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Geochemistry and preliminary assessment of resource potential for postorogenic granites of the east-central Arabian Shield, Kingdom of Saudi Arabia

by

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GEOCHEMISTRY AND PRELIMINARY ASSESSMENT OF RESOURCE POTENTIAL FOR POSTOROGENIC GRANITES OF THE EAST-CENTRAL ARABIAN SHIELD, KINGDOM OF SAUDI ARABIA

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ABSTRACT

Chemical analyses for postorogenic granitoids from 38 plutons in the east-central Arabian Shield show characteristics of primitive to highly evolved igneous rocks; most samples are highly evolved as indicated by differentiation indexes greater than 90 for 93 of 127 samples. Samples range from peralkaline to strongly peraluminous, most are weakly peraluminous. The degree of alumina saturation is longitudinally dependent in that the strongly peraluminous rocks are all from the eastern edge of the study area, whereas the peralkaline rocks are all from the western part of the area.

Comparison of the geochemical data for most of the samples to average data for anomalously metalliferous granites from the Arabian Shield shows that most of the plutons sampled are not as evolved as known metalliferous plutons; however, the plutons at Jabal Minya, Jabal Khinzir, Hadb ad Dayahin, and Jabal Khazaz are chemically similar to the metalliferous plutons, and therefore merit further detailed study. In addition, Jabal Minya and Suwaj, which is nearby, have anomalously high yttrium contents, and therefore these localities have a possibility for deposits of rare-earth elements.

The average uranium content for the postorogenic granites of the east-central Shield is high relative to average granite, and thus the study area is within a uranium province. However, there are no indications that the granites have acted as possible source rocks to secondary uranium deposits, and no samples that even approached ore grade were collected during this study. The most likely type of uranium ore deposit associated with the postorogenic granites is judged to be of an igneous or hydrothermal origin, and the most favorable areas are Jabal Minya and Jabal Khinzir.

Regional trends for the chemical data and geochemical correlations over the large area sampled suggest that the postorogenic granites were derived from a single protolith that formed by the mixing of oceanic sediments from the west and continental sediments from the east. Melting of two or more accreted protoliths is less consistent with existing data, but would be possible if terrane boundaries at depth were markedly different from those currently proposed at the surface.

1/ U.S. Geological Survey, Denver, CO

INTRODUCTION

Recent work in the Arabian Shield (Greenwood and others, 1976; Delfour, 1977; Fleck and others, 1980; Stoeser and Elliott, 1980; Fleck and Hadley, 1982; Schmidt and Brown, 1982; Elliott, 1983) has shown that the Shield is composed of metavolcanic, plutonic, and metasedimentary rocks that range in age from 1,100 Ma to 540 Ma and in composition from basaltic to rhyolitic. These rocks have been variably, and in some cases multiply, deformed. The character of magmatism during the formation of the Shield changed from unevolved mafic rocks to intermediate rocks to evolved silicic (or bimodal gabbroic-granitic) rocks. Towards the end of the last magmatic period the Arabian Shield was cut by the northwest trending Najd Fault system, which has a left-lateral displacement of as much as 240 km (Brown, 1972). This fault system is a particularly prominent feature in the area studied for this report (fig. 1).

The youngest granitic rocks (variously referred to as postorogenic, anorogenic, or post-tectonic) have received considerable attention because of their common enrichments in several elements of economic interest (Elliott, 1985; Jackson and Odell, 1984; Moore, 1984). Within the Arabian Shield, occurrences of tungsten (Cole and others, 1981), rare earth elements and thorium (Harris and Marriner, 1980; Stuckless, Knight, and others, 1982; Stuckless, Quick, and VanTrump, 1984), molybdenum (Dodge, 1979), and tin (Elliott, 1985; du Bray, 1985) have been reported, and a good potential exists for niobium and tantalum (Ramsay and others, 1982; Elliott, 1983). These youngest granites have also been studied for clues to the origin of peralkaline granites (Radain and others, 1981; Harris, 1981; Stuckless, Nkomo, and Wenner, 1982; Jackson, 1984). Data for the young granites have been used in the debate concerning the origin of the Arabian Shield (Stacey and others, 1980; Delfour, 1981; Schmidt and Brown, 1982; Fleck and Hadley, 1982; Stacey and Stoeser, 1983; Stuckless, Hedge, and others, 1984).

The postorogenic plutons of the Arabian Shield were intruded from about 660 Ma to 540 Ma (Fleck and others, 1980). Geochronologic investigations by Fleck and Hadley (1982), Calvez and Kemp (1982), Stuckless, Hedge, and others (1984), and Stuckless (unpublished data) within and immediately adjacent to the study area (fig. 1) indicate that plutonism for the east-central part of the Shield occurred between 610 Ma and 570 Ma. Limited K/Ar data compiled by Moore (1984) suggest that an early Cambrian heating event, noted in the southern Shield (Fleck and others, 1976), did not extend as far north as the study area.

The work on which this report is based was performed in accordance with the cooperative agreement between the Saudi Arabian Ministry of Petroleum and Mineral Resources and the U.S. Geological Survey. The research is part of a program to study the petrogenesis and mineral potential of granitic rocks of the Arabian Shield. In particular, this report will present further information on the postorogenic granites of the east-central Shield (fig. 1) and will compare some of the geochemical characteristics of these granites with other postorogenic granites that are known to be mineralized.

No new mineral localities resulted from this work, and therefore no Mineral Occurrence Documentation System (MODS) entries were prepared. No other data for the samples used in this study are available in RASS; however, reports on other analytical work done on samples described here are in preparation, and previous analytical work done for some of the samples is reported by Moore (1984).

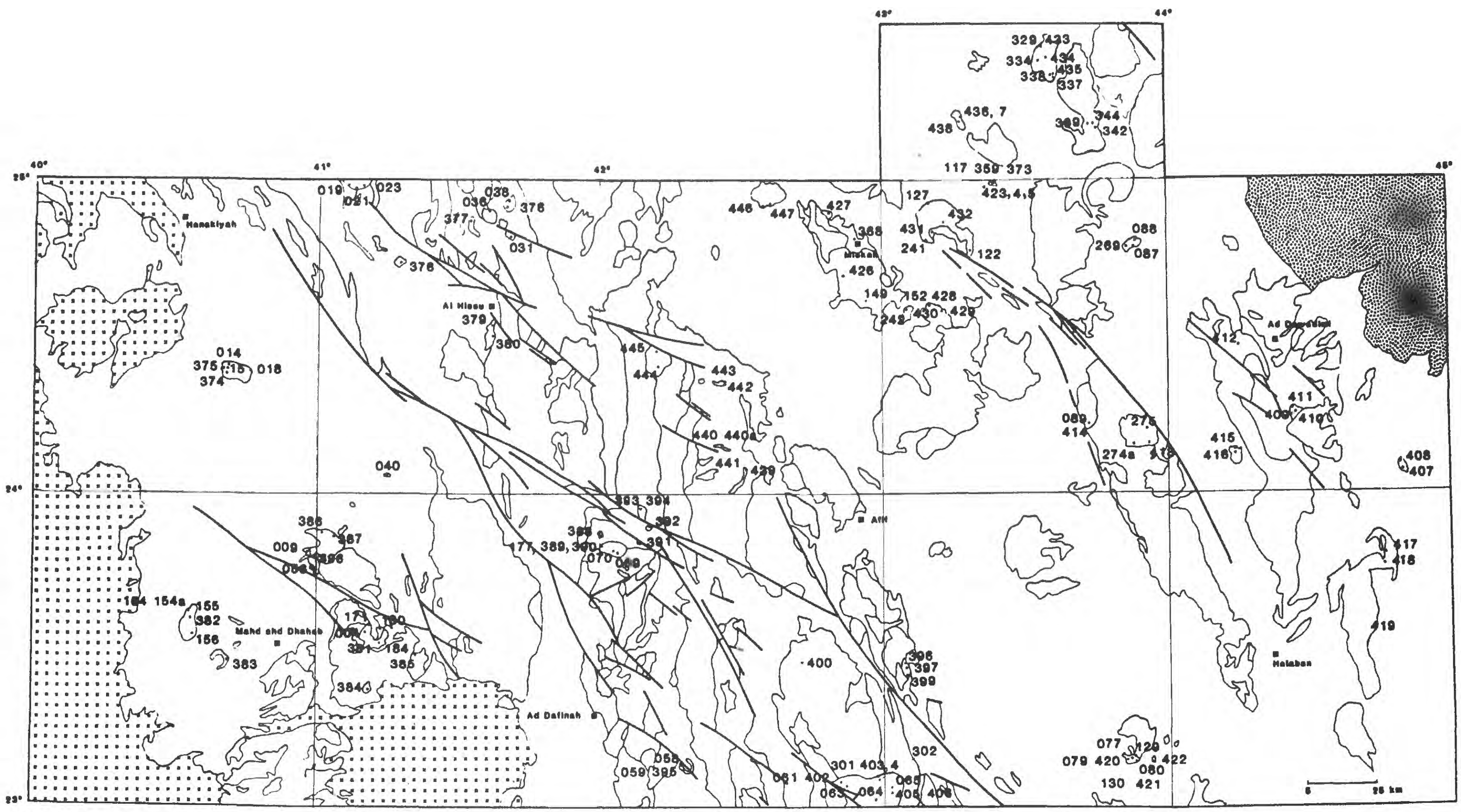

Figure 1.--*Generalized geologic map of the study area showing generalized geology (after Moore, 1984) and sample-site localities. Paleozoic cover rocks are shown by the dot pattern, and Cenozoic volcanic rocks are shown by the small x pattern. Sample localities are shown by small dots and labelled with the last three digits of the sample numbers (tables 1 and 2).*

The classification of plutonic rocks used in this report is that recommended by the International Union of Geological Sciences (IUGS) Subcommission on the Systematics of Plutonic Rocks (Streckeisen, 1976). Subdivision of the rocks on the basis of alumina saturation is based on the definitions of Shand (1951) such that rocks with molar $Al/(Na+K)<1$ are peralkaline; $Al/(Na+K+Ca)>1$ are peraluminous; $Al/(Na+K+Ca)<1$ and $Al/(Na+K)>1$ are metaluminous.

ANALYTICAL PROCEDURES

Samples were collected from all of the large postorogenic plutons in the study area (fig. 1) identified by Moore (1984), as well as most of the smaller plutons. Each sample was judged to be representative of the freshest material available at the sample locality and was usually collected from a recent spall block. Samples weighed between two and five kg, were ground to approximately -32 mesh, and split. Analyses were made on aliquots from a 30-g split that had been ground to -200 mesh except as noted below.

The concentrations of major elements reported in table 1 were determined by high-precision X-ray fluorescence (Taggart and others, 1982) on 0.8-g splits of fused sample powder. Results are precise and accurate within ± 2 percent of the amount reported (2 sigma) for abundances greater than 1 percent absolute. The fourth digit reported for SiO_2 and Al_2O_3 is not significant for any single sample, but may be significant in a statistical treatment of the entire data set (A. T. Miesch, oral commun., 1980). Elements for which reported values are below the limits of detection (MgO <0.10, P_2O_5 <0.05, and MnO <0.02) were arbitrarily assigned a value of one-half the limit of detection for purposes of statistical and normative calculations. Iron concentrations were determined as total ferric iron (table 1), but are also reported as total ferrous iron (FeO(t), table 2).

The concentrations of uranium (U) and thorium (Th) reported in table 2 were determined by the delayed neutron technique (Millard, 1976) on 8- to 10-g splits of sample powder. The precision and accuracy for individual determinations are dependent on counting statistics that are dependent on both concentrations and relative proportions of uranium and thorium. Uranium contents obtained for this study are generally accurate to within ± 4 percent of the amount reported (2 sigma). Thorium contents are generally accurate to within ± 6 percent of the amount reported (2 sigma) but are somewhat less accurate for samples with Th/U values >10 or Th contents <1 ppm.

Radium-equivalent uranium (RaeU), thorium (eTh), and potassium (eK) contents (table 2) were determined for approximately half of the samples by sealed-can gamma-ray spectrometry (Bunker and Bush, 1966, 1967). This technique uses approximately 600-g of coarsely-crushed material (-32 mesh), and thus provides a measurement that is less susceptible to splitting errors that can produce anomalous results for trace-element contents in coarse-grained rocks. The prefix "e" is used to distinguish values determined by this method. RaeU is not a direct measure of uranium, but rather a measure of the amount of uranium needed for secular equilibrium between ^{238}U and ^{226}Ra. Although eTh is not determined directly from thorium, disequilibrium within the thorium decay chain is unlikely. Therefore, eTh is used as a true measure of thorium. Precision for eTh and RaeU is better than ± the quantity (2 percent of the amount reported plus 0.1 ppm absolute). The eK value obtained by gamma-ray spectrometry is a direct measure of potassium, which is precise to within ± the quantity (2 percent of the amount reported plus 0.03 percent absolute). Accuracies for the gamma-ray technique are generally equal to precision except where relative proportions of uranium, thorium and potassium deviate markedly from normal (approximately by more than a factor of 10) in which case accuracy for the element with relatively low abundance is decreased.

Concentrations for rubidium (Rb), strontium (Sr), yttrium (Y), niobium (Nb), and zirconium (Zr) were determined by X-ray fluorescence (XRF) on loose, finely-ground (-200 mesh) sample powders (table 2). Comparison of XRF and isotope-dilution results for Rb and Sr shows that precision and accuracy are equal and that for concentrations >50 ppm results are precise to within 3.2 and 3.4 percent (2 sigma) of the amount reported, respectively. Errors for both elements increase to 100 percent at a concentration of about 5 ppm. Precision, as determined from replicate analyses, is less accurate for Zr (10.5%), Y (25.8%), and Nb (42.9%) at the concentration levels found for most of the samples used in the current study.

Normative mineralogy was calculated according to the methods described by Stuckless and VanTrump (1979). Statistical methods and formulae used are described by VanTrump and Miesch (1977). Mean and standard deviation for trace-element contents were calculated from the logarithms of the data and are reported as antilog values (table 3).

Table 1.--Chemical and normative composition of granitic samples from the east-central Arabian Shield.

