the Arabian Shield by a belt of calc-alkalic plutonic rocks of intermediate composition (Stoeser and Elliott, 1979). Greenwood and others (1976) report these intermediate composition plutonic rocks were intruded during two episodes; the first being tonalite plutonism about 960 Ma, followed by a second period of tonalitic plutonism 800 - 680 Ma. Granodiorite was intruded as gneiss domes during the latter part of the second episode of plutonism (Nebert, 1970; Fleck and others 1978). Intermediate volcanic and clastic sedimentary rocks were being deposited in the northern part of the Shield during this period. Plutonism shifted to more felsic magmas about 700 - 680 Ma, and large amounts of calc-alkalic monzogranite were intruded (Fleck and others, 1976). These granites were emplaced predominantly as circular or ring-structured plutons (Dodge, 1979). About 600 Ma, the composition of magmas shifted from calc-alkalic to alkalic, and the tectonic environment changed from orogenic to anorogenic. These late Precambrian monzogranites and alkalic granites are currently of much interest as possible sources of Nb, Th, Sn, W, U, and Zr, and were sampled during the study

GEOCHEMICAL SAMPLING

All the wadi sediment sampling was done in November and December, 1982, by David Dellinger, assisted for three days by Rashid Samater. The procedure for sampling and sample preparation was that described by du Bray and others (1982). A total of 384 sites was sampled. Approximately 10 kg of medium- to coarse-grained sediment was collected at each site , and at about a third of the sample sites a large rock sample was also collected. Wadi sediment samples were collected from a depth of 5 to 10 cms, subsequently screened through a 12-mesh sieve (U.S. Standard Sieve 0.0165 inch) to remove coarse material, and panned with a standard gold pan to produce a **heavy-mineral** concentrate. Magnetite was removed from the pan concentrate with a hand-held magnet.

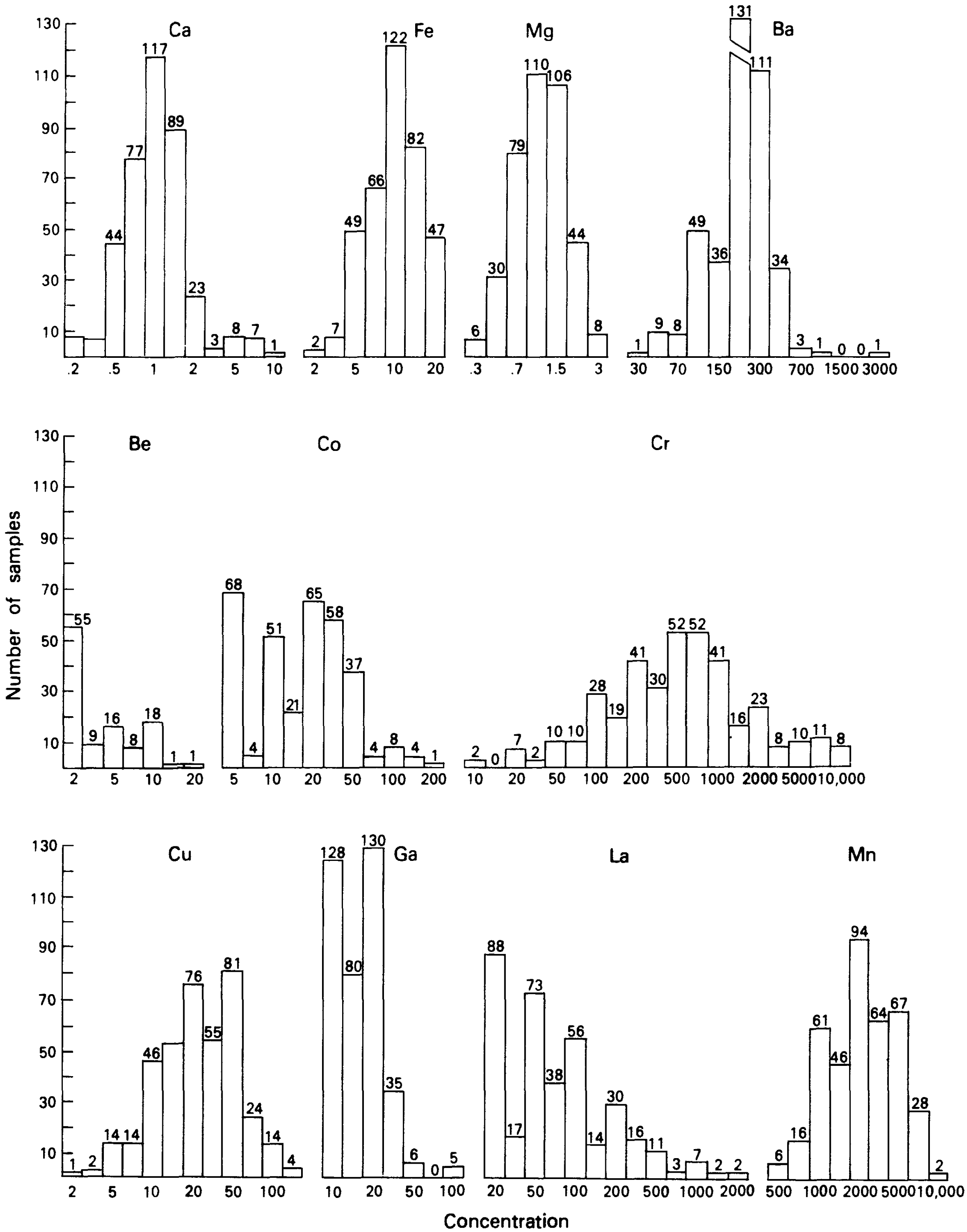
CHEMICAL ANALYSES

The 384 pan concentrates from the wadi sediments samples, and the 145 rock samples, were sent to Skyline Labs. Inc., of Wheat Ridge, Colorado, for analysis for 31 elements by semiquantative emission spectrographic methods. The 145 rock samples were also analysed for fluorine (F) and lithium (Li) contents, by selected ion electrode, and atomic absorbtion methods, respectively. The semiquantative emission spectrographic analyses are reported in parts per million to the nearest number in the series 1, 1.5, 2, 3, 5, 7, 10 within each order of magnitude. These numbers are considered to be within plus or minus one-step at the 68 percent confidence level, and within plus or minus two-steps at the 95 percents confidence level. The analytical data for the geochemical samples were handled in the manner described by du Bray and others (1982) and du Bray (1983). The reader is referred to their papers for a more exhaustive description of the data treatment. The spectrographic data for 23 elements in the 384 pan concentrate samples are given as histograms (fig. 2). Eight other elements have no unqualified data. They are silver (Ag) (<1 ppm), arsenic (As) (<200 ppm), bismuth (Bi) (<10 ppm), cadmium (Cd) (<50 ppm), germanium (Ge) (<20 ppm), antimony (Sb) (<100 ppm), titanium (Ti) (>10,000 ppm), and W (<50 ppm). Figure 3 presents similar histograms of the analytical data for the rock samples. The location of sample sites and the analytical data are archived in the DGMR/USGS Rock Analysis Storage System (RASS) computerized data bank, in file DELLING.MAS., and requests for, or inquires concerning, these data should be addressed to the U. S. Geological Survey, Jiddah, Kingdom of Saudi Arabia.

GEOCHEMICAL DATA INTERPRETATION

The objectives of this sampling program were to identify and evaluate areas that contain geochemically anomalous concentrations of elements in the felsic plutonic rocks of the Nuqrah quadrangle. No sampling was carried out in the adjacent metavolcanic and sedimentary rocks. It was necessary first to establish a threshold anomalous value for each element that was analysed and considered to be of potential economic interest. Du Bray (1982) has reviewed procedures for identification of threshold concentrations, and settled on a method that involves construction of cumulative frequency tables for each element, and plotting a cumulative frequency curve with the log of concentration plotted against cumulative frequency. Most frequency distribution of elements in specific geologic materials have lognormal distributions (Ahrens, 1954, 1957; Sinclair, 1974). Such geochemical distributions in nature plot as approximately straight lines in a cumulative frequency plot when the log of concentration is plotted against frequency on an arithmetic probability scale. Elements that have lognormal distributions are considered in anomalous concentrations if the sample concentration exceeds the arithmetic mean concentration plus two standard deviations ($\bar{x} + 2\sigma$). The accepted threshold concentration for lognormally distributed elements in this study follows the ($\bar{x} + 2\sigma$) criterion (table 1).