[Analyses reported in weight percent. D.I. is differentiation index of Thornton and Tuttle (1960). M is cation ratio of Watson and Harrison (1983). Fe203 and FeO calculated from the Total iron by assuming 2/3 of the iron is present as FeO. LOI is loss on ignition at 920 C. Analyst: A. J. Bartel]

Sample	184385	184412	889494	893039	893159	893235	184122	184127	184241
SiO2	71.46	71.14	75.32	76.40	75.32	77.75	75.73	75.81	76.64
Al2O3	14.49	15.07	12.44	11.27	11.76	10.76	11.85	11.69	11.71
Fe2O3	0.62	0.42	0.55	0.58	0.66	0.63	0.68	0.73	0.59
FeO	1.12	0.75	1.00	1.04	1.19	1.13	1.22	1.32	1.06
MgO	0.45	0.62	0.11	0.14	0.12	0.14	0.13	0.15	0.11
CaO	1.37	1.88	0.63	0.59	0.70	0.62	0.38	0.47	0.18
Na2O	4.25	3.76	3.50	2.78	1.63	1.82	3.67	3.77	3.50
K2O	4.73	4.53	4.66	4.31	5.64	4.77	4.81	4.72	5.31
LOI	0.30	0.95	0.74	1.11	1.25	1.00	0.27	0.44	0.25
TiO2	0.35	0.23	0.08	0.09	0.10	0.10	0.17	0.18	0.17
P2O5	0.15	0.10	0.02	0.02	0.02	0.02	0.01	0.02	0.02
MnO	0.03	0.01	0.02	0.06	0.08	0.04	0.01	0.02	0.01
ZrO2	0.02	0.02	0.02	0.02	0.02	0.02	0.05	0.07	0.04
Total	99.35	99.48	99.09	98.40	98.49	98.80	98.98	99.39	99.58
CIPW Normative Minerals									
Q	25.144	27.089	35.402	42.351	42.528	47.315	34.712	34.361	35.096
C	0.249	0.807	0.546	1.023	1.776	1.542			
Z	0.030	0.030	0.030	0.030	0.030	0.030	0.075	0.105	0.060
CR	28.135	26.910	27.790	25.882	33.840	28.528	28.715	28.062	31.510
AB	36.199	31.984	29.888	23.905	14.004	15.587	31.373	32.095	29.740
AN	5.855	8.719	3.022	2.842	3.393	2.981	1.672	1.041	0.561
WO							0.070	0.490	0.085
EN	1.128	1.552	0.276	0.354	0.303	0.353	0.327	0.376	0.275
FS	1.029	0.675	1.288	1.415	1.644	1.488	1.438	1.567	1.197
MT	0.910	0.607	0.810	0.850	0.972	0.924	0.996	1.070	0.854
IL	0.669	0.439	0.153	0.174	0.193	0.192	0.326	0.344	0.324
AP	0.358	0.238	0.048	0.048	0.048	0.048	0.024	0.048	0.048
Total	99.706	99.050	99.254	98.874	98.733	98.989	99.728	99.559	99.750
D.I.	89.478	85.983	93.081	92.138	90.373	91.430	94.800	94.518	96.346
M	1.500	1.430	1.340	1.230	1.160	1.140	1.400	1.450	1.390

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184431	184432	184154	184154A	184155	184156	184382	184383	184004
SiO2	71.71	74.51	76.64	76.17	73.76	71.32	72.04	69.84	75.51
Al2O3	13.66	12.08	12.42	12.78	13.80	14.28	14.00	14.34	11.29
Fe2O3	0.68	0.61	0.35	0.29	0.47	0.77	0.61	1.22	1.09
FeO	1.23	1.09	0.62	0.52	0.85	1.38	1.10	2.19	1.96
MgO	0.44	0.14	0.10	0.10	0.29	0.64	0.47	0.70	0.05
CaO	1.21	0.49	0.55	0.55	1.50	1.98	1.83	2.12	0.01
Na2O	3.46	3.62	3.46	3.56	3.60	3.46	3.55	4.56	4.66
K2O	5.00	5.04	4.51	4.61	4.15	4.13	4.07	3.11	4.20
LOI	0.46	0.26	0.39	0.39	0.26	0.66	0.70	0.49	0.13
TiO2	0.25	0.15	0.05	0.03	0.14	0.30	0.19	0.47	0.08
P2O5	0.08	0.02	0.16	0.14	0.02	0.10	0.07	0.11	0.02
MnO	0.02	0.01	0.01	0.01	0.02	0.03	0.05	0.06	0.01
ZrO2	0.03	0.06	0.01	0.01	0.01	0.02	0.02	0.06	0.01
Total	98.23	98.08	99.27	99.16	98.88	99.07	98.71	99.27	99.01
CIPW Normative Minerals									
Q	29.330	33.092	38.291	36.879	33.272	30.081	31.193	25.294	32.479
C	0.558		1.239	1.280	0.715	0.764	0.603		
Z	0.045	0.091	0.015	0.015	0.015	0.030	0.030	0.090	0.015
OR	30.078	30.366	26.847	27.472	24.802	24.635	24.366	18.514	25.067
AB	29.804	31.232	29.493	30.378	30.809	29.553	30.433	38.871	35.035
AN	5.579	1.863	1.696	1.829	7.394	9.256	8.734	9.544	
AC									3.175
NS									0.276
WO		0.201						0.136	
EN	1.116	0.356	0.251	0.251	0.730	1.609	1.186	1.756	0.126
FS	1.342	1.299	0.801	0.694	0.990	1.474	1.316	2.368	3.512
MT	1.009	0.897	0.506	0.424	0.694	1.122	0.901	1.777	
IL	0.483	0.290	0.096	0.057	0.269	0.575	0.366	0.899	0.153
AP	0.193	0.048	0.382	0.334	0.048	0.239	0.168	0.262	0.018
Total	99.536	99.736	99.616	99.614	99.738	99.339	99.295	99.513	99.857
D.I.	89.212	94.690	94.631	94.729	88.883	84.269	85.991	82.679	92.581
M	1.420	1.430	1.280	1.280	1.360	1.420	1.410	1.550	1.520

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184171	184180	184184	184381	184415	184416	184384	184014	184015
SiO2	76.81	71.11	77.14	74.95	74.19	74.24	71.79	58.56	58.51
Al2O3	7.32	14.47	9.15	11.68	13.48	13.34	14.82	16.38	16.17
Fe2O3	2.24	0.70	1.50	0.82	0.48	0.46	0.62	1.89	2.19
FeO	4.03	1.27	2.69	1.48	0.87	0.83	1.11	3.41	3.94
MgO	0.05	0.64	0.12	0.05	0.18	0.16	0.60	2.65	3.15
CaO	0.12	1.90	0.09	0.31	0.48	0.67	2.04	4.13	4.58
Na2O	4.33	3.79	4.20	3.92	3.56	3.50	3.52	4.69	4.62
K2O	2.88	3.95	3.78	4.71	5.01	4.77	3.95	3.97	3.31
LOI	0.10	0.67	0.14	0.79	0.27	0.62	0.88	0.51	0.34
TiO2	0.15	0.28	0.12	0.19	0.10	0.09	0.16	1.17	1.33
P2O5	0.02	0.08	0.02	0.02	0.07	0.06	0.10	0.40	0.46
MnO	0.04	0.02	0.06	0.03	0.05	0.05	0.05	0.07	0.10
ZrO2	0.28	0.02	0.07	0.07	0.01	0.01	0.01	0.05	0.04
Total	98.36	98.90	99.08	99.03	98.75	98.80	99.65	97.88	98.74
CIPW Normative Minerals									
Q	43.802	28.857	39.881	33.144	33.106	34.033	30.701	4.456	5.572
C		0.705			1.515	1.361	1.289		
Z	0.423	0.030	0.105	0.105	0.015	0.015	0.015	0.076	0.060
OR	17.302	23.601	22.544	28.107	29.979	28.530	23.424	23.968	19.809
AB	21.978	32.427	26.262	33.497	30.504	29.976	29.891	40.545	39.592
AN		9.002		0.367	1.948	2.968	9.501	12.175	13.781
AC	6.579		4.370						
NS	1.816		1.082						
WO	0.197		0.133	0.440				2.542	2.583
EN	0.127	1.612	0.302	0.126	0.454	0.403	1.500	6.743	7.945
FS	7.338	1.333	4.904	1.800	1.140	1.098	1.362	2.953	3.461
MT		1.031		1.206	0.710	0.675	0.897	2.805	3.216
IL	0.290	0.538	0.230	0.364	0.192	0.173	0.305	2.270	2.558
AP	0.048	0.192	0.048	0.048	0.168	0.144	0.238	0.968	1.103
Total	99.900	99.327	99.860	99.204	99.731	99.376	99.123	99.501	99.681
D.I.	83.081	84.885	88.687	94.747	93.589	92.539	84.017	68.969	64.973
K	1.920	1.420	1.650	1.450	1.280	1.280	1.360	2.110	2.150

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184018	184374	184375	184019	184021	184023	184089	184414	184386
SiO_2	64.01	45.13	62.09	71.37	71.75	71.86	76.97	73.52	76.42
Al_2O_3	16.05	19.36	15.83	12.56	13.10	12.67	11.84	13.29	12.52
Fe_2O_3	1.28	3.77	1.71	1.22	0.99	1.08	0.40	0.56	0.22
FeO	2.30	6.78	3.07	2.19	1.78	1.94	0.71	1.01	0.39
MgO	1.56	4.98	1.99	0.41	0.31	0.32	0.05	0.16	0.14
CaO	2.81	11.10	3.27	0.51	0.54	0.40	0.56	0.81	0.49
Na_2O	4.61	2.98	4.60	4.75	4.60	4.72	3.43	3.63	4.02
K_2O	4.09	0.65	3.96	4.74	4.89	4.80	4.71	5.16	4.51
LOI	0.52	1.76	0.37	0.30	0.63	0.15	0.39	0.51	0.69
TiO_2	0.74	1.77	0.94	0.46	0.36	0.39	0.07	0.14	0.10
P_2O_5	0.23	0.41	0.33	0.08	0.05	0.05	0.02	0.02	0.02
MnO	0.07	0.11	0.06	0.11	0.07	0.08	0.01	0.01	0.04
ZrO_2	0.04	0.01	0.06	0.03	0.02	0.04	0.02	0.03	0.01
Total	98.30	98.81	98.28	98.73	99.08	98.49	99.18	98.86	99.57
CIPW Normative Minerals									
Q	13.416		10.717	23.953	24.481	24.735	37.671	30.536	34.517
C							0.130	0.312	0.183
Z	0.061	0.015	0.091	0.045	0.030	0.060	0.030	0.045	0.015
OR	24.586	3.887	23.811	28.371	29.164	28.798	28.063	30.844	26.767
AB	39.681	23.449	39.606	38.708	39.284	39.035	29.264	31.071	34.164
AN	11.212	37.983	11.040		0.661		2.669	3.933	2.310
NE		1.122							
AC				1.765		1.335			
WO	0.602	6.279	1.367	0.849	0.715	0.703			
EN	3.952	3.860	5.043	1.034	0.779	0.809	0.126	0.403	0.350
FS	2.108	2.059	2.838	2.996	1.999	2.588	0.893	1.197	0.448
FO		6.092							
FA		3.582							
MT	1.883	5.527	2.518	0.902	1.444	0.916	0.580	0.826	0.316
IL	1.430	3.402	1.817	0.885	0.690	0.752	0.134	0.269	0.191
AP	0.554	0.983	0.795	0.192	0.120	0.120	0.048	0.048	0.048
Total	99.484	98.242	99.642	99.702	99.368	99.851	99.608	99.485	99.309
D.I.	77.683	28.459	74.133	91.033	92.930	92.568	94.998	92.452	95.448
M	1.750	2.970	1.890	1.630	1.560	1.590	1.360	1.400	1.370

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184387	184031	184036	184038	184377	184378	184040	184379	184380
SiO2	65.91	75.99	74.86	73.84	72.38	73.41	75.38	76.75	75.79
Al2O3	14.80	11.79	11.99	12.09	12.98	12.54	12.20	11.54	12.15
Fe2O3	1.55	0.87	0.98	0.93	1.00	0.89	0.52	0.44	0.44
FeO	2.80	1.57	1.76	1.68	1.81	1.60	0.94	0.79	0.79
MgO	1.71	0.12	0.25	0.21	0.14	0.23	0.23	0.05	0.05
CaO	3.88	0.29	0.74	0.61	0.35	0.72	0.46	0.40	0.48
Na2O	2.98	3.88	3.87	3.98	4.66	4.09	3.67	3.45	3.97
K2O	3.56	4.74	4.51	4.70	4.67	4.77	4.60	4.58	4.44
LOI	1.34	0.11	0.30	0.30	0.22	0.26	0.74	0.36	0.39
TiO2	0.49	0.22	0.30	0.26	0.35	0.15	0.10	0.08	0.04
P2O5	0.15	0.02	0.05	0.02	0.02	0.02	0.05	0.02	0.02
MnO	0.08	0.04	0.04	0.04	0.10	0.04	0.01	0.01	0.01
ZrO2	0.03	0.04	0.09	0.04	0.03	0.04	0.02	0.03	0.03
Total	99.28	99.68	99.73	98.70	98.71	98.75	98.92	98.49	98.59
CIPW Normative Minerals									
Q	23.599	33.897	32.690	30.987	26.062	29.322	35.092	38.403	34.669
C							0.472	0.231	
Z	0.045	0.060	0.134	0.060	0.045	0.060	0.030	0.045	0.045
OR	21.190	28.101	26.722	28.139	27.957	28.543	27.481	27.479	26.612
AB	25.399	32.938	32.834	34.120	39.947	35.046	31.395	29.640	34.073
AN	16.613	0.757	2.030	1.259	0.717	1.793	1.977	1.882	2.251
WO	0.747	0.232	0.552	0.699	0.380	0.707			0.013
EN	4.290	0.300	0.624	0.530	0.353	0.580	0.579	0.126	0.126
FS	3.213	1.873	2.005	1.984	2.122	2.050	1.155	0.984	1.050
MT	2.269	1.266	1.420	1.371	1.474	1.302	0.762	0.643	0.642
IL	0.937	0.419	0.571	0.500	0.673	0.288	0.192	0.154	0.077
AP	0.351	0.048	0.119	0.048	0.048	0.048	0.120	0.048	0.048
Total	98.659	99.891	99.702	99.698	99.779	99.738	99.255	99.636	99.606
D.I.	70.188	94.937	92.246	93.246	93.967	92.911	93.968	95.522	95.353
M	1.670	1.420	1.480	1.500	1.500	1.510	1.350	1.340	1.390

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184009	184056	184396	184087	184088	184269	184069	184070	184177
SiO2	75.15	75.66	68.74	75.40	75.32	74.90	71.87	70.73	71.25
Al2O3	10.98	10.76	14.15	12.98	12.80	12.97	13.72	12.96	13.16
Fe2O3	1.21	1.21	1.38	0.51	0.46	0.56	1.25	1.41	1.41
FeO	2.18	2.17	2.48	0.92	0.83	1.01	2.24	2.54	2.54
MgO	0.05	0.05	1.40	0.13	0.16	0.14	0.33	0.31	0.31
CaO	0.11	0.13	4.59	0.80	0.80	0.85	1.15	1.38	1.32
Na2O	4.65	4.87	3.40	3.45	3.44	3.40	4.03	3.91	3.95
K2O	3.82	3.78	1.16	4.79	4.75	4.94	5.13	4.66	4.82
LOI	0.61	0.20	0.75	0.29	0.50	0.42	0.20	0.33	0.20
TiO2	0.09	0.08	0.47	0.13	0.10	0.13	0.38	0.43	0.45
P2O5	0.02	0.02	0.10	0.02	0.02	0.02	0.07	0.07	0.08
MnO	0.03	0.03	0.07	0.02	0.02	0.03	0.06	0.07	0.07
ZrO2	0.13	0.10	0.01	0.02	0.02	0.02		0.07	0.07
Total	99.04	99.06	98.70	99.46	99.22	99.39	100.43	98.88	99.63
CIPW Normative Minerals									
Q	32.788	33.764	32.511	34.834	35.040	33.883	24.986	26.368	25.964
C				0.717	0.598	0.536			
Z	0.195	0.150	0.015	0.030	0.030	0.030		0.105	0.105
CR	22.793	22.549	6.945	28.460	28.290	29.372	30.185	27.850	28.589
AB	35.553	34.627	29.148	29.352	29.338	28.947	33.955	33.461	33.549
AN			20.184	3.859	3.868	4.111	4.178	4.095	3.957
AC	3.544	3.524							
NS	0.036	0.692							
WO	0.175	0.217	0.929				0.437	0.988	0.873
EN	0.126	0.126	3.533	0.326	0.402	0.351	0.818	0.781	0.775
FS	3.955	3.948	2.811	1.092	1.020	1.237	2.563	2.956	2.893
MT			2.027	0.743	0.672	0.817	1.800	2.072	2.052
IL	0.173	0.153	0.904	0.248	0.191	0.248	0.719	0.826	0.858
AP	0.048	0.048	0.240	0.048	0.048	0.048	0.165	0.168	0.190
Total	99.385	99.800	99.246	99.710	99.497	99.579	99.805	99.671	99.804
D.I.	91.134	90.941	68.604	92.646	92.668	92.201	89.125	87.679	88.102
K	1.530	1.600	1.610	1.330	1.340	1.360	1.550	1.600	1.590

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184388	184389	184390	184329	184334	184337	184338	184433	184434
SiO2	73.89	73.38	73.54	77.42	76.46	76.14	75.86	76.74	75.27
Al2O3	13.17	13.45	13.81	12.24	12.15	13.35	13.01	12.62	13.00
Fe2O3	0.52	0.53	0.51	0.35	0.43	0.38	0.34	0.27	0.40
FeO	0.94	0.95	0.92	0.63	0.77	0.69	0.62	0.49	0.73
MgO	0.31	0.36	0.38	0.12	0.15	0.05	0.05	0.13	0.22
CaO	1.23	1.31	1.52	0.51	0.62	0.22	0.26	0.48	0.72
Na2O	3.18	3.43	3.70	2.93	3.03	3.74	3.61	3.31	3.21
K2O	4.86	4.61	4.27	5.15	4.68	4.18	4.39	5.09	5.02
LOI	0.76	0.62	0.86	0.40	0.66	0.59	0.49	0.47	0.47
TiO2	0.20	0.20	0.20	0.10	0.11	0.04	0.05	0.07	0.15
P2O5	0.C2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.06
MnO	0.02	0.02	0.02	0.01	0.01	0.05	0.02	0.01	0.02
ZrO2	0.02	0.02	0.02	0.01	0.01			0.01	0.01
Total	99.13	98.90	99.77	99.89	99.10	99.45	98.72	99.71	99.28
CIPW Normative Minerals									
Q	33.580	32.380	31.532	39.163	39.367	37.661	37.601	36.684	35.578
C	0.494	0.489	0.387	0.967	1.030	2.334	1.919	0.843	1.129
Z	0.030	0.030	0.030	0.015	0.015			0.015	0.015
CR	28.973	27.544	25.291	30.466	27.905	24.837	26.278	30.167	29.880
AB	27.146	29.345	31.381	24.820	25.871	31.821	30.943	28.091	27.359
AN	6.024	6.439	7.427	2.402	2.972	0.966	1.174	2.257	3.203
EN	0.779	0.907	0.949	0.299	0.377	0.125	0.126	0.325	0.552
FS	1.013	1.032	0.973	0.722	0.911	0.982	0.816	0.574	0.795
MT	0.765	0.777	0.741	0.508	0.629	0.559	0.504	0.393	0.589
IL	0.383	0.384	0.381	0.190	0.211	0.076	0.096	0.133	0.287
AP	0.048	0.048	0.047	0.047	0.048	0.048	0.048	0.048	0.143
Total	99.235	99.374	99.139	99.601	99.335	99.408	99.505	99.530	99.530
D.I.	89.698	89.269	88.204	94.450	93.143	94.318	94.821	94.942	92.817
M	1.370	1.380	1.400	1.260	1.260	1.150	1.190	1.290	1.290

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184435	184419	184077	184079	184080	184129	184130	184420	184421
SiO2	75.92	75.51	75.76	75.76	74.38	73.10	72.41	75.41	72.40
Al2O3	13.17	12.75	13.03	13.05	12.92	13.75	13.90	13.50	14.08
Fe2O3	0.28	0.40	0.28	0.35	0.63	0.57	0.70	0.18	0.59
FeO	0.51	0.73	0.50	0.62	1.14	1.03	1.26	0.32	1.06
MgO	0.10	0.12	0.05	0.05	0.26	0.30	0.37	0.05	0.34
CaO	0.31	0.76	0.40	0.38	0.99	1.05	1.26	0.31	1.30
Na2O	3.72	3.49	4.08	4.03	3.57	3.47	3.55	4.57	3.72
K2O	4.29	4.72	4.21	4.23	4.37	5.15	4.86	4.11	4.79
LOI	0.70	0.44	0.54	0.59	0.41	0.55	0.46	0.44	0.47
TiO2	0.02	0.07	0.05	0.04	0.19	0.22	0.21	0.01	0.20
P2O5	0.02	0.02	0.02	0.02	0.06	0.02	0.08	0.02	0.06
MnO	0.03	0.01	0.02	0.03	0.03	0.03	0.03	0.01	0.03
ZrO2	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.02
Total	99.08	99.03	98.94	99.16	98.97	99.26	99.11	98.94	99.05
CIPW Normative Minerals									
Q	37.113	35.323	35.116	35.203	34.296	30.279	29.734	32.552	29.036
C	1.909	0.572	1.093	1.209	0.668	0.611	0.707	1.029	0.561
Z	0.015	0.015	0.015	0.015	0.030	0.030	0.030	0.015	0.030
OR	25.585	28.165	25.143	25.208	26.091	30.661	28.977	24.546	28.576
AB	31.769	29.821	34.892	34.389	30.522	29.582	30.309	39.083	31.779
AN	1.420	3.675	1.874	1.769	4.566	5.116	5.780	1.422	6.115
EN	0.251	0.302	0.126	0.126	0.654	0.753	0.930	0.126	0.855
FS	0.732	0.911	0.647	0.856	1.325	1.114	1.457	0.453	1.191
MT	0.415	0.591	0.405	0.507	0.928	0.833	1.024	0.264	0.859
IL	0.038	0.134	0.096	0.077	0.365	0.421	0.402	0.019	0.383
AP	0.048	0.048	0.048	0.048	0.144	0.048	0.191	0.048	0.143
Total	99.295	99.557	99.456	99.406	99.589	99.447	99.540	99.556	99.529
D.I.	94.467	93.309	95.151	94.800	90.910	90.522	89.020	96.181	89.391
M	1.190	1.340	1.280	1.270	1.350	1.380	1.400	1.310	1.410

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184422	184117	184359	184373	184423	184424	184425	184376	184439
SiO2	67.41	73.65	74.49	74.83	72.89	72.47	72.76	67.45	76.26
Al2O3	15.43	13.31	13.03	12.73	13.63	13.91	15.42	14.19	12.65
Fe2O3	0.61	0.56	0.58	0.65	0.53	0.55	0.16	1.50	0.20
FeO	1.09	1.01	1.04	1.17	0.95	1.00	0.29	2.71	0.36
MgO	0.79	0.14	0.17	0.17	0.13	0.15	0.10	0.76	0.11
CaO	2.32	0.93	0.94	0.80	1.02	1.02	0.54	2.22	0.43
Na2O	4.67	3.27	3.50	3.40	3.58	3.54	4.49	3.45	3.86
K2O	3.25	5.28	4.59	4.41	4.90	5.07	3.51	4.61	4.71
LOI	2.90	0.96	0.69	1.16	0.86	1.07	0.87	0.46	0.26
TiO2	0.31	0.13	0.13	0.13	0.10	0.11	0.01	0.64	0.09
P2O5	0.12	0.02	0.02	0.02	0.02	0.02	0.02	0.24	0.02
MnO	0.01	0.04	0.03	0.03	0.04	0.03	0.25	0.08	0.01
ZrO2	0.02	0.02	0.02	0.02	0.02	0.02		0.06	0.01
Total	98.93	99.32	99.22	99.52	98.67	98.96	98.43	98.37	98.97
CIPW Normative Minerals									
Q	21.762	31.916	34.031	35.766	30.834	29.858	32.077	23.600	34.943
C	0.302	0.577	0.648	0.961	0.639	0.801	3.353	0.064	0.473
Z	0.030	0.030	0.030	0.030	0.030	0.030		0.091	0.015
OR	19.413	31.415	27.336	26.186	29.345	30.275	21.073	27.693	28.122
AB	39.944	27.860	29.848	28.909	30.700	30.270	38.600	29.677	33.002
AN	10.842	4.514	4.568	3.857	4.996	4.981	2.589	9.602	2.023
EN	1.989	0.351	0.427	0.425	0.328	0.378	0.253	1.924	0.277
FS	1.021	1.256	1.280	1.459	1.239	1.259	0.867	2.865	0.369
MT	0.889	0.818	0.843	0.947	0.779	0.811	0.241	2.216	0.293
IL	0.595	0.249	0.249	0.248	0.192	0.211	0.019	1.236	0.173
AP	0.287	0.048	0.048	0.048	0.048	0.048	0.048	0.578	0.048
Total	97.075	99.035	99.306	98.836	99.130	98.920	99.120	99.546	99.738
D.I.	81.119	91.193	91.214	90.861	90.878	90.402	91.750	80.971	96.067
M	1.540	1.370	1.350	1.300	1.370	1.370	1.140	1.590	1.340

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	18444G	184440A	184441	184061	184063	184064	184065	184301	184302
SiO2	76.28	75.50	74.19	71.65	66.19	72.93	66.31	77.74	76.32
Al2O3	12.55	12.54	12.46	13.85	16.14	13.53	14.82	11.79	12.01
Fe2O3	0.24	0.34	0.64	0.82	0.97	0.48	1.67	0.36	0.53
FeO	0.43	0.61	1.15	1.47	1.75	0.87	3.01	0.65	0.95
MgO	0.05	0.05	0.35	0.29	0.46	0.25	0.40	0.20	0.12
CaO	0.37	0.35	0.82	0.63	1.02	0.61	1.10	0.51	0.39
Na2O	3.88	3.70	3.41	3.46	4.25	3.90	4.42	3.05	3.54
K2O	4.75	4.81	5.03	6.47	6.81	5.35	5.57	4.93	4.95
LOI	0.35	1.00	0.21	0.26	0.45	0.31	0.35	0.23	0.25
TiO2	0.35	0.09	0.35	0.35	0.65	0.26	0.61	0.21	0.19
P2O5	0.02	0.02	0.06	0.02	0.11	0.06	0.12	0.02	0.02
MnO	0.05	0.04	0.04	0.05	0.11	0.03	0.13	0.01	0.02
ZrO2	0.01	0.01	0.03	0.06	0.09	0.03	0.11	0.01	0.03
Total	99.33	99.05	98.73	99.38	99.00	98.61	98.62	99.71	99.32
CIPW Normative Minerals									
Q	34.901	34.781	32.910	24.461	12.227	28.263	15.407	39.652	35.581
C	0.404	0.665	0.060	0.058	0.188	0.363		0.559	0.169
Z	0.015	0.015	0.045	0.090	0.135	0.045	0.166	0.015	0.045
OR	28.258	28.695	30.105	38.473	40.650	32.059	33.377	29.218	29.450
AB	33.052	31.608	29.225	29.461	36.327	33.465	37.926	25.884	30.158
AN	1.716	1.621	3.723	3.014	4.386	2.671	4.206	2.406	1.816
WO							0.223		
EN	0.125	0.126	0.883	0.727	1.157	0.631	1.010	0.500	0.301
FS	0.111	0.767	1.088	1.549	1.551	0.836	3.421	0.566	1.044
MT	0.350	0.493	0.935	1.192	1.421	0.711	2.455	0.523	0.774
IL	0.669	0.173	0.673	0.669	1.247	0.501	1.175	0.400	0.363
AP	0.048	0.048	0.144	0.048	0.263	0.144	0.288	0.048	0.048
Total	99.649	98.992	99.791	99.740	99.553	99.689	99.653	99.770	99.750
D.I.	96.211	95.085	92.240	92.395	89.204	93.787	86.709	94.754	95.190
M	1.350	1.320	1.420	1.480	1.610	1.420	1.640	1.300	1.370

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184402	184403	184404	184405	184406	181859	181871	181872	181964
SiO2	69.47	74.22	76.51	72.15	75.53	76.13	76.07	74.88	76.03
Al2O3	14.37	13.22	12.72	14.22	12.47	12.90	12.70	14.07	12.28
Fe2O3	0.92	0.39	0.19	0.52	0.40	0.28	0.25	0.16	0.39
FeO	1.66	0.70	0.34	0.93	0.72	0.50	0.44	0.28	0.71
MgO	0.33	0.27	0.10	0.32	0.22	0.10	0.10	0.10	0.12
CaO	0.77	0.73	0.39	0.17	0.71	0.26	0.22	0.13	0.54
Na2O	3.43	3.43	3.70	4.21	3.57	4.03	3.96	5.12	3.36
K2O	6.65	5.36	4.88	4.66	4.19	4.32	4.26	3.45	4.82
LOI	0.71	0.11	0.20	0.27	0.78	0.51	0.67	0.47	0.61
TiO2	0.46	0.22	0.04	0.21	0.15	0.02	0.02	0.02	0.08
P2O5	0.06	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
MnO	0.07	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01
ZrO2	0.09	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.02
Total	98.99	98.71	99.11	97.73	98.80	99.08	98.73	98.72	98.99
CIPW Normative Minerals									
Q	21.520	31.957	35.501	29.252	37.016	35.522	36.354	31.757	36.729
C	0.276	0.503	0.696	2.035	0.829	1.180	1.238	1.747	0.608
Z	0.135	0.030	0.030	0.046	0.030	0.015	0.015	0.015	0.030
CR	39.699	32.087	29.095	28.178	25.061	25.764	25.497	20.652	28.773
AB	29.321	29.402	31.589	36.453	30.575	34.416	33.939	43.886	28.721
AN	3.463	3.536	1.820	0.729	3.433	1.170	0.973	0.521	2.574
EN	0.830	0.681	0.251	0.816	0.555	0.251	0.252	0.252	0.302
FS	1.668	0.649	0.419	0.994	0.790	0.677	0.605	0.379	0.870
MT	1.348	0.573	0.273	0.767	0.587	0.405	0.362	0.230	0.576
IL	0.883	0.423	0.077	0.408	0.288	0.038	0.038	0.038	0.153
AP	0.144	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
Total	99.287	99.890	99.799	99.725	99.212	99.486	99.323	99.525	99.385
D.I.	90.540	93.446	96.185	93.882	92.652	95.701	95.791	96.295	94.223
M	1.500	1.370	1.310	1.250	1.300	1.270	1.250	1.250	1.320

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184392	184393	184394	184391	184417	184418	184407	184408	184444
SiO2	74.82	73.12	74.25	76.20	68.44	75.74	72.03	75.62	75.22
Al2O3	12.35	12.81	12.70	11.84	14.56	12.12	14.40	12.99	12.87
Fe2O3	0.59	0.67	0.57	0.54	1.29	0.54	0.52	0.03	0.30
FeO	1.06	1.20	1.03	0.98	2.33	0.97	0.94	0.06	0.53
MgO	0.11	0.20	0.22	0.05	0.86	0.11	0.48	0.05	0.20
CaO	0.31	0.85	0.65	0.33	2.10	0.76	1.21	0.61	0.71
Na2O	4.36	3.49	3.64	3.73	3.47	2.87	4.09	3.82	3.41
K2O	4.40	4.99	4.84	4.80	4.45	5.18	4.45	5.12	5.08
LOI	0.45	1.16	0.85	0.46	0.77	0.44	0.84	0.60	0.79
TiO2	0.10	0.20	0.18	0.12	0.45	0.10	0.14	0.01	0.14
P2O5	0.02	0.02	0.02	0.02	1.17	0.02	0.02	0.02	0.02
MnO	0.01	0.01	0.01	0.01	0.05	0.01	0.03	0.01	0.02
ZrO2	0.05	0.04	0.04	0.03	0.04	0.02	0.02	0.01	0.01
Total	98.62	98.76	99.01	99.11	99.98	98.87	99.18	98.95	99.30
CIPW Normative Minerals									
Q	31.726	31.421	32.676	35.202	27.568	37.359	27.666	32.781	34.169
C		0.172	0.343		3.019	0.463	0.709	0.104	0.523
Z	0.075	0.060	0.060	0.045	0.060	0.030	0.030	0.015	0.015
OR	26.364	29.859	28.888	28.619	26.301	30.959	26.515	30.575	30.231
AB	37.408	29.903	31.110	31.845	29.368	24.562	34.896	32.666	29.058
AN	1.148	4.138	3.125	1.400	2.775	3.681	5.921	2.926	3.416
WO	0.116			0.050					
EN	0.278	0.504	0.553	0.126	2.142	0.277	1.205	0.126	0.502
FS	1.326	1.358	1.154	1.178	2.556	1.197	1.131	0.086	0.545
MT	0.862	0.979	0.840	0.795	1.876	0.787	0.765	0.049	0.433
IL	0.193	0.385	0.345	0.230	0.855	0.192	0.268	0.019	0.268
AP	0.048	0.048	0.048	0.048	2.772	0.048	0.048	0.048	0.048
Total	99.545	98.827	99.143	99.537	99.291	99.556	99.154	99.395	99.206
D.I.	95.498	91.183	92.675	95.666	83.237	92.880	89.077	96.022	93.457
M	1.420	1.410	1.380	1.390	1.500	1.330	1.400	1.390	1.350