The geochemical data from the histograms, which give the number of samples per concentration interval for both the pan concentrates and the rock samples (figs 2 and 3), were compiled as cumulative frequency tables for each element that was considered to have significant data. The arithmetic mean ($\bar{x}$) and the standard deviation (σ) were calculated and the $\bar{x} + 2\sigma$ criterion determined (tables 1 and 2) Data from the cumulative frequency tables were then plotted as logarithms of the concentrations against cumulative percent frequencies (figs. 4 - 7). These plots were then examined visually for linearity. The $\bar{x} + 2\sigma$ criterion was used to determine threshold concentrations of elements, when the plot was assessed to be linear or nearly so. An inflection point was picked and a dual resolution of the populations, resolved using Sinclair's (1974) dual populations, where one or more inflection occurred in a plot in the nonlinear cases and multiple superimposed populations were suspected. The plot of the two resolved frequency distributions was examined visually to determine if two lognormal populations were resolved. Another point was selected in the inflection if satisfactory dual lognormal populations were not resolved, and the procedure repeated until the two most nearly lognormal populations were resolved. Departures from lognormal distribution, that is bimodal or polymodal distributions, may indicate superpositions of two or more populations. This may result from samples collected from different geologic terranes, or from wadi samples that have a multiple geologic source.


Ca
Fe
Mg
Ba
Be
Co
Cr
Cu
Ga
La
Mn
Number of samples
Concentration

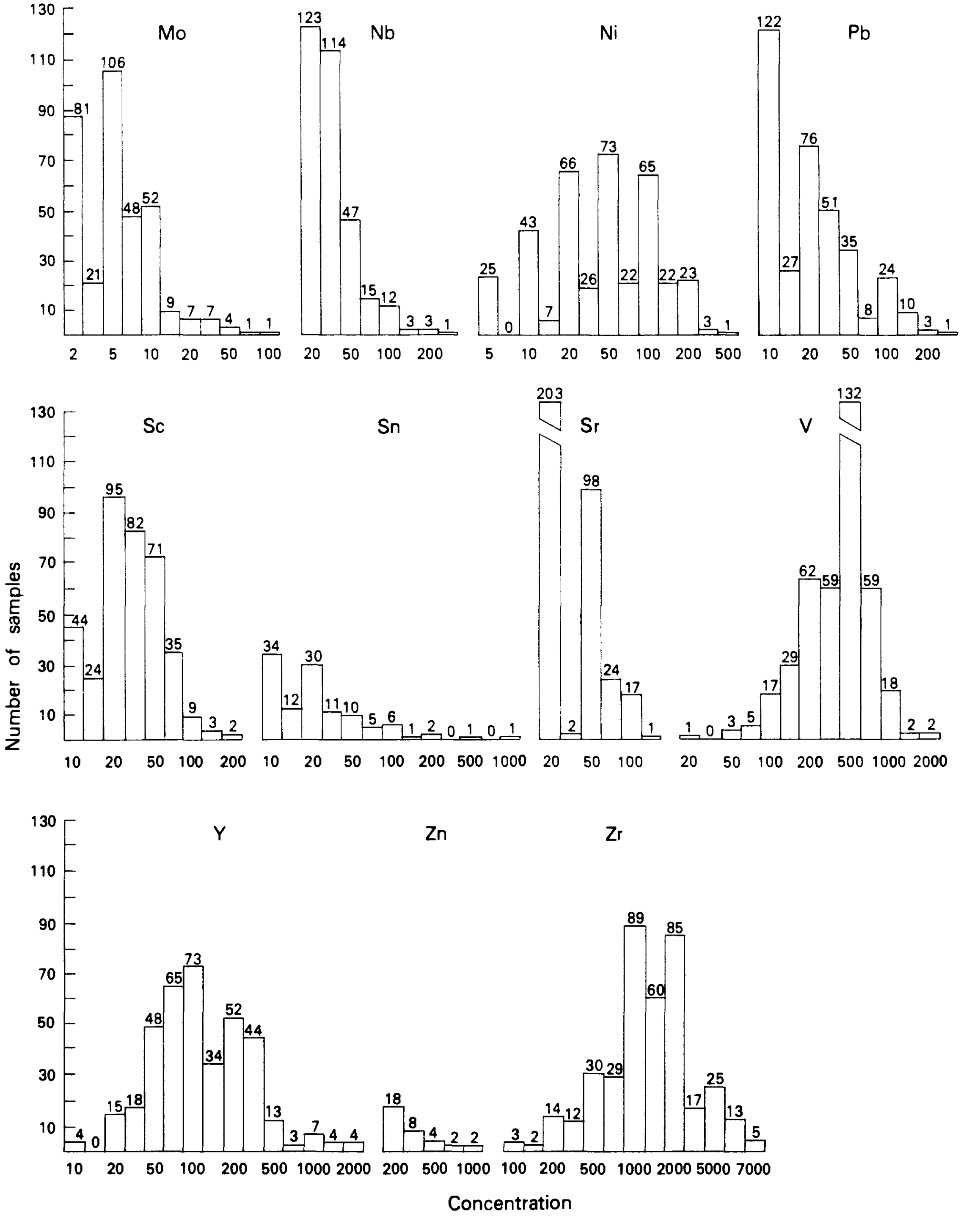
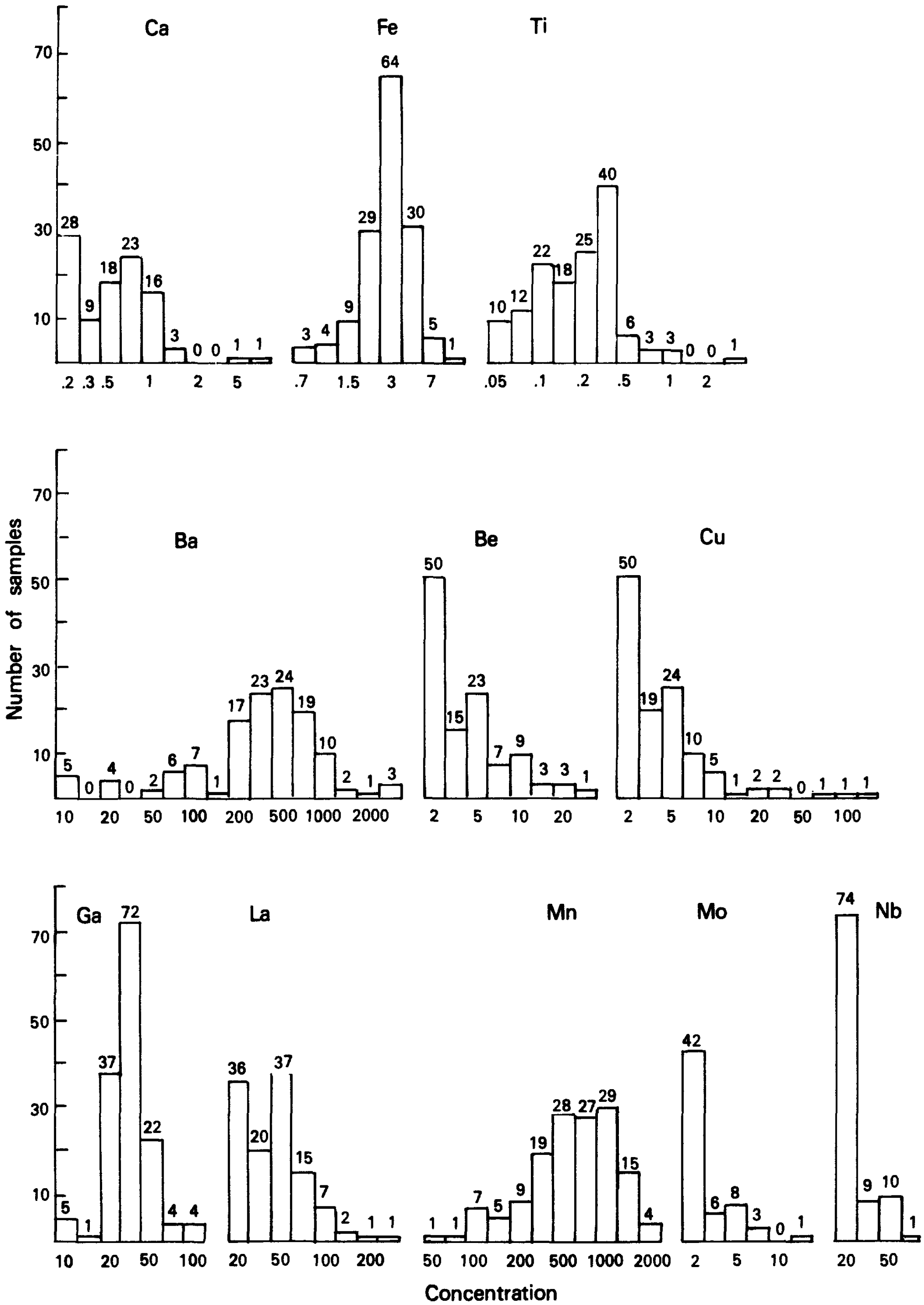


Figure 2.--Histograms of semiquantitative spectrographic analyses for 384 pan concentrate samples collected in the Nuqrah quadrangle, Kingdom of Saudi Arabia. Calcium, iron, and magnesium concentrates in percent; rest are in parts per million. Midpoints of concentration intervals are in the series: 1, 1.5, 2, 3, 5, 7, and 10.