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184445	184397	184398	184399	184058	184059	184395	184339	184342
SiO2	72.58	75.31	75.60	75.71	76.02	71.76	71.04	72.98	74.11
Al2O3	13.66	12.62	12.52	12.35	11.29	13.56	12.93	14.06	14.29
Fe2O3	0.36	0.38	0.40	0.40	0.74	0.91	1.10	0.51	0.14
FeO	0.65	0.69	0.71	0.72	1.34	1.63	1.97	0.91	0.25
MgO	0.20	0.25	0.24	0.22	0.05	0.19	0.23	0.36	0.15
CaO	1.40	0.84	0.97	0.80	0.26	0.63	0.99	1.00	1.04
Na2O	3.35	3.51	3.36	3.35	3.78	4.22	4.40	3.21	3.24
K2O	4.93	4.48	4.45	4.66	4.60	4.91	4.63	5.15	5.76
LOI	1.78	0.59	0.56	0.54	0.25	0.36	0.77	0.49	0.49
TiO2	0.15	0.18	0.18	0.18	0.15	0.24	0.29	0.21	0.06
P2O5	0.02	0.02	0.02	0.02	0.02	0.08	0.05	0.10	0.02
MnO	0.01	0.01	0.02	0.01	0.03	0.05	0.07	0.03	0.01
ZrO2	0.02	0.02	0.02	0.02	0.04	0.05	0.06	0.02	0.01
Total	99.12	98.90	99.05	98.98	98.57	98.59	98.53	99.03	99.57
CIPW Normative Minerals									
Q	30.944	35.709	36.655	36.442	35.790	26.480	25.257	32.065	30.831
C	0.318	0.523	0.465	0.393		0.354		1.642	0.886
Z	0.030	0.030	0.030	0.030	0.060	0.075	0.091	0.030	0.015
OR	29.392	26.767	26.548	27.821	27.577	29.430	27.768	30.731	34.184
AB	28.599	30.030	28.704	28.639	32.449	36.220	37.787	27.429	27.534
AN	6.875	4.081	4.726	3.878	0.257	2.640	1.884	4.350	5.050
WO					0.384		1.156		
EN	0.503	0.630	0.603	0.554	0.126	0.480	0.581	0.905	0.375
FS	0.677	0.679	0.730	0.720	1.674	1.972	2.405	0.974	0.268
MT	0.531	0.562	0.581	0.586	1.093	1.333	1.614	0.742	0.204
IL	0.287	0.346	0.345	0.345	0.289	0.462	0.559	0.403	0.114
AP	0.048	0.048	0.048	0.048	0.048	0.192	0.120	0.239	0.048
Total	98.205	99.405	99.436	99.456	99.748	99.640	99.222	99.511	99.509
D.I.	88.935	92.506	91.908	92.902	95.816	92.130	90.812	90.225	92.549
M	1.410	1.340	1.340	1.350	1.420	1.450	1.600	1.300	1.350

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184344	184149	184426	184242	184368	184427	184446	184447	184152
SiO2	73.41	75.21	72.23	74.09	64.65	73.86	73.71	72.18	70.81
Al2O3	14.15	12.51	14.18	13.58	17.54	13.30	13.57	14.19	13.89
Fe2O3	0.34	0.59	0.54	0.53	0.83	0.51	0.45	0.44	0.89
FeO	0.61	1.07	0.97	0.96	1.49	0.92	0.80	0.79	1.61
MgO	0.25	0.21	0.37	0.20	0.44	0.35	0.36	0.31	0.73
CaO	1.48	0.80	1.19	0.82	0.86	1.11	1.06	1.09	1.29
Na2O	3.41	3.21	3.42	3.60	4.91	3.34	3.84	4.01	3.60
K2O	4.90	4.91	5.29	5.12	7.12	4.89	4.59	4.97	4.77
LOI	0.52	0.29	0.44	0.29	0.26	0.41	0.56	0.66	0.36
TiO2	0.10	0.18	0.21	0.15	0.46	0.22	0.21	0.21	0.60
P2O5	0.02	0.02	0.06	0.02	0.09	0.06	0.05	0.06	0.12
MnO	0.01	0.01	0.01	0.03	0.05	0.02	0.05	0.04	0.05
ZrO2	0.01	0.02	0.02	0.02	0.08	0.02	0.02	0.02	0.03
Total	99.21	99.03	98.92	99.41	98.78	99.02	99.27	98.97	98.75
CIPW Normative Minerals									
Q	31.260	35.570	29.007	31.216	5.999	32.870	30.969	27.103	27.836
C	0.598	0.513	0.817	0.677	0.413	0.645	0.481	0.380	0.756
Z	0.015	0.030	0.030	0.030	0.120	0.030	0.030	0.030	0.045
OR	29.185	29.298	31.601	30.434	42.592	29.183	27.323	29.674	28.544
AB	29.084	27.428	29.254	30.642	42.059	28.543	32.732	34.284	30.847
AN	7.269	3.876	5.572	3.961	3.724	5.165	4.968	5.068	5.687
EN	0.628	0.528	0.932	0.501	1.109	0.880	0.903	0.780	1.841
FS	0.702	1.204	1.013	1.137	1.408	0.956	0.860	0.827	1.333
MT	0.497	0.869	0.787	0.778	1.218	0.752	0.652	0.645	1.312
IL	0.191	0.345	0.403	0.287	0.884	0.422	0.402	0.403	1.154
AP	0.048	0.048	0.144	0.048	0.216	0.144	0.119	0.144	0.288
Total	99.477	99.708	99.558	99.710	99.742	99.589	99.439	99.337	99.642
D.I.	89.529	92.296	89.862	92.292	90.649	90.596	91.024	91.062	87.227
M	1.380	1.340	1.390	1.360	1.640	1.370	1.400	1.440	1.430

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184428	184429	184430	184409	184410	184411	184436	184437	184438
SiO2	70.61	72.75	76.19	72.39	72.17	72.61	75.61	74.75	75.91
Al2O3	14.61	13.68	12.33	14.25	14.40	14.12	12.67	12.70	12.36
Fe2O3	0.62	0.50	0.30	0.42	0.42	0.40	0.34	0.43	0.40
FeO	1.12	0.91	0.55	0.76	0.76	0.73	0.61	0.78	0.72
MgO	0.49	0.39	0.22	0.37	0.38	0.38	0.05	0.12	0.10
CaO	1.25	0.97	0.64	1.25	1.15	0.96	0.52	0.66	0.53
Na2O	3.80	3.61	3.17	3.34	3.47	3.34	3.69	3.44	3.29
K2O	5.46	5.22	5.08	5.29	5.16	5.16	4.70	5.27	5.18
LOI	0.42	0.56	0.36	0.75	1.57	0.89	0.42	0.44	0.32
TiO2	0.37	0.30	0.18	0.18	0.19	0.16	0.05	0.10	0.08
P2O5	0.09	0.07	0.05	0.09	0.10	0.11	0.02	0.02	0.02
MnO	0.03	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01
ZrO2	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.02
Total	98.91	99.00	99.09	99.13	99.82	98.89	98.70	98.75	98.94
CIPW Normative Minerals									
Q	24.257	29.236	36.868	29.641	29.183	31.115	35.123	33.011	35.690
C	0.396	0.500	0.578	0.981	1.257	1.576	0.623	0.187	0.430
Z	0.045	0.030	0.015	0.030	0.030	0.030	0.030	0.045	0.030
OR	32.622	31.158	30.295	31.536	30.548	30.834	28.139	31.535	30.938
AE	32.511	30.856	27.070	28.512	29.417	28.580	31.634	29.476	28.137
AN	5.675	4.399	2.875	5.663	5.061	4.089	2.481	3.183	2.525
EN	1.234	0.981	0.553	0.930	0.948	0.957	0.126	0.303	0.252
FS	1.001	0.797	0.478	0.777	0.774	0.763	0.781	0.939	0.887
MT	0.914	0.737	0.444	0.619	0.615	0.591	0.495	0.636	0.586
IL	0.710	0.576	0.345	0.345	0.362	0.307	0.096	0.192	0.154
AP	0.216	0.167	0.120	0.215	0.237	0.263	0.048	0.048	0.048
Total	99.580	99.438	99.639	99.248	98.433	99.106	99.576	99.556	99.678
D.I.	89.389	91.250	94.233	89.688	89.148	90.529	94.896	94.022	94.766
K	1.480	1.410	1.330	1.380	1.350	1.310	1.330	1.390	1.340

Table 1.--Chemical and normative composition of granitic samples--Continued

Sample	184274A	184275	184413	184400	184442	184443
SiO2	74.67	75.25	74.46	72.13	63.99	72.14
Al2O3	13.30	12.89	13.58	14.33	18.15	14.70
Fe2O3	0.30	0.27	0.29	0.44	0.60	0.35
FeO	0.55	0.49	0.52	0.79	1.08	0.64
MgO	0.22	0.14	0.20	0.43	0.28	0.41
CaO	0.84	0.85	0.86	1.29	0.95	1.44
Na2O	3.56	3.59	3.67	3.52	4.84	3.96
K2O	4.89	5.02	5.09	5.02	7.70	4.63
LOI	0.34	0.43	0.77	1.36	1.20	1.06
TiO2	0.14	0.08	0.12	0.27	0.48	0.17
P2O5	0.02	0.02	0.02	0.08	0.02	0.05
MnO	0.02	0.01	0.02	0.01	0.02	0.01
ZrO2	0.01	0.01	0.01	0.0	0.07	0.02
Total	98.86	99.06	99.61	99.69	99.38	99.58
CIPW Normative Minerals						
Q	33.299	33.236	31.412	29.041	3.629	27.659
C	0.679	0.054	0.520	0.955	0.175	0.679
Z	0.015	0.015	0.015	0.045	0.105	0.030
CR	29.230	29.947	30.195	29.756	45.785	27.476
AB	30.471	30.667	31.176	29.877	41.210	33.650
AN	4.083	4.125	4.152	5.895	4.611	6.846
EN	0.554	0.352	0.500	1.074	0.702	1.025
FS	0.564	0.569	0.560	0.657	0.736	0.616
MT	0.445	0.400	0.422	0.635	0.875	0.514
IL	0.269	0.153	0.229	0.514	0.917	0.324
AP	0.048	0.048	0.048	0.190	0.048	0.119
Total	99.657	99.567	99.228	98.640	98.794	98.938
D.I.	93.000	93.851	92.783	88.674	90.624	88.785
M	1.340	1.400	1.370	1.380	1.670	1.410

Table 2.--Sample locality data, trace-element concentrations, and chemical ratios for granite samples from the east-central Arabian Shield.

[Leaders (- - -) indicates no data]

Sample	Latitude (north)	Longitude (east)	U (ppm)	RaeU (ppm)	Th (ppm)	eTh (wt %)	K (wt %)	eK (wt %)	FeO(t) (wt %)
				Al Bara batholith					
184385	23 28 52	-41 20 15	4.07	5.10	14.00	15.70	3.93	3.76	1.68
				Al Maslukah					
184412	24 28 26	-44 13 53	3.46	3.40	18.00	20.10	3.76	3.68	1.12
				Baid al Jimalah					
889494	25 8 55	-42 41 15	13.30	9.90	35.20	34.20	3.87	3.71	1.49
893039	25 8 55	-42 41 15	11.80	12.00	24.40	28.40	3.74	3.73	1.56
893159	25 8 55	-42 41 15	11.30	11.30	29.60	29.90	4.68	4.65	1.78
893235	25 8 55	-42 41 15	10.30	10.10	28.90	27.20	3.96	4.06	1.70
				Dukhnah					
184122	24 46 44	-43 18 42	4.77	---	14.00	---	3.99	---	1.84
184127	24 55 38	-43 9 50	6.55	---	20.30	---	3.92	---	1.98
184241	24 48 30	-43 9 7	1.53	---	7.80	---	4.41	---	1.58
184431	24 50 52	-43 9 43	7.05	6.51	13.20	14.70	4.15	3.95	1.84
184432	24 52 26	-43 12 56	4.46	5.19	10.30	11.80	4.18	4.28	1.64
				Gharnaq Pluton					
184154	23 36 54	-40 32 45	5.46	---	12.50	---	3.74	---	.94
184154A	23 36 54	-40 32 45	5.49	5.55	11.50	13.10	3.83	3.91	.78
184155	23 35 54	-40 33 39	4.49	---	9.53	---	3.45	---	1.28
184156	23 32 54	-40 33 58	3.54	---	11.50	---	3.43	---	2.07
184382	23 35 29	-40 33 19	4.80	3.84	11.60	11.40	3.38	3.35	1.66
				Jabal Ramram					
184383	23 27 33	-40 41 15	2.33	2.48	5.60	5.57	2.58	2.62	3.28
				Hadb ad Dayahin					
184004	23 32 34	-41 10 2	2.81	---	<2.70	---	3.49	---	2.93
184171	23 35 19	-41 11 18	13.70	---	28.50	---	2.39	---	6.04
184180	23 34 15	-41 13 37	5.50	---	4.10	---	3.28	---	1.90
184184	23 31 1	-41 13 43	5.18	---	<4.20	---	3.14	---	4.04
184381	23 30 32	-41 12 57	2.77	3.28	8.20	8.30	3.91	4.12	2.22
				Hadbat Tayma					
184415	24 8 28	-44 13 31	8.47	8.34	26.70	24.70	4.16	3.95	1.30
184416	24 7 27	-44 13 37	14.60	15.20	---	25.50	3.96	4.01	1.24
				Hudayb al Jidar					
184384	23 22 10	-41 10 34	5.52	5.30	12.20	12.00	3.28	3.25	1.66

Table 2.--Sample locality, concentrations, and chemical ratios--Continued

Sample	Rb (ppm)	Sr (ppm)	Y (ppm)	Nb (ppm)	Zr (ppm)	Th/U	K/U	Th/K	eU/U	K/Rb	Rb/Sr	Al/ Na+K	Al/ Na+K+Ca
					Al Bara batholith								
184385	122.0	346.0	15.0	13.0	165	3.86	.96	4.00	1.25	322.0	.35	1.20	.99
					Al Maslukah								
184412	130.0	415.0	4.0	1.0	129	5.81	1.09	5.34	.98	289.0	.31	1.36	1.04
					Baid al Jimalah								
889494	316.0	25.0	86.0	52.0	158	2.57	.29	8.84	.74	122.0	12.64	1.15	1.04
893039	363.0	16.0	64.0	29.0	142	2.41	.32	7.59	1.02	103.0	22.69	1.19	1.07
893159	251.0	28.0	59.0	34.0	149	2.65	.41	6.39	1.00	187.0	8.96	1.34	1.17
893235	291.0	18.0	63.0	29.0	140	2.64	.38	6.87	.98	136.0	16.17	1.32	1.16
					Dukhnah								
184122	159.0	29.1	59.4	40.3	389	2.94	.84	3.51	---	251.0	5.46	1.05	.99
184127	197.0	31.6	77.1	51.9	494	3.10	.60	5.18	---	199.0	6.23	1.03	.96
184241	115.0	10.8	34.0	26.0	286	5.10	2.88	1.77	---	383.0	10.65	1.02	.99
184431	173.0	138.0	34.0	19.0	248	2.09	.59	3.54	.92	240.0	1.25	1.23	1.03
184432	165.0	44.0	59.0	21.0	415	2.65	.94	2.82	1.16	254.0	3.75	1.06	.98
					Gharnaq Pluton								
184154	172.0	31.5	31.6	14.1	61	2.29	.69	3.34	---	218.0	5.46	1.17	1.07
184154A	172.0	32.0	36.0	7.0	71	2.39	.70	3.42	1.01	223.0	5.38	1.18	1.08
184155	137.0	214.0	23.7	15.3	102	2.12	.77	2.77	---	252.0	.64	1.33	1.05
184156	123.0	326.0	15.7	12.9	140	3.25	.97	3.35	---	279.0	.38	1.41	1.04
184382	159.0	183.0	30.0	10.0	142	2.38	.70	3.37	.80	213.0	.87	1.37	1.03
					Jabal Ramram								
184383	58.0	179.0	48.0	5.0	411	2.39	1.11	2.16	1.06	445.0	.32	1.32	.97
					Hadb ad Dayahin								
184004	412.0	3.6	31.5	13.3	90	---	1.24	---	---	84.6	114.44	.92	.92
184171	211.0	38.8	98.4	155.0	2,050	2.08	.17	11.92	---	113.0	5.44	.71	.70
184180	154.0	389.0	10.1	13.0	144	.75	.60	1.25	---	213.0	.40	1.38	1.04
184184	536.0	21.8	42.8	174.0	484	---	.61	---	---	58.5	24.59	.83	.82
184381	69.0	13.0	58.0	6.0	536	3.00	1.41	2.12	1.18	567.0	5.31	1.01	.96
					Hadbat Tayma								
184415	371.0	40.0	48.0	31.0	99	2.92	.49	5.94	.98	112.0	9.28	1.20	1.11
184416	358.0	39.0	55.0	34.0	104	1.75	.27	6.44	1.04	111.0	9.18	1.22	1.10
					Hudayb al Jidar								
184384	125.0	269.0	18.0	1.0	97	2.17	.59	3.66	.96	262.0	.46	1.47	1.08

Table 2.--Sample locality, concentrations, and chemical ratios--Continued

Sample	Rb (ppm)	Sr (ppm)	Y (ppm)	Nb (ppm)	Zr (ppm)	Th/U	K/U	Th/K	eU/U	K/Rb	Rb/Sr	Al/ Na+K	Al/ Na+K+Ca
Jabal Abha													
184014	111.0	864.0	13.3	14.9	356	3.02	.48	6.31	---	297.0	.13	1.36	.84
184015	105.0	1,010.0	16.2	12.6	330	2.61	.32	8.04	---	262.0	.10	1.45	.83
184018	121.0	612.0	16.6	17.9	319	3.27	.37	8.78	---	281.0	.20	1.34	.94
184374	1.0	1,633.0	17.0	1.0	66	2.69	1.00	2.69	1.20	5,400.0	.0	3.45	.75
184375	106.0	920.0	25.0	6.0	438	3.37	.43	7.91	1.01	310.0	.12	1.34	.89
Jabal Ajir													
184019	115.0	47.3	34.7	19.2	223	3.40	1.40	2.44	---	342.0	2.43	.97	.91
184021	102.0	43.5	27.4	17.9	176	2.97	1.57	1.90	---	398.0	2.34	1.02	.95
184023	107.0	35.3	28.8	18.5	321	2.49	1.09	2.28	---	372.0	3.03	.98	.93
Jabal Dhuray													
184089	201.0	22.0	58.0	19.0	139	2.97	.64	4.63	---	195.0	9.14	1.10	1.01
184414	196.0	54.0	41.0	18.0	202	2.65	.51	5.18	.81	219.0	3.63	1.15	1.02
Jabal Dumah													
184386	258.0	46.0	10.0	10.0	91	2.28	.24	9.62	1.03	145.0	5.61	1.09	1.01
184387	104.0	323.0	27.0	2.0	189	2.84	.67	4.23	.91	284.0	.32	1.69	.94
Jabal Furqayn (north)													
184031	102.0	18.0	33.9	13.3	298	2.12	1.21	1.75	---	386.0	5.67	1.02	.98
184036	81.7	70.1	26.7	9.3	645	3.07	1.77	1.74	---	458.0	1.17	1.07	.95
184038	87.0	57.0	25.0	7.0	289	3.54	1.84	1.92	---	449.0	1.53	1.04	.95
184377	66.0	15.0	33.0	4.0	235	2.90	1.68	1.73	1.22	587.0	4.40	1.02	.97
184378	95.0	57.0	34.0	6.0	333	3.16	1.51	2.09	1.06	417.0	1.67	1.05	.95
Jabal Furqayn (south)													
184040	164.0	43.0	50.0	60.0	164	2.79	.50	5.58	---	233.0	3.81	1.11	1.03
Jabal Habhab al Jissu													
184379	150.0	11.0	91.0	26.0	190	1.95	.47	4.10	1.00	254.0	13.64	1.09	1.02
184380	362.0	18.0	115.0	68.0	243	2.32	.29	8.00	.94	102.0	20.11	1.07	.99
Jabal Hadb ash Sharar													
184009	257.0	11.0	85.6	89.0	971	2.70	.39	6.91	---	123.0	23.36	.93	.92
184056	228.0	13.3	178.0	41.3	733	1.72	.44	3.92	---	138.0	17.14	.89	.87
184396	20.0	310.0	28.0	1.0	104	2.38	1.40	1.70	1.04	482.0	.06	2.07	.93
Jabal Jabalah													
184087	191.0	31.8	46.0	15.1	116	2.41	.95	2.54	---	208.0	6.01	1.20	1.05
184088	217.0	37.7	59.8	22.9	121	2.30	.58	3.96	---	182.0	5.76	1.19	1.04
184269	215.0	42.0	53.6	21.2	125	1.07	.52	2.07	---	191.0	5.12	1.19	1.04

Table 2.--Sample locality, concentrations, and chemical ratios--Continued

Sample	Latitude (north)	Longitude (east)	U (ppm)	RaeU (ppm)	Th (ppm)	eTh (wt %)	K (wt %)	eK (wt %)	FeO(t) (wt %)
				Jabal Abha					
184014	24 24 19	-40 41 15	6.89	---	20.80	---	3.30	---	5.11
184015	24 23 43	-40 41 6	8.48	---	22.10	---	2.75	---	5.91
184018	24 23 14	-40 46 9	9.12	---	29.80	---	3.40	---	3.45
184374	24 21 26	-40 40 41	.54	.65	2.00	1.45	.54	.57	10.17
184375	24 22 38	-40 40 9	7.72	7.82	25.60	26.00	3.29	3.41	4.61
				Jabal Ajir					
184019	24 58 57	-41 6 56	2.82	---	9.60	---	3.93	---	3.28
184021	24 58 25	-41 8 30	2.59	---	7.70	---	4.06	---	2.66
184023	24 58 48	-41 10 13	3.66	---	9.10	---	3.98	---	2.91
				Jabal Dhuray					
184089	24 13 4	-43 43 12	6.09	---	18.10	---	3.91	---	1.07
184414	24 13 3	-43 42 57	8.37	6.82	18.20	22.20	4.28	4.11	1.52
				Jabal Dumah					
184386	23 51 1	-41 3 28	15.80	16.20	35.20	36.00	3.74	3.88	.58
184387	23 51 52	-41 0 56	4.40	3.99	13.00	12.50	2.96	2.91	4.19
				Jabal Furqayn (north)					
184031	24 49 13	-41 40 49	3.26	---	6.90	---	3.93	---	2.35
184036	24 54 15	-41 36 17	2.12	---	6.50	---	3.74	---	2.64
184038	24 55 59	-41 40 53	2.12	---	7.50	---	3.90	---	2.52
184377	24 52 45	-41 32 40	2.31	2.81	6.10	6.78	3.88	4.04	2.71
184378	24 54 37	-41 39 48	2.62	2.77	7.40	8.27	3.96	3.88	2.39
				Jabal Furqayn (south)					
184040	24 3 29	-41 15 6	7.63	---	21.30	---	3.82	---	1.40
				Jabal Habhab al Jissu					
184379	24 31 24	-41 36 50	8.01	8.00	15.00	15.60	3.80	3.87	1.18
184380	24 27 25	-41 35 40	12.70	12.00	28.50	29.50	3.69	3.64	1.18
				Jabal Hadb ash Sharar					
184009	23 48 48	-40 58 19	8.11	---	21.90	---	3.17	---	3.28
184056	23 46 20	-40 58 53	7.16	---	12.30	---	3.14	---	3.26
184396	23 47 22	-40 59 19	.69	.72	2.00	1.64	.96	.93	3.73
				Jabal Jabalah					
184087	24 46 41	-43 53 19	4.19	---	10.10	---	3.98	---	1.38
184088	24 48 9	-43 53 26	6.79	---	15.60	---	3.94	---	1.24
184269	24 46 53	-43 51 44	7.96	---	8.50	---	4.10	---	1.51

Table 2.--Sample locality, concentrations, and chemical ratios--Continued

Sample	Latitude (north)	Longitude (east)	U (ppm)	RaeU (ppm)	Th (ppm)	eTh (wt %)	K (wt %)	eK (wt %)	FeO(t) (wt %)
				Jabal Haslah					
184069	23 48 24	-42 3 58	---	---	---	---	4.26	---	3.37
184070	23 48 57	-42 3 12	2.42	---	7.60	---	3.87	---	3.82
184177	23 49 42	-42 0 28	2.55	---	8.00	---	4.00	---	3.81
184388	23 51 42	-42 0 7	4.35	4.30	15.80	16.50	4.03	4.12	1.41
184389	23 49 42	-42 0 2	2.98	3.31	9.30	10.30	3.83	3.87	1.43
184390	23 49 41	-42 0 3	3.27	3.39	11.50	10.80	3.54	3.55	1.38
				Jabal Khazaz					
184329	25 25 20	-43 33 59	6.27	---	27.50	---	4.28	---	.94
184334	25 22 30	-43 33 17	3.87	---	28.60	---	3.89	---	1.16
184337	25 19 29	-43 36 16	6.24	---	21.90	---	3.47	---	1.03
184338	25 19 54	-43 35 50	9.07	---	25.50	---	3.64	---	.93
184433	25 25 25	-43 33 54	3.83	3.58	17.40	19.20	4.23	4.32	.73
184434	25 23 5	-43 34 59	3.24	3.25	18.70	19.10	4.17	4.22	1.09
184435	25 19 58	-43 36 14	7.43	6.48	13.90	19.10	3.56	3.71	.76
				Jabal Khurs					
184419	23 34 42	-44 41 40	7.57	7.55	19.70	21.10	3.92	4.10	1.09
				Jabal Khinzir					
184077	23 10 11	-43 49 27	30.30	---	<8.30	---	3.49	---	.75
184079	23 8 57	-43 50 9	20.00	---	22.80	---	3.51	---	.94
184080	23 8 17	-43 52 13	9.81	---	27.10	---	3.63	---	1.71
184129	23 9 41	-43 51 48	10.30	---	21.60	---	4.28	---	1.54
184130	23 9 11	-43 50 48	10.60	---	24.20	---	4.03	---	1.89
184420	23 9 19	-43 47 8	12.20	9.13	12.30	23.00	3.41	3.39	.49
184421	23 8 56	-43 48 30	12.20	11.50	26.80	25.20	3.98	3.91	1.58
184422	23 8 3	-43 53 42	2.27	2.16	4.80	6.82	2.70	2.80	1.64
				Jabal Minya					
184117	24 59 11	-43 24 1	16.10	---	24.10	---	4.38	---	1.51
184359	24 59 15	-43 23 6	14.20	---	37.40	---	3.81	---	1.56
184373	24 59 18	-43 23 28	23.70	---	38.50	---	3.66	---	1.75
184423	24 57 55	-43 20 56	11.20	10.80	27.20	27.40	4.07	4.09	1.43
184424	24 57 55	-43 20 57	13.70	12.70	27.10	28.00	4.21	4.12	1.49
184425	24 57 31	-43 19 45	11.60	11.20	15.90	16.80	2.91	2.94	.44
				Jabal Sanam					
184376	24 43 54	-41 17 28	3.30	3.43	8.30	10.00	3.83	4.08	4.06
				Jabal Shiib					
184439	24 5 2	-42 31 30	7.08	5.84	42.10	46.20	3.91	4.04	.54
184440	24 9 35	-42 26 20	13.80	12.60	47.10	48.60	3.94	3.97	.65
184440A	24 9 35	-42 26 20	14.60	16.10	44.00	46.90	3.99	4.04	.91
184441	24 4 41	-42 25 16	7.62	4.60	17.00	20.90	4.18	4.08	1.72

Table 2.--Sample locality, concentrations, and chemical ratios--Continued

Sample	Rb (ppm)	Sr (ppm)	Y (ppm)	Nb (ppm)	Zr (ppm)	Th/U	K/U	Th/K	eU/U	K/Rb	Rb/Sr	Al/ Na+K	Al/ Na+K+Ca
						Jabal Haslah							
184069	---	---	---	---	---	---	---	---	---	---	---	1.13	.96
184070	60.9	85.3	53.3	17.7	492	3.14	1.60	1.96	---	635.0	.71	1.13	.93
184177	69.0	92.3	52.5	19.3	507	3.14	1.57	2.00	---	580.0	.75	1.12	.93
184388	148.0	108.0	34.0	5.0	153	3.79	.93	4.09	.92	273.0	1.37	1.26	1.03
184389	93.0	151.0	27.0	3.0	144	3.46	1.28	2.69	1.11	412.0	.62	1.27	1.03
184390	102.0	158.0	29.0	4.0	137	3.30	1.08	3.05	1.04	348.0	.65	1.29	1.02
						Jabal Khazaz							
184329	243.0	19.1	19.8	6.4	59	4.39	.68	6.43	---	176.0	12.72	1.18	1.08
184334	252.0	17.8	30.3	7.4	67	7.39	1.00	7.36	---	154.0	14.16	1.21	1.09
184337	544.0	3.3	34.6	24.9	29	3.51	.56	6.31	---	63.8	164.85	1.25	1.21
184338	460.0	4.0	35.5	19.7	37	2.81	.40	7.00	---	79.2	115.00	1.22	1.17
184433	287.0	14.0	29.0	4.0	57	5.01	1.10	4.54	.93	147.0	20.50	1.15	1.07
184434	253.0	62.0	31.0	6.0	100	5.90	1.29	4.58	1.00	165.0	4.08	1.21	1.08
184435	512.0	6.0	38.0	12.0	39	2.57	.48	5.36	.87	69.6	85.33	1.22	1.16
						Jabal Khurs							
184419	213.0	10.0	105.0	12.0	98	2.79	.52	5.38	1.00	184.0	21.30	1.18	1.04
						Jabal Khinzir							
184077	611.0	10.7	74.8	57.3	56	---	.12	---	---	57.2	57.10	1.16	1.09
184079	568.0	13.4	82.8	55.4	59	1.14	.18	6.49	---	61.8	42.39	1.16	1.10
184080	294.0	118.0	66.2	41.1	164	2.76	.37	7.47	---	123.0	2.49	1.22	1.04
184129	309.0	151.0	41.4	23.8	150	2.10	.42	5.05	---	138.0	2.05	1.22	1.04
184130	275.0	182.0	54.7	32.0	173	2.28	.38	6.00	---	147.0	1.51	1.25	1.04
184420	548.0	11.0	104.0	37.0	75	1.89	.28	6.74	.75	62.3	49.82	1.13	1.08
184421	266.0	173.0	49.0	23.0	180	2.07	.33	6.34	.94	150.0	1.54	1.25	1.03
184422	82.0	312.0	1.0	1.0	112	3.00	1.19	2.53	.95	329.0	.26	1.38	1.00
						Jabal Minya							
184117	521.0	56.0	92.4	48.5	136	1.50	.27	5.50	---	84.1	9.30	1.20	1.04
184359	433.0	52.0	114.0	53.7	143	2.63	.27	9.82	---	88.0	8.33	1.21	1.05
184373	458.0	44.1	111.0	51.0	165	1.62	.15	10.52	---	79.9	10.39	1.23	1.08
184423	492.0	57.0	106.0	41.0	149	2.45	.36	6.74	.96	82.7	8.63	1.22	1.04
184424	505.0	43.0	97.0	37.0	149	2.04	.31	6.65	.93	83.3	11.74	1.23	1.06
184425	659.0	183.0	49.0	58.0	20	1.45	.25	5.77	.97	44.2	3.60	1.38	1.27
						Jabal Sanam							
184376	112.0	303.0	49.0	20.0	445	3.03	1.16	2.61	1.04	342.0	.37	1.33	.97
						Jabal Shiib							
184439	267.0	11.0	23.0	17.0	107	6.53	.55	11.82	.82	146.0	24.27	1.11	1.03
184440	339.0	1.0	13.0	26.0	105	3.52	.29	12.32	.91	116.0	339.00	1.09	1.03
184440A	342.0	30.0	16.0	25.0	71	3.21	.27	11.75	1.10	117.0	11.40	1.11	1.05
184441	101.0	101.0	18.0	19.0	257	2.74	.55	5.01	.60	413.0	1.00	1.13	.99