Number of samples
Concentration
Ca
.2 .3 .5 1 2 5
Fe
.7 1.5 3 7
Ti
.05 .1 .2 .5 1 2
Ba
10 20 50 100 200 500 1000 2000
Be
2 5 10 20
Cu
2 5 10 20 50 100
Ga
10 20 50 100
La
20 50 100 200
Mn
50 100 200 500 1000 2000
Mo
2 5 10
Nb
20 50

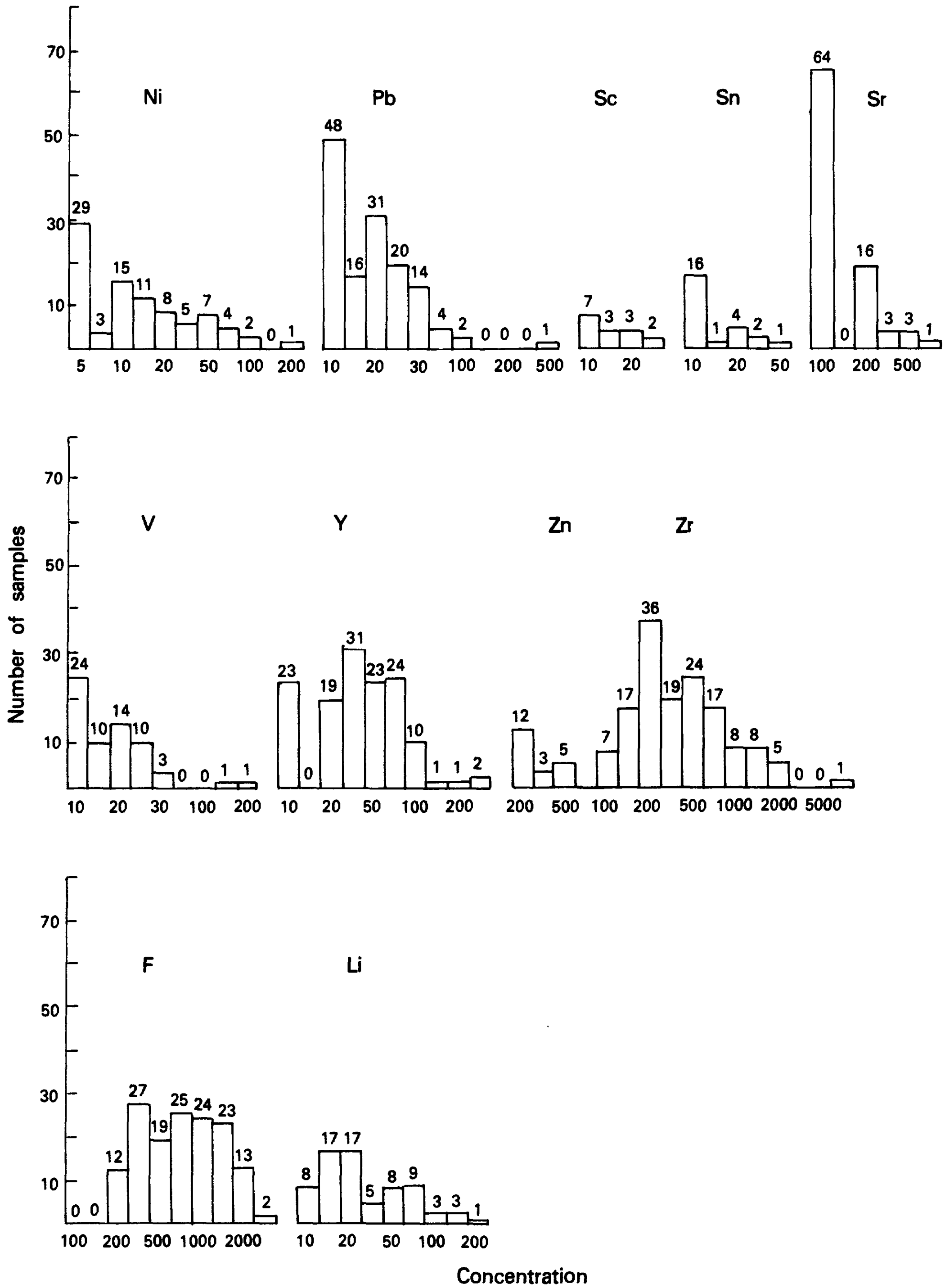


Figure 3.—Histograms of semiquantitative spectrographic analyses for 145 felsic plutonic rock samples collected in the Nuqrah quadrangle, Kingdom of Saudi Arabia. Calcium, iron, magnesium, and titanium concentrations in percent; rest are in parts per million. Midpoints of concentration intervals are in the series: 1, 1.5, 2, 3, 5, 7, and 10.

Table 1.--Statistical data and threshold concentrations of semiquantitative spectrographic data for pan concentrates.

[Only data not qualified by L (less than) or G (greater than) were used in the calculations. Fe, Mg, and Ca are in weight percent; rest are in parts per million.]

Element	Number of Values	Mean $\bar{X}$	Standard Deviation	$\bar{X} + 2\sigma$	Sinclair Threshold	Threshold Concentration
Fe	375	9.912	1.603		(2)	(2)
Mg	384	1.066	1.590		(2)	(2)
Ca	384	1.013	1.845		(2)	(2)
Ba	384	244.6	188	621	500	500
Be	108	4.5	3.5	12	15	15
Co	321	24.8	26	77	70	70
Cr	370	482			(2)	1500
Cu	384	32.1	26	83	(1)	100
Ga	381	18.1	12	42	50	50
La	357	136.4	243	622	700	700
Mn	384	2,249			(2)	7000
Mo	344	6.1	8	21	(1)	20
Nb	324	37.2	31	99	(1)	100
Ni	370	46.4	51	148	150	150
Pb	358	33.0	38	108	(1)	100
Sc	365	35.4	26	88	100	100
Sn	113	43.8	106	256	200	200
Sr	345	164.1	102	368	(1)	300
V	384	190.5	123	437	500	500
Y	384	191.2	283	756	500	500
Zn	34	335.3	227	769	(1)	700
Zr	383	2,491	3686	9863	7000	7000

(1) Sinclair threshold not calculated

(2) Sinclair threshold not calculated as no ore deposits expected

Table 2.--Statistical data and threshold concentrations of semiquantitative spectrographic and quantitative data for rock samples.

[Only data not qualified by L (less than) or G (greater than) were used in calculations. Values for Fe, Mg, Ca, and Ti are in weight percent; rest are in parts per million.]

Element	Number of Values	Mean $\overline{X}$	Standard Deviation	$\overline{X} + 2\sigma$	Sinclair Threshold	Threshold Concentration
Fe	145	3.2	1.5	6.2	(2)	
Mg	145	.6	.5	1.6	(2)	
Ca	145	.7	.8	2.3	(2)	
Ti	144	1723			(2)	5000
Ba	124	493	520	1534	1500	1500
Be	111	4.8	4.6	14	15	15
Cu	116	7.2	17.7	43	30	30
Ga	145	32.7	16.5	66	70	70
La	120	48.5	37.8	124	150	150
Mn	145	542			(1)	1500
Mo	60	3	2.1	7.2	(1)	7
Nb	94	24.7	10.5	46	(1)	50
Ni	85	21.4	28	79	(1)	70
Pb	136	26.6	44.3	115	100	70
Sn	24	15.2	9.5	34	(1)	30
Sr	90	147.2	102	353	300	300
V	63	17.5			(1)	50
Y	134	23.3	29.5	82	(1)	100
Zn	20	(3)			(3)	(3)
Zr	145	543	7086	1958	(1)	2000
F	145	880			(1)	2000
Li	145	39.5			(1)	100

(1) Sinclair threshold not calculated. Threshold concentration determined by inspection of histogram.

(2) Sinclair threshold not calculated as no ore deposits expected

(3) Statistics not calculated as too few data

Pan concentrate samples

The cumulative frequency distribution curves of selected elements from the pan concentrate samples are shown in figures 4 - 6 and the anomalous threshold concentrations given in table 1. The cumulative frequency distribution plots for barium (Ba), copper(Cu), molybdenum (Mo), Nb, lead (Pb), zinc (Zn), and Zr are interpreted to be lognormally distributed. For these elements the anomalous threshold values were determined by the $\bar{x} + 2\sigma$ criterion, and the Sinclair (1974) method was not employed. Threshold concentrations were not determined for iron, magnesium, and calcium, as they are major constituents of the plutonic rocks and do not provide information regarding the likelihood of deposits of other elements.

Some of the cumulative frequency curves have long, flat tails at the low concentration end of the population. These tails were ignored in the selection of inflection points. It appears that the tails result from analytical bias whereby values were preferentially put into the interval just above the detection limit rather than in the next higher interval or in the category less than that interval.

Copper is the most lognormal of all the elements (fig. 4). It appears to have a small inflection at the low concentration end of the curve, but the data there are sparse. Mo, Nb, Pb, and Zn have long, flat tails that were not considered. The Pb curve (fig. 3) appears to be affected by analytical bias in the middle part, but may be a bimodal distribution shown by only one interval. The 70 ppm interval was reported in only eight samples, while the adjacent intervals were reported 24 and 35 times respectively. The Zn curve was affected by censoring at the low concentration end. There were only 350 analyses that were less than the detection limit of 200 ppm, so only the high concentration end of the curve was modelled.