Table 2.--Sample locality, concentrations, and chemical ratios--Continued

Sample	Latitude (north)	Longitude (east)	U (ppm)	RaeU (ppm)	Th (ppm)	eTh (wt %)	K (wt %)	eK (wt %)	FeO(t) (wt %)
				Jabal Saqrah					
184061	23 4 31	-42 50 57	1.78	---	20.10	---	5.37	---	2.20
184063	23 3 43	-42 52 20	1.78	---	8.60	---	5.65	---	2.63
184064	23 1 7	-42 58 25	1.41	---	7.70	---	4.44	---	1.30
184065	23 3 32	-43 1 53	2.63	---	13.50	---	4.62	---	4.51
184301	23 6 16	-42 58 19	3.56	---	12.40	---	4.09	---	.97
184302	23 4 59	-42 58 57	1.69	---	6.50	---	4.11	---	1.43
184402	23 4 16	-42 49 11	1.83	1.74	24.00	27.40	5.52	5.43	2.48
184403	23 6 5	-42 56 30	5.57	5.68	32.00	33.10	4.45	4.29	1.05
184404	23 6 4	-42 56 30	26.30	17.40	49.80	52.30	4.05	4.03	.50
184405	23 3 18	-43 0 0	3.57	3.09	20.70	21.90	3.87	3.85	1.39
184406	23 2 0	-43 1 0	3.96	3.91	14.10	15.20	3.48	3.59	1.08
				Jabal Silsilah					
181859	26 5 41	-42 39 11	12.10	10.50	36.10	36.90	3.59	3.70	.75
181871	26 5 16	-42 39 47	8.39	8.30	33.90	35.40	3.54	3.62	.67
181872	26 4 39	-42 39 44	13.80	9.03	22.30	23.20	2.86	2.98	.42
181964	26 6 13	-42 38 48	6.28	4.71	21.70	22.50	4.00	4.05	1.06
				Jabal Tukhfah					
184392	23 53 3	-42 9 51	9.86	9.07	25.00	28.40	3.65	3.76	1.58
184393	23 56 14	-42 7 29	7.48	6.51	25.20	25.40	4.14	4.28	1.80
184394	23 56 14	-42 7 31	7.91	6.49	25.40	26.20	4.02	4.24	1.55
				Jabal Umm Adban					
184391	23 50 27	-42 7 31	2.15	2.64	7.10	7.81	3.98	4.00	1.47
				Jabal Za'abah					
184417	23 48 24	-44 46 6	3.85	3.60	11.45	12.30	3.69	3.77	3.49
184418	23 46 18	-44 45 55	5.60	5.27	17.50	17.20	4.30	4.55	1.45
				Jabal al Ihn					
184407	24 3 59	-44 49 52	8.44	7.50	---	15.30	3.69	3.63	1.41
184408	24 5 7	-44 49 23	8.48	5.45	---	13.70	4.25	4.17	.09
				Jabal al Mudayh					
184444	24 24 30	-42 12 30	8.21	7.74	38.40	40.00	4.22	4.25	.80
184445	24 26 58	-42 12 0	7.55	7.50	24.90	23.10	4.09	4.24	.98
				Jabal al Yanufi					
184397	23 25 59	-43 4 23	4.57	4.48	13.10	14.80	3.72	3.83	1.03
184398	23 27 9	-43 4 22	2.84	2.71	14.30	15.00	3.69	3.82	1.07
184399	23 24 20	-43 4 58	2.80	2.68	15.40	15.10	3.87	3.96	1.08

Table 2.--Sample locality, concentrations, and chemical ratios--Continued

Sample	Rb (ppm)	Sr (ppm)	Y (ppm)	Nb (ppm)	Zr (ppm)	Th/U	K/U	Th/K	eU/U	K/Rb	Rb/Sr	Al/ Na+K	Al/ Na+K+Ca
					Jabal Saqrah								
184061	126.0	39.4	21.9	18.3	451	11.29	3.02	3.74	---	426.0	3.20	1.09	1.00
184063	98.2	39.2	30.8	23.0	645	4.83	3.18	1.52	---	576.0	2.51	1.12	1.00
184064	121.0	93.3	25.7	49.1	213	5.46	3.15	1.73	---	367.0	1.30	1.11	1.02
184065	91.0	118.0	43.7	34.1	831	5.13	1.76	2.92	---	508.0	.77	1.11	.97
184301	160.0	61.5	10.9	13.5	85	3.48	1.15	3.03	---	256.0	2.60	1.14	1.04
184302	77.0	43.3	15.6	11.7	225	3.85	2.43	1.58	---	534.0	1.78	1.07	1.01
184402	120.0	37.0	36.0	18.0	680	14.97	3.02	4.96	.95	460.0	3.24	1.12	1.01
184403	187.0	99.0	17.0	10.0	126	5.94	.80	7.44	1.02	238.0	1.89	1.16	1.03
184404	224.0	3.0	10.0	23.0	132	1.99	.15	12.91	.66	181.0	74.67	1.12	1.05
184405	137.0	182.0	24.0	15.0	235	6.13	1.08	5.66	.87	282.0	.75	1.19	1.01
184406	111.0	47.0	25.0	1.0	126	3.84	.88	4.37	.99	313.0	2.36	1.20	1.07
					Jabal Silsilah								
181859	632.0	1.0	92.0	40.0	94	3.05	.30	10.29	.87	56.7	632.00	1.14	1.10
181871	701.0	3.0	80.0	46.0	93	4.22	.42	10.01	.99	50.4	233.67	1.14	1.10
181872	954.0	1.0	46.0	66.0	71	1.68	.21	8.10	.65	30.0	954.00	1.16	1.14
181964	240.0	12.0	50.0	15.0	141	3.58	.64	5.62	.75	167.0	20.00	1.14	1.05
					Jabal Tukhfah								
184392	354.0	27.0	107.0	106.0	342	2.88	.37	7.78	.92	103.0	13.11	1.03	.99
184393	230.0	72.0	62.0	46.0	311	3.40	.55	6.13	.87	180.0	3.19	1.15	1.01
184394	217.0	65.0	61.0	51.0	265	3.31	.51	6.52	.82	185.0	3.34	1.13	1.02
					Jabal Umm Adban								
184391	90.0	13.0	41.0	7.0	255	3.63	1.85	1.96	1.23	443.0	6.92	1.04	.99
					Jabal Ẓa'abah								
184417	122.0	137.0	30.0	1.0	305	3.19	.96	3.33	.94	303.0	.89	1.38	1.02
184418	149.0	19.0	54.0	11.0	136	3.07	.77	4.00	.94	289.0	7.84	1.17	1.03
					Jabal al Ihn								
184407	253.0	117.0	41.0	5.0	115	1.81	.44	4.14	.89	146.0	2.16	1.25	1.05
184408	384.0	13.0	82.0	29.0	47	1.62	.50	3.22	.64	111.0	29.54	1.10	1.00
					Jabal al Mudayh								
184444	189.0	88.0	8.0	6.0	102	4.87	.51	9.48	.94	223.0	2.15	1.16	1.04
184445	188.0	196.0	8.0	4.0	132	3.06	.54	5.64	.99	218.0	.96	1.26	1.02
					Jabal al Yanufi								
184397	122.0	59.0	18.0	1.0	135	3.24	.81	3.98	.98	305.0	2.07	1.19	1.04
184398	133.0	75.0	28.0	1.0	141	5.28	1.30	4.06	.95	278.0	1.77	1.21	1.03
184399	140.0	57.0	19.0	1.0	132	5.39	1.38	3.90	.96	276.0	2.46	1.17	1.03

Table 2.--Sample locality, concentrations, and chemical ratios--Continued

Sample	Latitude (north)	Longitude (east)	U (ppm)	RaeU (ppm)	Th (ppm)	eTh (wt %)	K (wt %)	eK (wt %)	FeO(t) (wt %)
				Jabal as Safwah					
184058	23 8 23	-42 17 13	3.25	---	13.10	---	3.82	---	2.01
184059	23 7 43	-42 17 32	5.32	---	15.80	---	4.08	---	2.45
184395	23 7 24	-42 16 5	8.08	7.02	20.20	19.30	3.84	3.97	2.96
				Malik Granite					
184339	25 10 23	-43 39 3	1.64	---	25.30	---	4.28	---	1.37
184342	25 7 50	-43 47 6	3.31	---	18.70	---	4.78	---	.38
184344	25 10 39	-43 44 19	3.83	---	28.90	---	4.07	---	.92
				Miskah 1					
184149	24 36 57	-42 56 30	5.88	---	18.90	---	4.08	---	1.60
184426	24 41 4	-42 51 0	7.60	6.78	24.40	26.50	4.39	4.22	1.45
184242	24 35 16	-43 5 1	9.51	---	29.00	---	4.25	---	1.44
				Miskah 2					
184368	24 48 56	-42 54 11	<.44	---	14.60	---	5.91	---	2.24
184427	24 54 46	-42 48 12	7.21	9.26	16.50	24.30	4.06	4.12	1.39
184446	24 55 35	-42 34 24	12.40	9.83	25.80	29.40	3.81	3.78	1.21
184447	24 56 5	-42 35 41	11.80	11.80	19.50	20.10	4.13	4.07	1.19
				Miskan 3					
184152	24 35 31	-43 10 5	3.03	---	9.20	---	3.96	---	2.41
184428	24 35 27	-43 10 7	2.56	2.42	12.90	13.10	4.53	4.58	1.68
184429	24 34 50	-43 12 55	2.03	2.09	8.40	14.20	4.33	3.99	1.36
184430	24 35 27	-43 10 7	2.41	2.41	8.30	11.50	4.22	4.15	.82
				Najirah					
184409	24 14 0	-44 25 31	4.61	3.64	18.90	19.90	4.39	4.33	1.14
184410	24 14 1	-44 26 28	5.06	2.54	16.10	17.00	4.28	4.18	1.14
184411	24 15 45	-44 26 39	4.56	4.29	17.20	17.20	4.28	4.26	1.09
				Suwaj					
184436	25 11 57	-43 17 16	11.90	11.00	24.20	24.30	3.90	3.90	.91
184437	25 11 57	-43 17 16	9.81	9.80	19.20	19.10	4.37	4.37	1.17
184438	25 10 58	-43 16 57	7.86	7.04	21.20	18.40	4.30	4.30	1.08
				Unnamed 1					
184274A	24 9 0	-43 52 32	3.67	2.70	19.30	16.20	4.06	4.50	.82
184275	24 11 58	-43 55 20	3.57	---	15.60	---	4.17	---	.74
184413	24 9 26	-43 55 34	8.32	6.83	19.90	21.00	4.23	4.00	.78

Table 2.--Sample locality, concentrations, and chemical ratios--Continued

Sample	Rb (ppm)	Sr (ppm)	Y (ppm)	Nb (ppm)	Zr (ppm)	Th/U	K/U	Th/K	eU/U	K/Rb	Rb/Sr	Al/ Na+K	Al/ Na+K+Ca
					Jabal as Safwah								
184058	119.0	12.3	38.3	64.7	330	4.03	1.17	3.43	---	321.0	9.67	1.01	.97
184059	144.0	96.4	38.7	58.0	362	2.97	.77	3.88	---	283.0	1.49	1.11	1.01
184395	127.0	80.0	54.0	64.0	477	2.39	.48	5.02	.87	303.0	1.59	1.06	.92
					Malik Granite								
184339	244.0	122.0	14.9	11.1	120	15.43	2.61	5.91	---	175.0	2.00	1.30	1.11
184342	103.0	193.0	20.0	5.0	56	5.65	1.44	3.91	---	464.0	.53	1.24	1.06
184344	102.0	233.0	10.6	7.6	87	7.55	1.06	7.10	---	399.0	.44	1.30	1.04
					Miskah 1								
184149	188.0	70.7	27.2	28.0	152	3.21	.69	4.64	---	217.0	2.66	1.18	1.04
184426	215.0	176.0	14.0	10.0	163	3.49	.58	6.03	.89	204.0	1.22	1.25	1.05
184242	254.0	70.4	32.2	35.1	132	3.05	.45	6.82	---	167.0	3.61	1.18	1.05
					Miskah 2								
184368	96.4	79.9	29.1	15.3	562	---	---	2.47	---	613.0	1.21	1.11	1.01
184427	205.0	159.0	18.0	14.0	158	3.37	.56	5.99	1.28	198.0	1.29	1.23	1.04
184446	256.0	155.0	29.0	13.0	133	2.37	.31	7.72	.79	149.0	1.65	1.20	1.03
184447	270.0	176.0	21.0	14.0	142	1.70	.35	4.87	1.00	153.0	1.53	1.18	1.02
					Miskah 3								
184152	87.8	281.0	22.1	18.8	234	3.04	1.31	2.32	---	451.0	.31	1.25	1.03
184428	84.0	279.0	22.0	3.0	207	5.12	1.77	2.89	.95	540.0	.30	1.20	1.01
184429	87.0	206.0	17.0	5.0	142	7.00	2.13	3.28	1.03	498.0	.42	1.18	1.02
184430	66.0	94.0	6.0	4.0	96	4.77	1.75	2.73	1.00	639.0	.70	1.15	1.04
					Najirah								
184409	181.0	154.0	22.0	2.0	144	4.32	.95	4.53	.79	243.0	1.18	1.27	1.06
184410	200.0	146.0	12.0	3.0	135	3.36	.85	3.97	.50	214.0	1.37	1.28	1.08
184411	211.0	140.0	21.0	5.0	132	3.77	.94	4.02	.94	203.0	1.51	1.27	1.10
					Suwaj								
184436	270.0	4.0	86.0	32.0	151	2.04	.33	6.23	.92	145.0	67.50	1.14	1.05
184437	229.0	21.0	65.0	24.0	225	1.95	.45	4.37	1.00	191.0	10.90	1.12	1.01
184438	217.0	9.0	97.0	21.0	159	2.34	.55	4.28	.90	198.0	24.11	1.12	1.03
					Unnamed 1								
184274A	123.0	132.0	15.0	3.0	91	4.61	1.11	3.99	.74	330.0	.93	1.19	1.05
184275	110.0	69.0	13.0	1.0	74	4.37	1.17	3.74	---	379.0	1.59	1.14	1.00
184413	152.0	106.0	2.0	2.0	88	2.52	.51	4.97	.82	278.0	1.43	1.18	1.04

Table 2.--Sample locality, concentrations, and chemical ratios--Continued

Sample	Latitude (north)	Longitude (east)	U (ppm)	RaeU (ppm)	Th (ppm)	eTh (wt %)	K (wt %)	eK (wt %)	FeO(t) (wt %)
				Unnamed 2					
184400	23 27 40	-42 40 44	2.98	2.72	17.90	19.70	4.17	4.25	1.18
				Unnamed 3					
184442	24 21 8	-42 26 5	1.72	1.61	7.70	8.60	6.39	6.47	1.62
184443	24 21 8	-42 26 6	12.40	12.10	19.30	21.80	3.84	3.80	.95

Table 3.--Statistical summary of chemical compositions for the postorogenic granites from the east-central Arabian Shield.