Eight elements have bimodal distributions that were resolved into two approximately lognormal distribution populations by the Sinclair (1974) method. These are Be, cobalt (Co), lanthanum (La), nickel (Ni), scandium (Sc), Sn, vanadium (Va), and yttrium (Y) (fig. 5). Be, Co, La, Ni, Sc, and Sn are all censored at the low concentration range, but each of these elements has sufficient data in the high concentration range in the cumulative frequency plot to resolve a dual lognormal population (fig. 5). Co also may have analytical bias. The interval reported as 7 ppm has four values, while the adjacent intervals have 68 and 51 reported values. It is possible that this represents bimodal distribution.

Rock samples

Cumulative frequency plots for selected elements from the 145 rock samples are given in figures 6 and 7, and the statistical data and threshold concentrations are in table 2. The cumulative frequency distributions for Pb, Mo, Ni, Sn, fluorine (F), Li, Va, and Zr are lognormal. They represent single populations and the Sinclair (1974) method was not used. The Pb frequency distribution, although it is interpreted as being linear, has a much higher standard deviation than the arithmetic mean. This results in a much higher $\bar{x} + 2\sigma$ anomalous threshold concentration than is realistic, and therefore it was lowered to 70 ppm after inspection of the Pb histogram (fig. 3). The histograms for Mo and Va are censored at their low concentration end, but this does not affect the anomalous high threshold concentration determination.

The cumulative frequency distribution plots for Ba, Be, Cu, gallium (Ga), La, Nb, strontium (Sr), and Y are bimodal, and the Sinclair (1974) method was used to resolve the distributions into two lognormal populations that represent a background population and an anomalously high concentration population. Tin distribution may be bimodal, but the data are too sparse. Be, Cu, La, Pb, Mo, and Sr, had a large part of their distribution censored at the low concentration end, but there was sufficient data to resolve background and an anomalous high population. Nb, Sc, Sn, and Zn have large parts of their data censored by the detection limit. An anomalous high concentration threshold for each of these elements was estimated from their histograms.

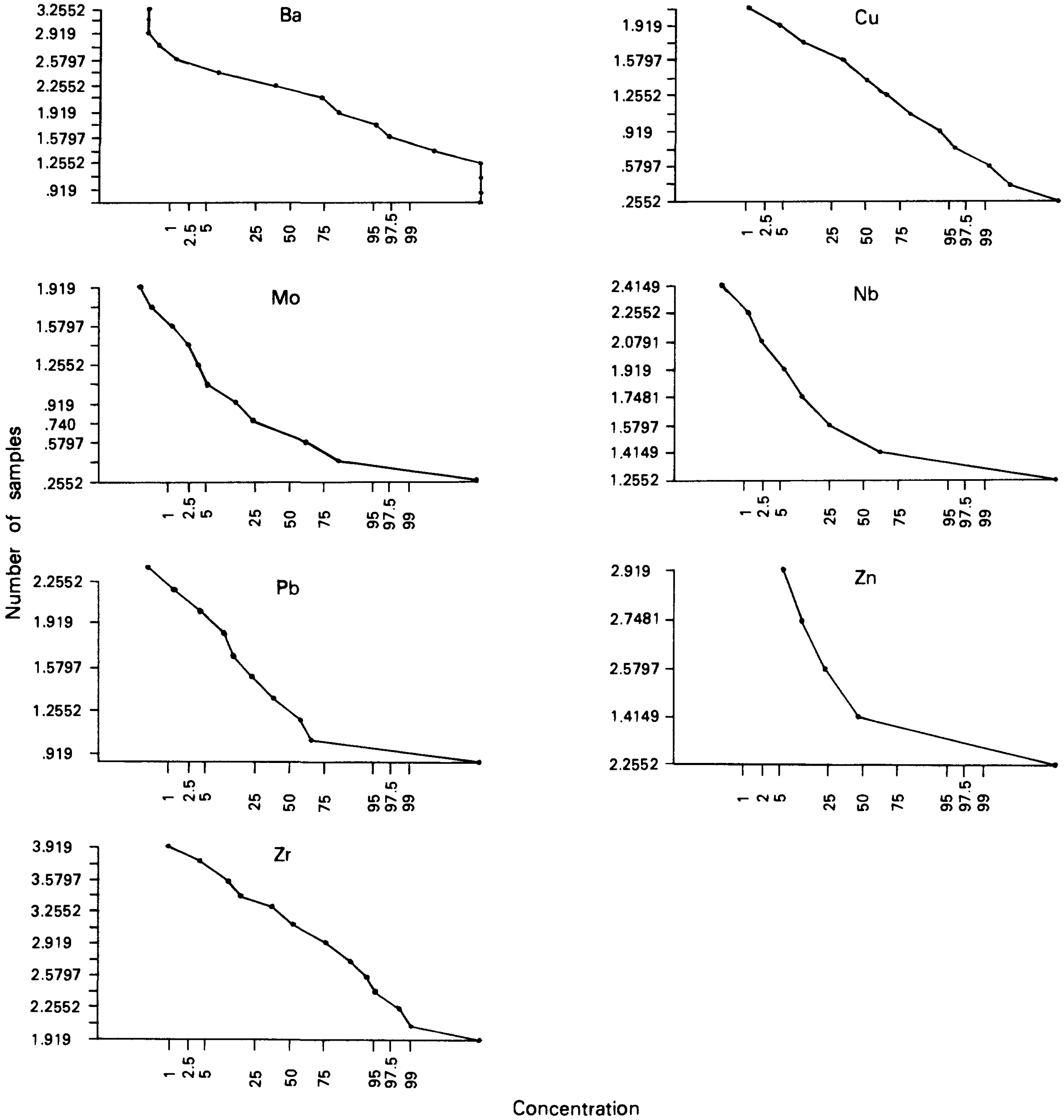


Figure 4.—Plots of the logarithm of reporting interval concentrations versus cumulative percent frequency by element for 384 pan-concentrate samples. Log normal distributions.

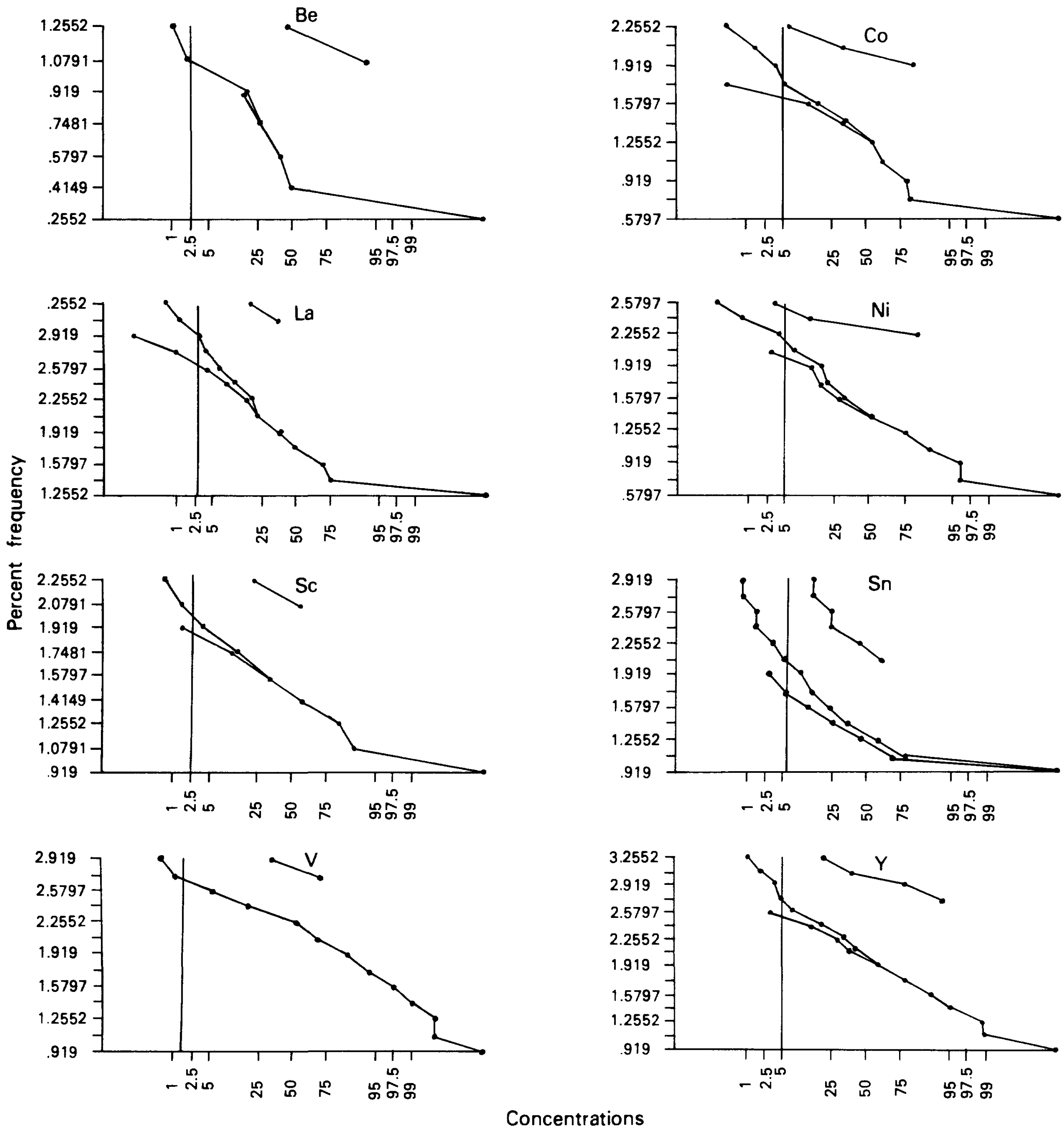


Figure 5.—Plots of the logarithm of reporting interval concentrations verses cumulative percent frequency by element for 384 pan-concentrate samples. Bimodal distribution.