[Oxide concentrations are in weight in percent; trace-element contents are in parts per million. Values for average granite are from Krauskopf (1967) with elements converted to oxides and normalized to 100 percent and Stuckless and VanTrump (1982)]

	Number of samples	Minimum	Maximum	Mean	Standard deviation	Skewness	Kurtosis	Average granite
SiO_2	127	45.13	77.74	73.02	±4.33	-3.11	14.47	72.64
Al_2O_3	127	7.32	19.36	13.27	±1.49	0.52	4.36	13.67
FeO(t)	127	0.09	10.17	1.87	±1.35	2.70	11.51	3.27
MgO	127	0.05	4.98	0.36	±0.61	5.03	30.56	0.25
CaO	127	0.01	11.1	1.05	±1.21	5.33	38.82	2.10
Na_2O	127	2.87	4.91	3.76	±0.47	0.72	-0.20	3.54
K_2O	127	0.65	7.70	4.69	±0.82	-0.98	8.55	3.74
TiO_2	127	0.01	1.77	0.24	±0.25	3.32	14.77	0.36
P_2O_5	127	0.02	0.46	0.06	±0.08	3.32	12.59	0.03
MnO	127	0.01	0.54	0.04	±0.05	6.53	55.04	0.05
RaeU/U	74	0.50	1.28	0.95	±0.14	-0.40	1.52	---
U	125	0.54	30.3	5.36	$^{+5.68}_{-2.76}$	-0.26	0.17	3.54
RaeU	74	0.65	17.4	5.16	$^{+5.11}_{-2.57}$	-0.53	0.47	---
Th	120	2.00	49.8	15.4	$^{+12.4}_{-6.9}$	-0.72	1.25	16.76
eTh	74	1.45	52.3	17.1	$^{+14.9}_{-7.95}$	-1.52	4.73	---
Rb	126	1.0	659	168	$^{+191}_{-89.4}$	-2.37	15.49	150
Sr	126	1.0	1633	57.8	$^{+158}_{-42.3}$	-0.24	0.24	285
Y	126	1.0	178	31.4	$^{+40.1}_{-17.6}$	-1.04	2.76	40
Nb	126	1.0	174	13.0	$^{+30.6}_{-9.2}$	-0.56	-0.11	20
Zr	126	20	2050	174	$^{+197}_{-92}$	0.21	0.52	180
Th/U	125	1.07	14.97	3.01	$^{+1.64}_{-1.06}$	0.64	1.74	4.73
K/U	125	0.12	3.72	0.70	$^{+0.74}_{-0.36}$	0.03	-0.32	0.95
Th/K	123	1.35	12.91	4.20	$^{+2.97}_{-1.74}$	-0.10	-0.59	5.00
Rb/Sr	125	0.06	339	3.10	$^{+12.9}_{-2.51}$	0.31	0.10	---
K/Rb	126	4.42	540	226	$^{+217}_{-111}$	0.44	2.93	---

RESULTS AND DISCUSSION

PETROGRAPHY

The postorogenic granites exhibit a marked range in texture, grain size, and modal mineralogy. About 20 percent of the samples analyzed during the current study are hypersolvus, and 25 percent are subsolvus, but slightly more than half of the samples are intermediate between these extremes. Most of the samples, except those collected at Jabal Abha, contain more than 20 percent modal quartz. Syenogranite and monzogranite are the dominant rock types (Moore, 1984), but alkali-feldspar granites are common as indicated by the high percentage of hypersolvus granites noted above.

The monzogranites and syenogranites are typically medium- to coarse-grained and hypidiomorphic equigranular to porphyritic; the latter texture is more characteristic of the monzogranites (Moore, 1984). Modal mineralogy is generally greater than 90 percent quartz, plagioclase, and perthitic microcline. Major non-felsic minerals include amphibole, biotite, and muscovite. Accessory minerals are dominated by apatite, zircon, and opaque oxides, but sphene and an epidote-family mineral were noted in several samples.

The alkali-feldspar granites are medium- to coarse-grained and typically hypidiomorphic granular. Coarsely perthitic microcline and quartz comprise more than 90 percent of most samples. Amphibole is the dominant mafic mineral, but pyroxene or biotite may be present; sodic pyriboles are distinctive phases in the peralkaline granites. Zircon is ubiquitous and commonly abundant. Fluorite and allanite have both been noted in some samples of the alkali-feldspar granites (Moore, 1984).

CHEMISTRY

Six samples, for which data are presented in tables 1 and 2, were collected from foliated plutons and are judged to belong to the orogenic episode of plutonism (samples 184339, 184342, 184344, 184384, 184385, and 184400). Data for these samples are not included in plots or statistical treatments that follow, but are included in tables 1 and 2 in order to make these data available. Samples from Baid al Jimalah and Jabal Silsilah were collected to provide a comparison to known mineralized plutons. These plutons are located north of the study area, and data for these samples are treated separately and are not included in any of the statistical treatments of the data set. The following discussion of granitiods from the east-central Shield is based on the remaining 127 samples (tables 1 and 2).

Data for major-element concentrations and CIPW normative mineralogy are presented in table 1. Most of the postorogenic granitoids are highly evolved as indicated by their generally high differentiation indexes (>90 for 93 of 127 samples, table 1). Only the pluton at Jabal Abha is uniformly unevolved, and it accounts for five of the seven samples that have differentiation indexes less than 80 (samples 184014 through 184375, table 1). The samples from Jabal Abha also account for the very large range in major element concentrations (table 3) relative to that reported for postorogenic granites to the north (Stuckless, VanTrump, and others, 1982) or to the south (Stuckless and others, 1983). In spite of the very large range in compositions, the average composition is more evolved than that of an average granite (Krauskopf, 1967) in that the average postorogenic granite contains less iron and calcium and more sodium and potassium (table 3).

In addition to the wide range of compositions, the postorogenic granites exhibit a wide range in degree of alumina saturation. Seven samples, which were collected from three plutons, are peralkaline as shown by their normative acmite (table 1) or by their Al/(Na+K) values of less than one (table 2). These samples were collected near the margins of plutons from zones that have the appearance of ring dikes or domed sill-like sheets. Eight samples, which were collected from five plutons, are strongly peraluminous as shown by Al/(Na+K+Ca) greater than 1.1 (table 2). Thirty samples, which were collected from 16 different plutons, are metaluminous (table 2). Most of the samples (82 of the 127 samples analyzed) are weakly peraluminous.

Several postorogenic granites from the Arabian Shield have been identified as metalliferous. Analyses for four samples from Jabal Silsilah, which is tin-bearing (du Bray, 1985), and Baid al Jimalah, which is tungsten-bearing (Cole and others, 1981), were analyzed as part of the current study (tables 1 and 2). Stuckless and others (1983) have reported data, which include the same elements determined by the same methods as the data set obtained in the current study, for Jabal al Gaharra, which is tin-bearing (Elliott, 1985), and for Jabal Tarban, Jabal Sabhah, Jabal al Hawshaw, and Bani Bwana which are enriched in several metals (du Bray and others, 1983). Average data for these seven plutons are compared to the average composition of the postorogenic granites from the east-central Arabian Shield (table 4). The averages show that the anomalously metalliferous plutons are slightly more evolved in that silica content is higher, and iron, calcium, magnesium, and titanium are lower.

A plot of the normative data for the anomalously metalliferous samples in the Q-Ab-Or system shows that most of the data approximate the polybaric minimum and that most of the deviation from the trend can be accounted for by hydrothermal addition of silica or potassium or both (fig. 2A). Although some of the normative data for the postorogenic granites from the east-central Shield yield a similar pattern, most of the data plot below the polybaric minimum (fig. 2B), which suggests that most of the samples crystallized under different physical conditions than those that prevailed for the metalliferous samples. A similar conclusion is indicated by the normative An-Ab-Or system, except that in this system the anomalously metalliferous samples uniformly indicate crystallization in a low-pressure, water-saturated environment (fig. 3).

In general, trace-element data tend to follow a log-normal distribution (Ahrens, 1957; Stuckless and VanTrump, 1982). Statistical assessment of the trace-element contents of the postorogenic granites (table 3) was therefore done on the logarithmically transformed data, and the results are reported as the antilogs. Deviation about the geometric mean is consequently assymetrical. The values for skewness and kurtosis for the logarithmic data are generally low (table 3) and much lower than the arithmetic values which indicates that the logarithmic treatment of the data is appropriate for samples from the east-central Shield.

Trace-element contents, like the major-element data, show that the average postorogenic granite of the east-central Shield is similar to an average granite, but slightly more evolved (table 3). Only strontium, which is strongly depleted in the postorogenic granites relative to an average granite, is statistically distinct. The uranium content is somewhat elevated. This feature seems to be typical of all the postorogenic granites from the eastern Arabian Shield (Stuckless, VanTrump, and others, 1982; Stuckless and others, 1983).

The radioelement data can be used to evaluate the east-central Shield as a uranium province and to choose areas that merit further or detailed study. Saunders (1979) noted that uranium provinces are marked by a regionally high content of uranium. The high average uranium content for the postorogenic granites suggests that this criterion is met in the east-central Shield, and figure 4 shows that anomalously uraniferous samples (relative to the mean and standard deviation of the average granite reported by Stuckless and VanTrump, have a wide distribution, and thus the slightly elevated average uranium content reflects a regional feature. Thirty four samples have uranium contents that exceed the mean plus one standard deviation of an average granite, and another 21 samples have uranium contents that exceed the mean by more than one-half a deviation. In contrast, only six samples contain less uranium than the average granite minus one standard deviation.

Two plutons stand out above the regional uranium high. All samples from Jabal Minya and all samples from Jabal Khinzir, except a sample of a granitic dike that cuts the granite, have anomalous uranium contents (table 2, and fig. 4). Although none of the samples analyzed in the current study approach ore grade, such uniformly high values over areas of several square kilometers suggest a good possibility for economic concentrations of uranium within fairly well defined target areas. Therefore, detailed examinations of these plutons and the immediately surrounding country rocks is recommended.

Thorium and uranium have a strong geochemical coherence in most magmatic environments, and therefore high-uranium granites that result from crystal-melt differentiation alone should also be enriched in thorium (Stuckless and VanTrump, 1982). The average thorium content for the postorogenic granites is approximately equal to that of an average granite (table 3), and only four samples have thorium contents that exceed the mean plus one standard deviation of an average granite and only nine other samples contain more than the mean plus half a standard deviation (fig. 5). In contrast, 62 thorium contents are within one-half a standard deviation of the average granite thorium content and 16 samples contain less than the mean minus one standard deviation. These features suggest that the regional uranium enrichment may have resulted from a partitioning of uranium into a late fluid phase, and consequently the most likely economic concentrations of uranium would be in a hydrothermal or pegmatitic environment.

Granitic rocks that have acted as source to uranium deposits in sedimentary rocks are characterized by high and variable Th/U values and a poor correlation between thorium and uranium (Stuckless and VanTrump, 1982). These features result from variable and generally large losses of uranium that is subsequently precipitated in near-by sediments to form uranium deposits. The correlation of thorium with uranium is fairly high for samples collected over such a large area (table 5), and the mean Th/U for average granite is actually greater than the mean plus one standard deviation for the postorogenic granites (table 3). In addition, the standard deviation is very low (+1.64 and -1.06) compared to that reported by Stuckless and VanTrump (+5.97 and -2.64). Only two samples have Th/U greater than that of an average granite plus one standard deviation, and there are no other samples that exceed that mean by half a standard deviation (fig. 6). In contrast, 29 samples have Th/U values that are more than one standard deviation below the mean of an average granite, and another 63 samples are more than half a standard deviation below that mean. The generally low Th/U values are shown graphically on figure 7B where most data points plot above the line that corresponds to a Th/U value of 4.73.

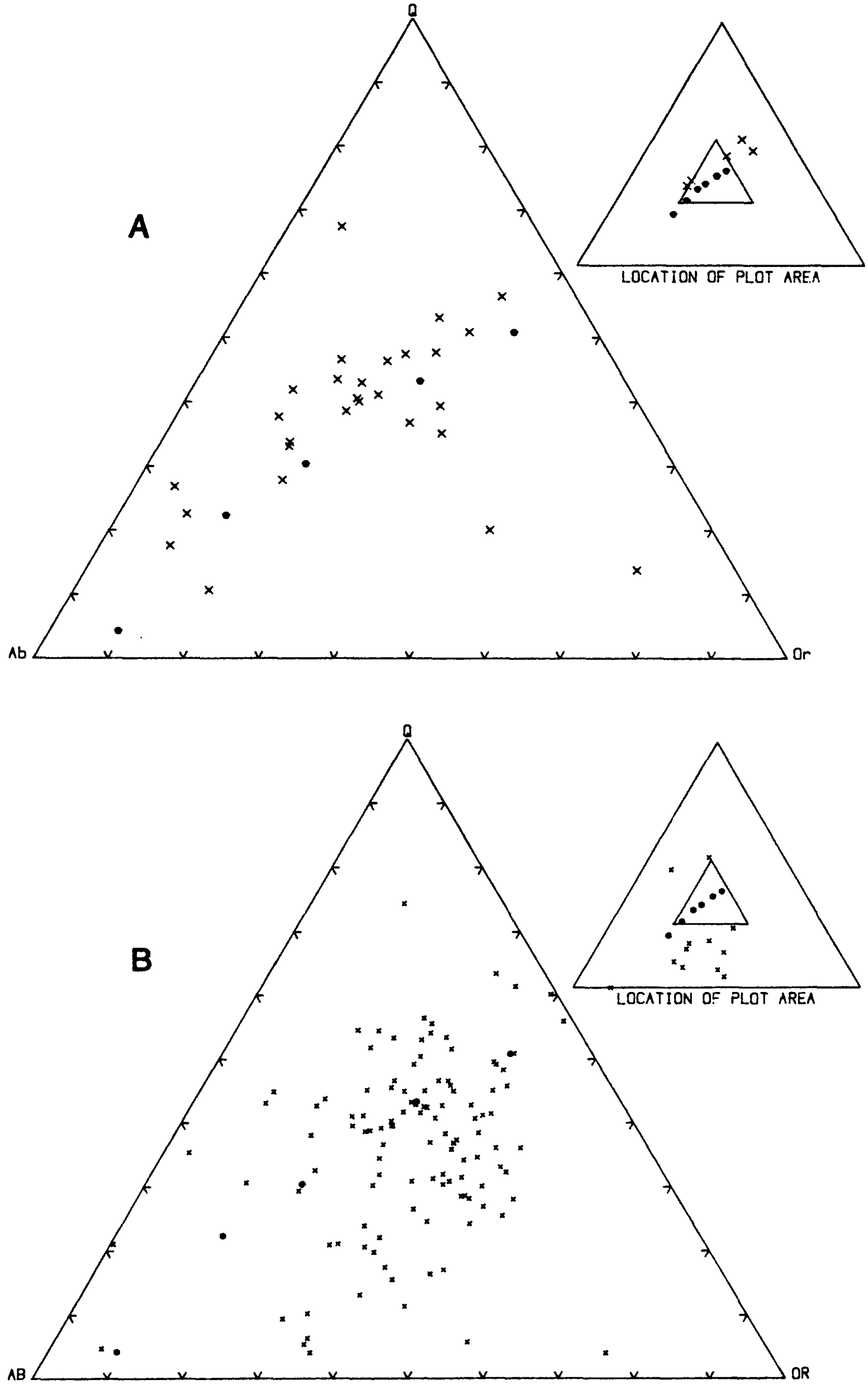

Figure 2.--*Ternary diagram showing the normative composition of anomalously metalliferous samples (A) and postorogenic samples from the east-central Shield (B) and the polybaric ternary minimum (delineated by dots) in the system Q-Ab-Or (Tuttle and Bowen, 1958; Luth and others, 1964). Insets show the expanded portion of the diagram as well as data points that plot outside the expanded portion.*