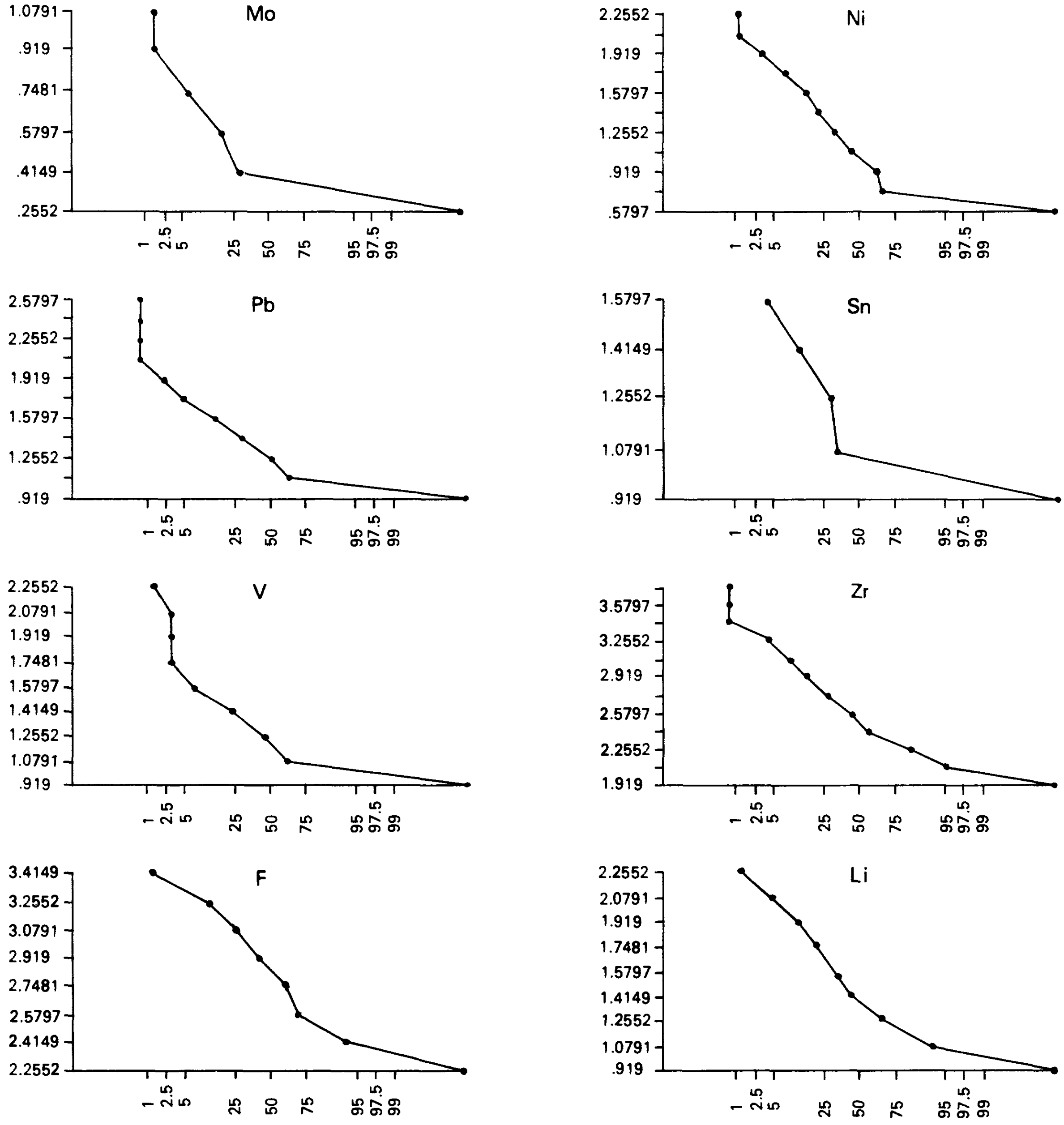


Figure 6.—Plots of the logarithm of reporting interval concentrations verses percent frequency by element for 145 felsic granitoid rocks. Log normal distributions.

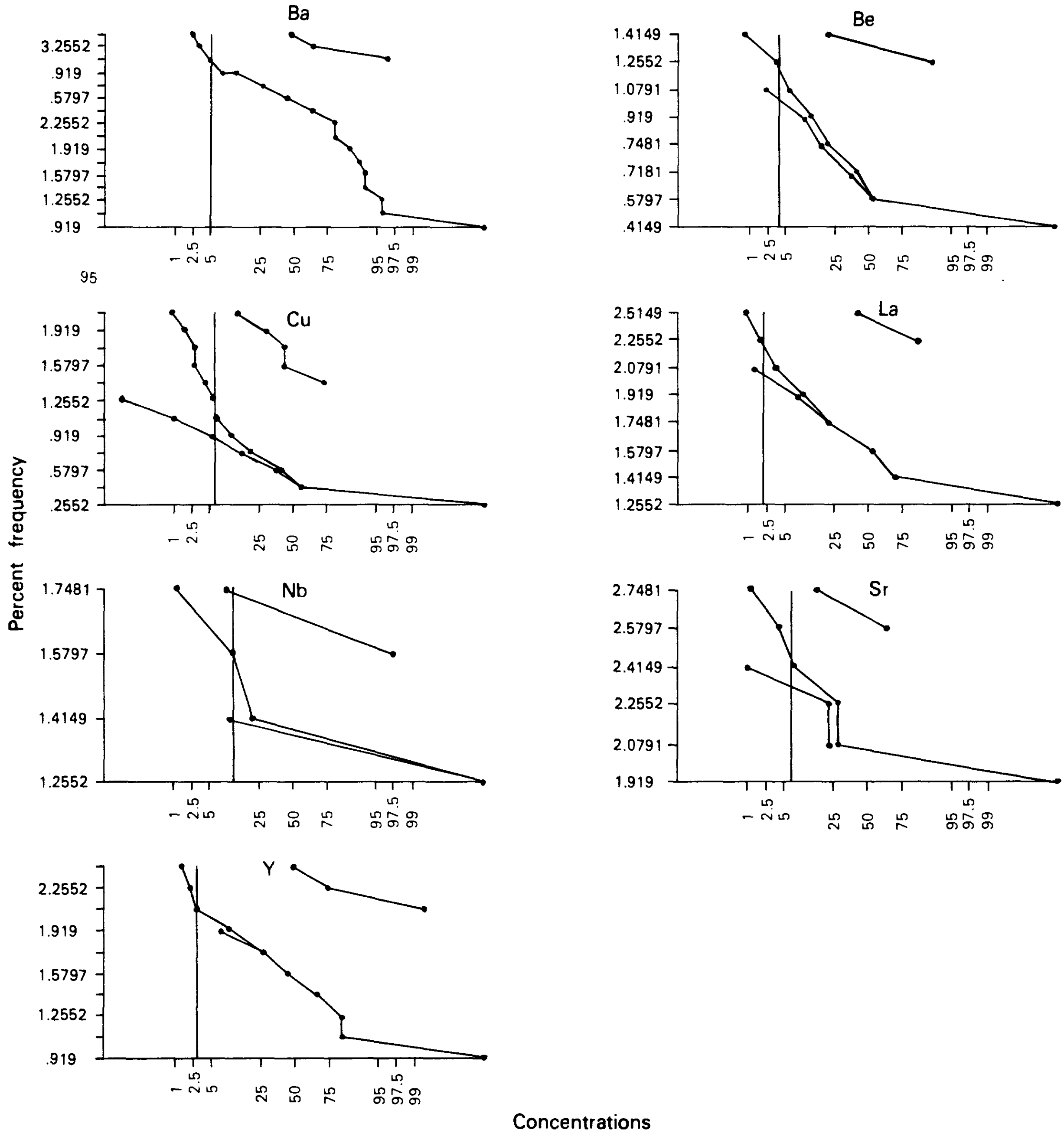


Figure 7.—Plots of logarithm of reporting interval concentrations verses cumulative percent frequency by element for 145 felsic granitoid rocks. Bimodal distribution.

AREAS OF ANOMALOUS CONCENTRATIONS OF ELEMENTS

The purpose of the preceding dialogue on selection of anomalous concentrations of the elements was to outline areas that should be evaluated for their mineral resource potential. Having selected anomalous concentrations of the elements, and with all sample sites and analyses stored, it was possible with statistical programs written by G.I.Selner to produce maps showing locations of anomalous elements (figs. 8 and 9). The anomalous concentrations of most interest fall into two areas of felsic rocks: (1) the plutons in the Jabal Tuwalah - Jabal Awja general area, and (2) the north end of Jabal Safad, where a Sn anomaly is identified. In addition, a radiometric survey (discussed later) showed an anomalously high total count at Jabal Safad East at Jabal Awja (fig. 10).

Jabal Tuwalah and Jabal Awja areas

The plutons in the Jabal Tuwalah and Jabal Awja areas are highly evolved alkalic peralkalic granites that have concentrated the same group of elements; these plutons will be discussed together. The two areas include the two plutons above, and Jabals ar Raqab and ar Rabuth. The areas have received intensive study because of their concentrations of Nb, rare earth elements, Th, U, and Zr. They are underlain by a medium- to coarse-grained pinkish-gray alkalic granite with a color index of 10 to 15, and by dark-red alkalic granite that weathers to a smooth, dark-gray surface. The alkalic granites consist of potassium feldspar with a patch pattern of perthite or a microcline grid twinning, 15 to 25 percent quartz, and 5 to 20 percent sodic amphibole. The exposures of the plutons at Jabal Tuwalah and Jabal ar Rabuth are near the roof of a flat-lying laccolith or sill-like intrusion. The granite has a pronounced gently dipping foliation, and many flat-lying, quartz-rich radioactive pegmatites. The chemical compositions and norms of representative samples of the felsic rocks are given in table 3.

The anomalous elements in pan concentrates and rock samples from the Jabal Tuwalah and Jabal Awja areas are shown in figures 8 and 9. The anomalous elements in the pan concentrates are La, Mo, Pb, Sn, Y, Zn, and Zr. La is anomalous mainly along the eastern margin of the plutons, while the other elements are distributed throughout the plutons. The anomalous elements from the rock samples from these areas are F, Pb, Mo, Nb, Sn, Y, and one anomalous Be from the Jabal Awja pluton (fig. 9). However, the concentrations of these elements are vastly less that in the Ghurayyah alkalic granite (Watts, Griffis and McOuat Ltd., 1976), or at Jabal Tawlah (Douch and Drysdall, 1980). The most highly evolved cores of plutons in the Jabal Tuwalah - Jabal Awja areas contain 0.005 - 0.007% Nb, 0.01 - 0.03% Y, 0.002 - 0.005% Sn, 0.2 - 0.7%, Zr, 0.01 - 0.05% Pb, and 0.05% Zn. These concentrations are so much lower that Jabal Tawlah or Ghurayyah that they make the Jabal Tuwalah - Jabal Awja areas unattractive as a source for these elements.

Jabal Safad area

The analyses of pan concentrates from the wadi samples taken around Jabal Safad have demonstrated an area of anomalous concentrations of Sn, Mo, Pb, and La, and rock samples from the northern part of Jabal Safad showed anomalous values of F. This is the same family of anomalous elements as in the Jabal Tawalah and Jabal Awja areas. The pan concentrates from the wadi samples collected at Jabal Safad North contain as much as 1,000 ppm Sn and anomalous concentrations of Mo, Pb, La, and are low in Zr and Y. The site of anomalous concentrations of these elements lies within a ring structure of alkalic granite mapped by Delfour (1976) in a peneplained area with very little outcrop. Most of the outcrop is covered by a thin layer of alluvium. The rock samples collected from these low, weathered outcrops of granite contained less than the detectable limits (10 ppm) of Sn, and were low in Y and Zr. The trace element concentrations indicate the alkalic granite at Jabal Safad North is not a highly evolved granite. The anomalous concentrations of elements in the pan concentrates (F, La, Pb, Mo, Sn) is an assemblage expected for Sn-W mineralization associated with monzogranites and aplites similar to those recognized in numerous localities in the northern and eastern Arabian Shield by Drysdall (1979), Stoeser and Elliott (1980), Elliot (1980, 1983), du Bray, Elliot, and Stoeser (1982), and du Bray (1983). There were two possibilities for producing this anomaly: (1) the Sn anomaly in the pan concentrates came from a source to the west, outside the ring of alkalic granite; and (2) the alkalic granite is intruded by a felsic pluton, not recognized during the reconnaissance due to poor exposure, that contributed the Sn-Mo-F-Pb-trace element signature to the pan concentrate samples. A brief reconnaissance of Jabal Safad North was made to check out these two possibilities.

An area of about 3 km^2 on the west side of the alkalic granite ring, underlain by metarhyolites and metasedimentary rocks, was traversed to look for greisen, muscovite-bearing plutonic rocks, or possibly quartz-wolframite or quartz-cassiterite veins. No evidence of greisen or Sn-W mineralization was noted. Traverses were then made inside the ring of structure in the vicinity of the geochemical anomaly. The outcropping alkalkic granite has a grain size of 2 - 3 mm and a color index of about 10. Mafic minerals are biotite and amphibole. The granite is cut by north-trending veinlets of gray, fine-grained quartz, 12 - 4 mm thick. Locally the alkalic granite is altered and fine grained, which apparently is a transition zone with an unexposed pluton. A set of quartz veins, 1 - 2 mm thick and trending N. 60 W., crop out through the alluvium at the northwest end of the area of anomalous Sn, in a zone about 25 m by 25 m. Float in this area is predominantly pinkish-gray aplite containing quartz, potassium feldspar, and plagioclase and minor dark-brown biotite, muscovite, and opaque minerals. The aplite is cut by thin veinlets of quartz, and has abundant miarolitic cavities. The abundant aplite float and the previously described alteration of the alkalic granite suggests the aplite is intrusive into the alkalic granite. The combination of aplite float and the assemblage of anomalous elements in the pan concentrate make this a favorable area for further prospecting for tin.

Table 3.--Chemical Analyses and Norms of representative alkalic granites, Nuqrah quadranle

*Major element analyses by x-ray spectroscopy under the supervision of J. E. Taggart, U and Th delayed neutron activation under the supervision of D. M. McKown

	186252 Jabal Safad East	186132 Jabal Tuwalah	186076 Jabal ar Raqab	186182 Jabal Awja
SiO_2	75.2	71.2	75.6	74.3
Al_2O_3	12.6	10.4	12.0	10.8
Fe_2O_3	0.94	4.36	1.50	1.95
FeO	0.10	4.26	0.38	1.82
MgO	0.13	0.43	0.12	0.16
CaO	0.74	0.44	0.34	0.38
Na_2O	4.26	3.00	3.80	4.14
K_2O	4.00	3.38	4.40	4.30
TiO_2	0.06	0.26	0.09	0.26
P_2O_5	.05	.05	.05	.05
MnO	.03	.02	.03	0.05
H_2O	0.55	1.31	0.52	0.55
Totals	98.66	99.01	98.83	98.96
Th (ppm)	49.0	84.2	31.7	37.8
U (ppm)	24.4	20.9	12.8	14.2
CIPW norms				
Q	34.08	38.02	36.30	34.02
or	23.91	20.57	26.69	25.58
ab	36.68	26.20	32.49	32.49
an	3.61	2.22	1.67	
C		.92	0.40	
hy	0.30	5.06	0.30	1.78
di				1.67
ac				2.77
mt	0.23	6.48	0.93	1.39
ap				
hm	0.80		0.96	
il	.15	.46	.15	0.46
Total	99.76	99.93	99.89	100.16
Salic	98.28	87.93	97.55	92.09
Mafic	1.48	12.00	2.34	8.07

SPECTROMETRIC SURVEY AND RESULTS

A total-count radiometric survey was made at each sample site with a portable gamma ray scintillometer containing a 31.75 mm by 25.4 mm sodium iodide crystal. A Scintrex digital differential/integral gamma-ray spectrometer (GAD-1) was used to discriminate the natural radioactive elements U, Th, and potassium, at 12 of the sites with the highest counts. Samples from four of these sites were analysed for U and Th. Figure 10 outlines the areas with anomalous total count. In general, the total count was highest where the concentrations of Pb, Zn, Zr, Y, and La occur. The highest total count was measured from a small circular pluton of alkalic granite that lies 3 1/2 kms east of the south end of Jabal Safad (fig. 1). It is a fine-grained pinkish - gray alkalic granite containing less than 5 percent biotite. The total count in the pluton ranges from 450 - 700 cps. The core of the alkalic granite at Jabal Awja is another area of high total count, ranging from 210 - 270 cps (fig. 10).

Ten pegmatites were examined at Jabal ar Rabuth and Jabal Tuwalah. The pegmatites are zoned, flat-lying bodies, with quartz cores. In some, the quartz crystals are as much as 60 cms long, oriented perpendicular to the zoning. The pegmatites are of two types: One type has a highly radioactive footwall consisting of potassium feldspar, amphibole, and Zr, and some contain black tourmaline; the other type has a nonradioactive footwall with potassium feldspar and massive fine-grained specularite. The largest radioactive pegmatite is 100 m long and 10 m wide, and trends N. 60 W. It contains a central zone, 1 m thick, and a highly radioactive footwall, 1 m thick, that contains potassium feldspar, black amphibolite, and zircon. The pegmatites are too small to contain significant values of Th and(or) U.

Table 3 gives the major element composition, and Th and U concentrations, of four samples of alkalic granite from Jabal Awja, Jabal ar Raqab, Jabal Tuwalah, and Jabal Safad East. The latter, with the highest total count, contained 49 ppm Th, and 24.4 ppm U. Sample 186132 from Jabal Tuwalah, with a total count of 290 cps, contained 84.2 ppm Th and 20.9 ppm U. Apparently, the U and Th concentrations are very erratic at the surface, and there is only general correspondence between the total count and the U and Th concentrations.

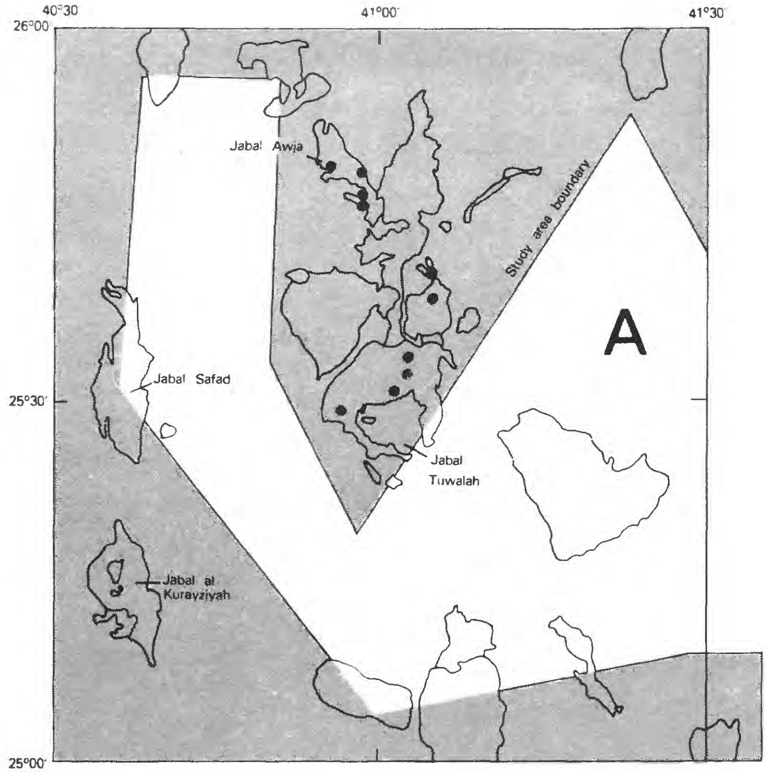


Figure 8.--Maps of the Nuqrah quadrangle showing sample locality sites (dots) of pan-concentrate samples that contained anomalous concentrations of metals:
A--Lanthanum, anomalous threshold concentration 700 ppm;
B--Molybdenum, anomalous threshold concentration 20 ppm;
C--Lead, anomalous threshold concentration 100 ppm;
D--Tin, anomalous threshold concentration 200 ppm;
E--Yttrium, anomalous threshold concentration 500 ppm;
F--Zinc, anomalous threshold concentration 700 ppm;
G--Zirconium, anomalous threshold concentration 7,000 ppm
Additional geographic locations and area of study shown on fig. 1.

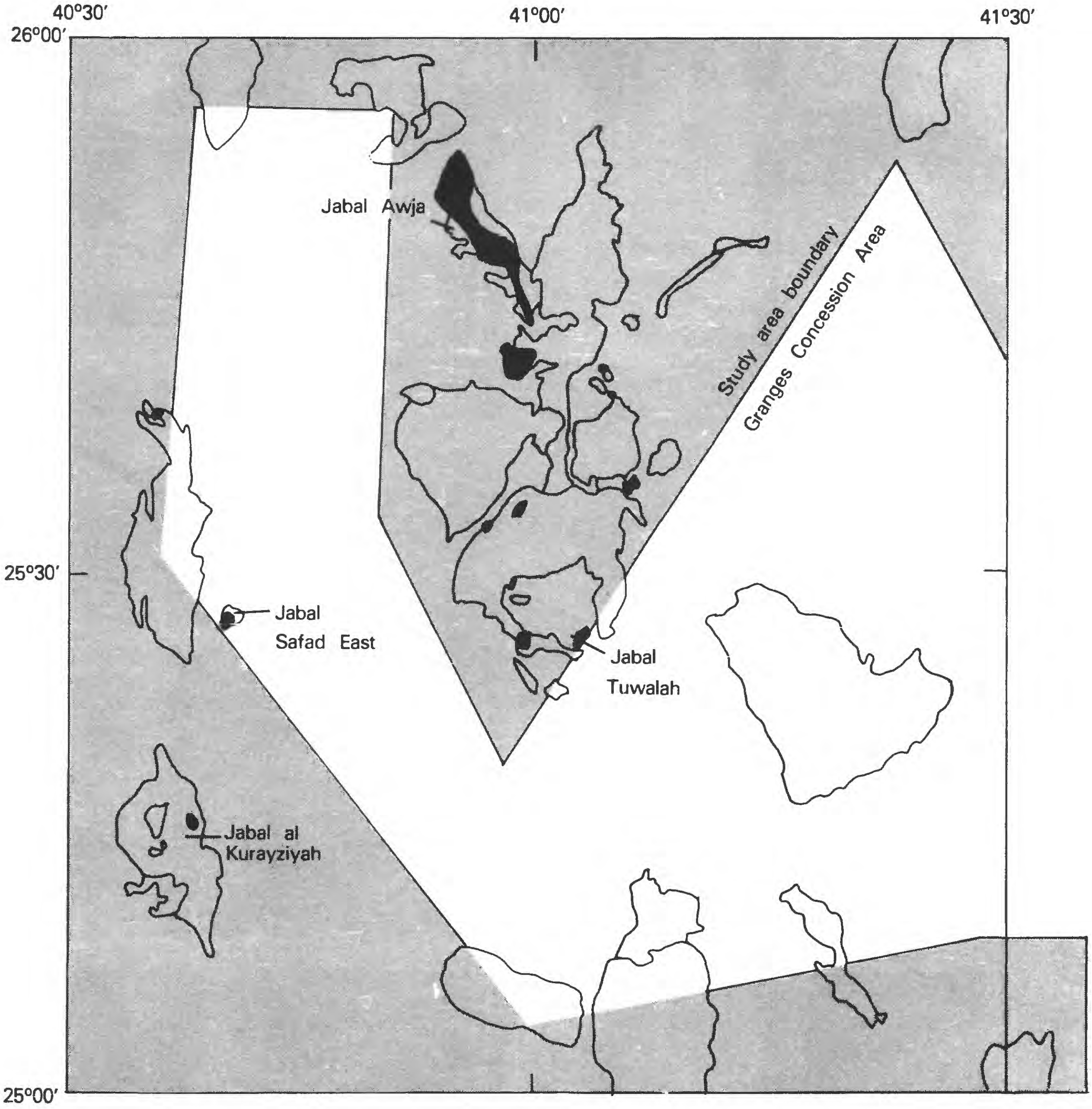


Figure 10.--Map of Nuqrah quadrangle showing areas of anomalous radioactivity in the felsic plutonic rocks. Areas of solid black pattern have a total count of over 210 spc.

← Figure 9.—Maps of the Nuqrah quadrangle showing sample locality sites (dots) of felsic granitoid rock samples that contained anomalous concentrations of metals:
A—Fluorine, anomalous threshold concentration 2,000 ppm;
B—Lanthanum, anomalous threshold concentration 150 ppm;
C—Molybdenum, anomalous threshold concentration 7 ppm;
D—Lead, anomalous threshold concentration 100 ppm;
E—Tin, anomalous threshold concentration 30 ppm;
F—Yttrium, anomalous threshold concentration 100 ppm;
Additional geographic locations and area of study shown on fig. 1.

CONCLUSIONS

The regional geochemical survey of the felsic plutonic rocks of the Nuqrah quadrangle, sheet 25 E, indicates that, although this peralkalic granite suite of rocks tends to be anomalous in its content of Be, La, Nb, Th, U, Sn, and Zr, these elements do not occur in significant concentrations. This is best exemplified by the Jabal Tuwalah and Jabal Awja plutons; these are highly evolved granites that have concentrated this family of element (figs. 1, 9). Thus these plutons are a large potential resource for these elements. They are, however, much less concentrated in this family of elements than the Jabal Tawlah radioactive microgranite, NW Hijaz (Douch and Drysdall 1980), or the Ghurayyah radioactive alkalic granite (Watts, Griffis and McOuat Ltd., 1976). Watts, Griffis and McOuat Ltd. (1976) estimate possible reserves at Ghurayyah of 440 million tonnes containing 0.75% Zr, 0.25% Nb-Ta, 0.115% U, 0.105% rare earth elements, and 0.02% Sn, to a depth of 100 m. The radioactive microgranite at Jabal Tawalah is even higher grade, but smaller in tonnage. The grade from surface samples is highly variable, but averages 0.3% Nb, 0.06% Sn, 0.09% Th, 3.7% Zr, 0.6% Y, 0.3% Zn (Douch and Drysdall, 1980).

An area of anomalous tin was identified from pan-concentrate samples from the northern part of Jabal Safad (figs. 1, 8G). The pan-concentrate samples contained between 250 and 1,000 ppm of Sn, associated with a small, poorly exposed pluton of aplite intrusive into the Jabal Safad alkalic granite complex. No greisen or quartz-cassiterite-bearing veins were found in a brief reconnaissance of this anomalous area. Further investigation of this anomaly is warranted.

DATA STORAGE

No mineral occurrences were added to MODS. Base Data File USGS-DF-04-29 (Hall and others) has been established for this study. Sample sites and analytical data are stored in RASS, in file DELLING.MAS.

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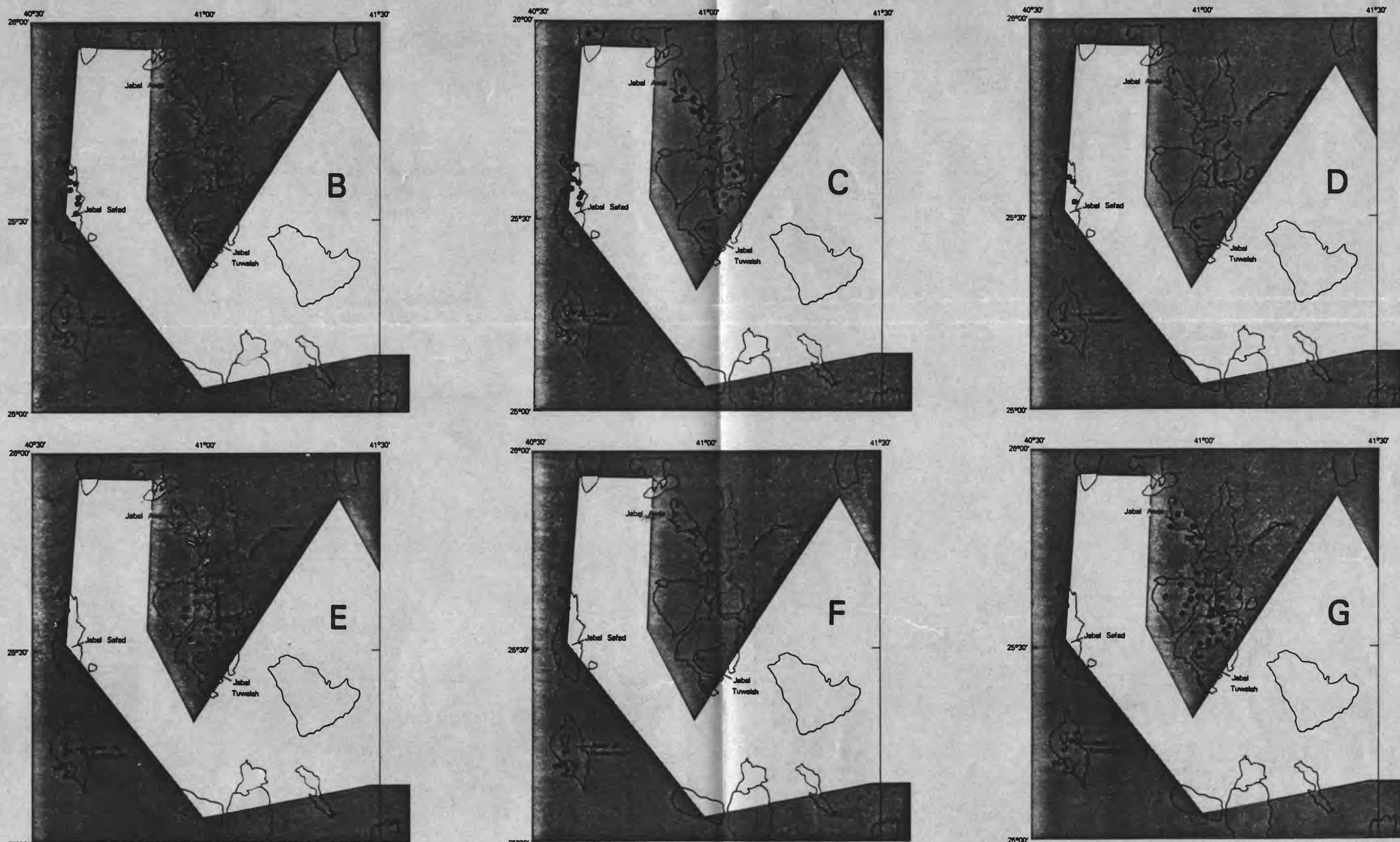
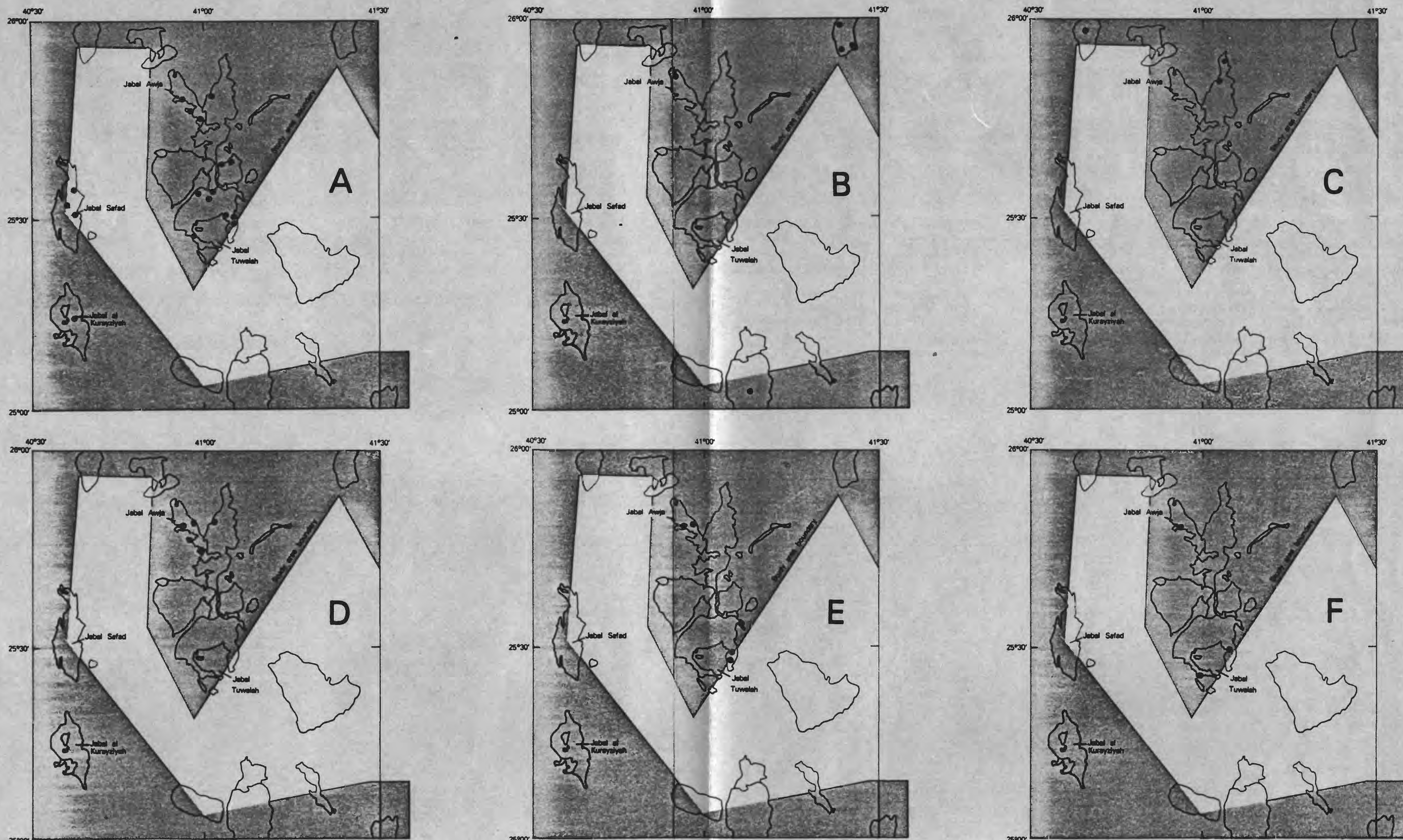


40°30'
41°00'
41°30'
26°00'
25°30'
25°00'
Jabal Sefad
Jabal Tuwalah
B
C
D
E
F
G

22A

85-25


40°30'
41°00'
41°30'
26°00'
25°30'
25°00'
Jabal Awja
Jabal Safad
Jabal Tuwalah
Jabal al Kurayziyah
Study area boundary
A
B
C
D
E
F

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