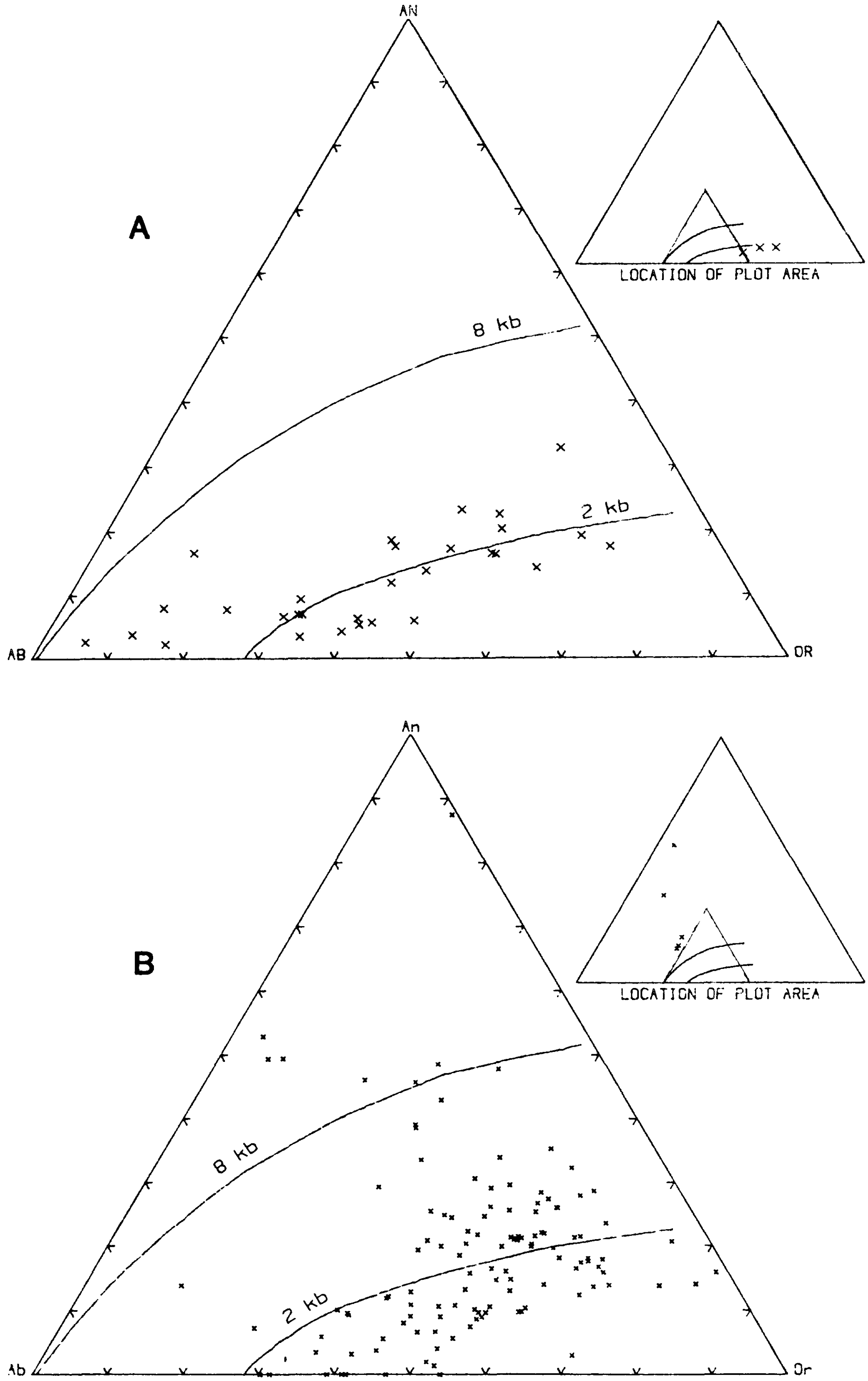

Figure 3.--*Ternary diagram showing the normative composition of anomalously metalliferous samples (A) and postorogenic samples from the east-central Shield (B) and the Water-saturated eutectic compositions at 2 and 8 kb (Whitney, 1975). Insets show the expanded portion of the diagram as well as data points that plot outside the expanded portion.*

Table 4.--Comparison of chemistry for anomalous plutons and those from the east-central Arabian Shield.

[Oxides concentrations are reported in weight percent; trace-element contents are in parts per million]

	East-central	Anomalous
SiO_2	73.02 ± 4.33	75.45 ± 1.45
Al_2O_3	13.27 ± 1.49	13.07 ± 0.97
FeO(t)	1.87 ± 1.35	0.99 ± 0.53
MgO	0.36 ± 0.61	0.10 ± 0.09
CaO	1.05 ± 1.21	0.50 ± 0.29
Na_2O	3.76 ± 0.47	3.86 ± 0.81
K_2O	4.69 ± 0.82	4.46 ± 0.57
TiO_2	0.24 ± 0.25	0.05 ± 0.07
P_2O_5	0.06 ± 0.08	0.02 ± 0.02
MnO	0.04 ± 0.05	0.03 ± 0.03
RaeU/U	0.95 ± 0.14	0.86 ± 0.11
U	$5.36^{+5.68}_{-2.76}$	$8.83^{+7.54}_{-4.07}$
RaeU	$5.16^{+5.11}_{-2.57}$	$7.50^{+7.12}_{-3.65}$
Th	$15.4^{+12.4}_{-6.9}$	$29.1^{+11.4}_{-8.2}$
eTh	$17.1^{+14.9}_{-7.95}$	$27.5^{+11.9}_{-8.29}$
Rb	$168^{+191}_{-89.4}$	470^{+277}_{-174}
Sr	$57.8^{+158}_{-42.3}$	$8.59^{+25.3}_{-6.4}$
Y	$31.4^{+40.1}_{-17.6}$	$70.1^{+69.2}_{-34.8}$
Nb	$13.0^{+30.6}_{-9.2}$	$25.9^{32.0}_{-14.3}$
Zr	174^{+197}_{-92}	90^{+50}_{-32}
Th/U	$3.01^{+1.64}_{-1.06}$	$3.11^{+2.18}_{-1.28}$
K/U	$0.70^{+0.74}_{-0.36}$	$0.41^{+0.41}_{-0.19}$
Th/K	$4.20^{+2.97}_{-1.74}$	$7.91^{+3.30}_{-2.34}$
Rb/Sr	$3.10^{+12.9}_{-2.51}$	$54.7^{+250}_{-44.9}$
K/Rb	226^{+217}_{-111}	$78.3^{+54.7}_{-32.6}$

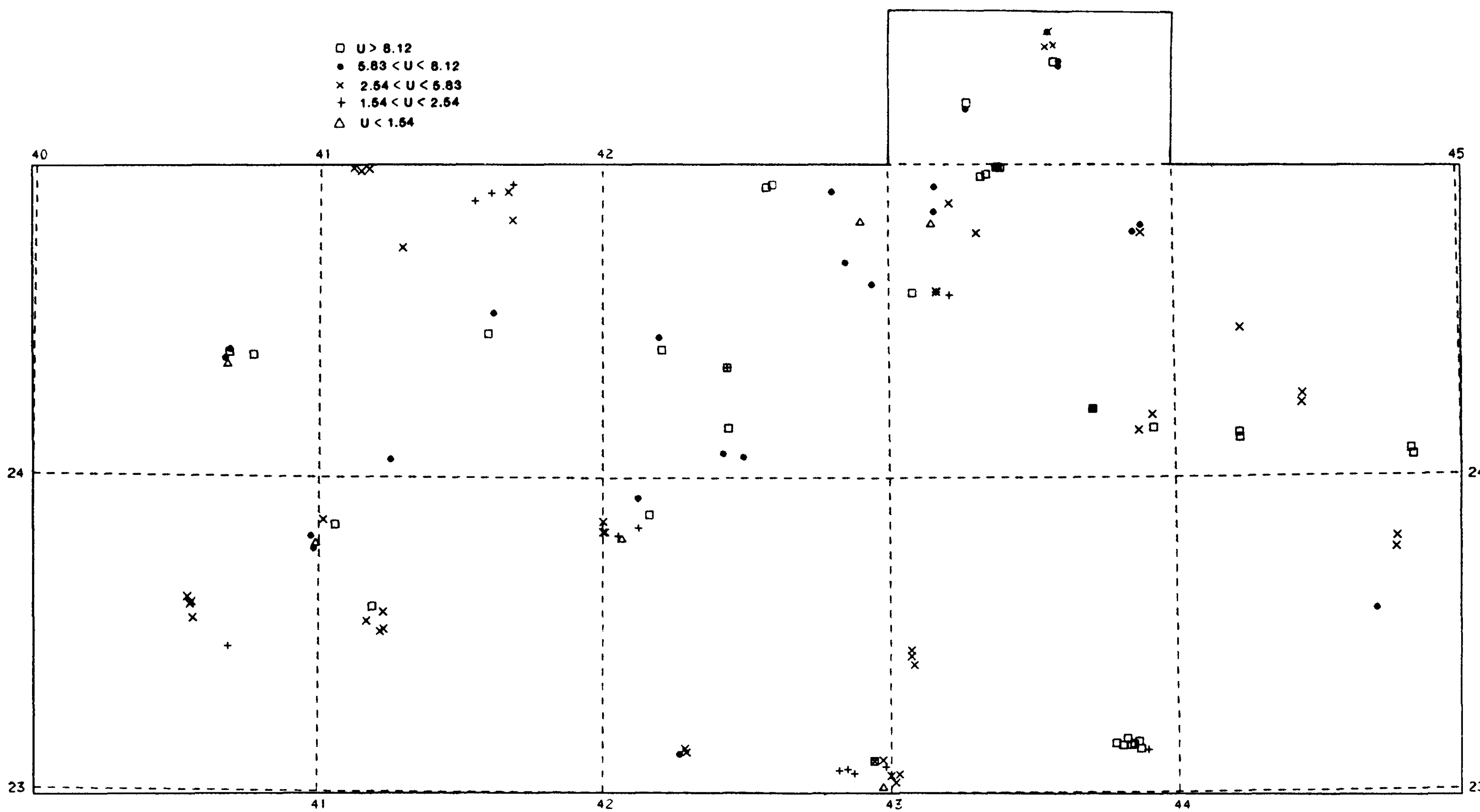

Figure 4.--*Map showing uranium contents of postorogenic samples from the east-central Shield relative to average granite (Stuckless and VanTrump, 1982). Classes represent plus or minus one-half sigma from the mean, plus or minus one-half to one sigma from the mean, and more than plus or minus one sigma from the mean.*

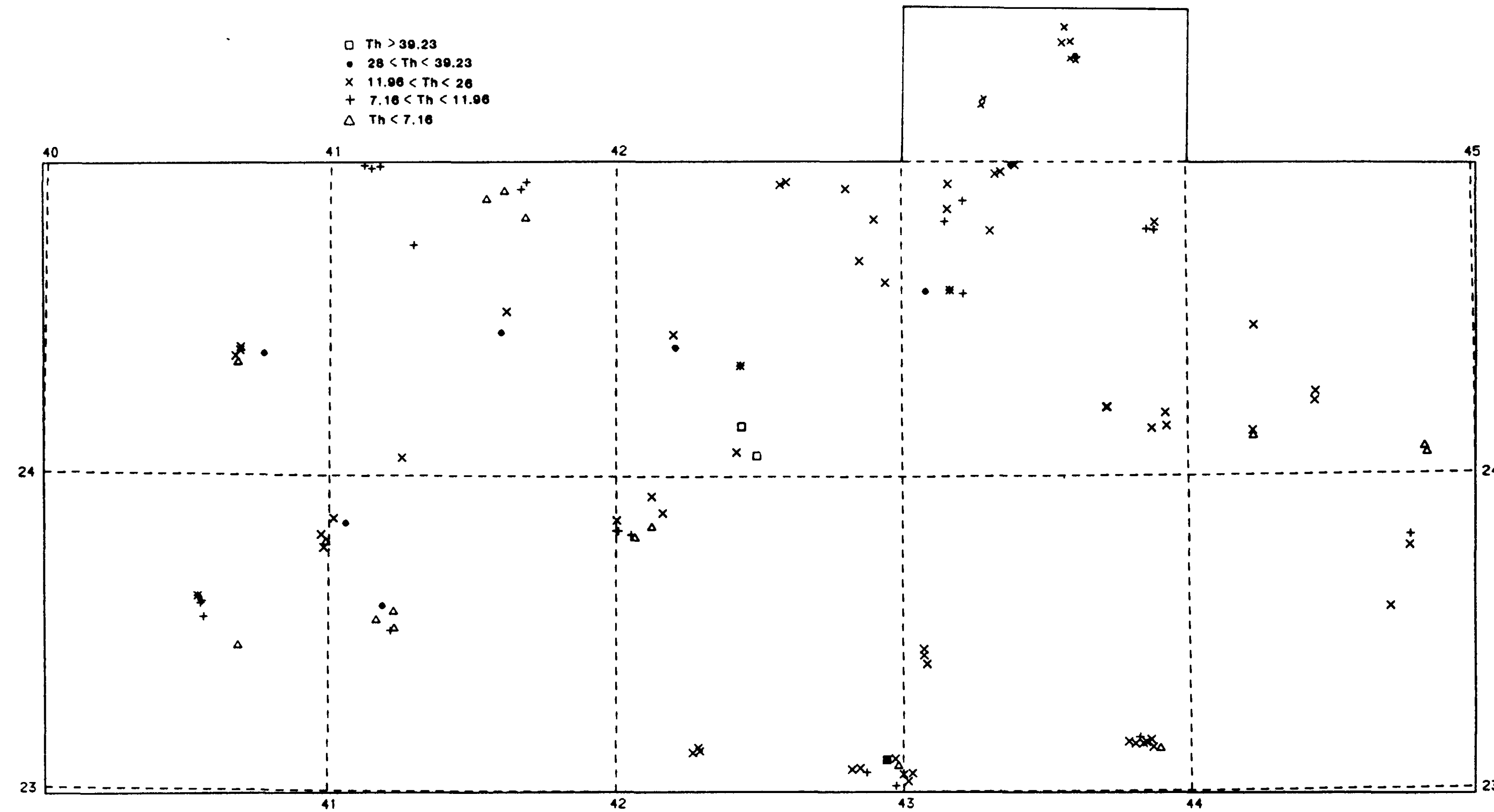

Figure 5.--*Map showing thorium contents of postorogenic samples from the east-central Shield relative to average granite (Stuckless and VanTrump, 1982). Classes represent plus or minus one-half sigma from the mean, plus or minus one-half to one sigma from the mean, and more than plus or minus one sigma from the mean.*

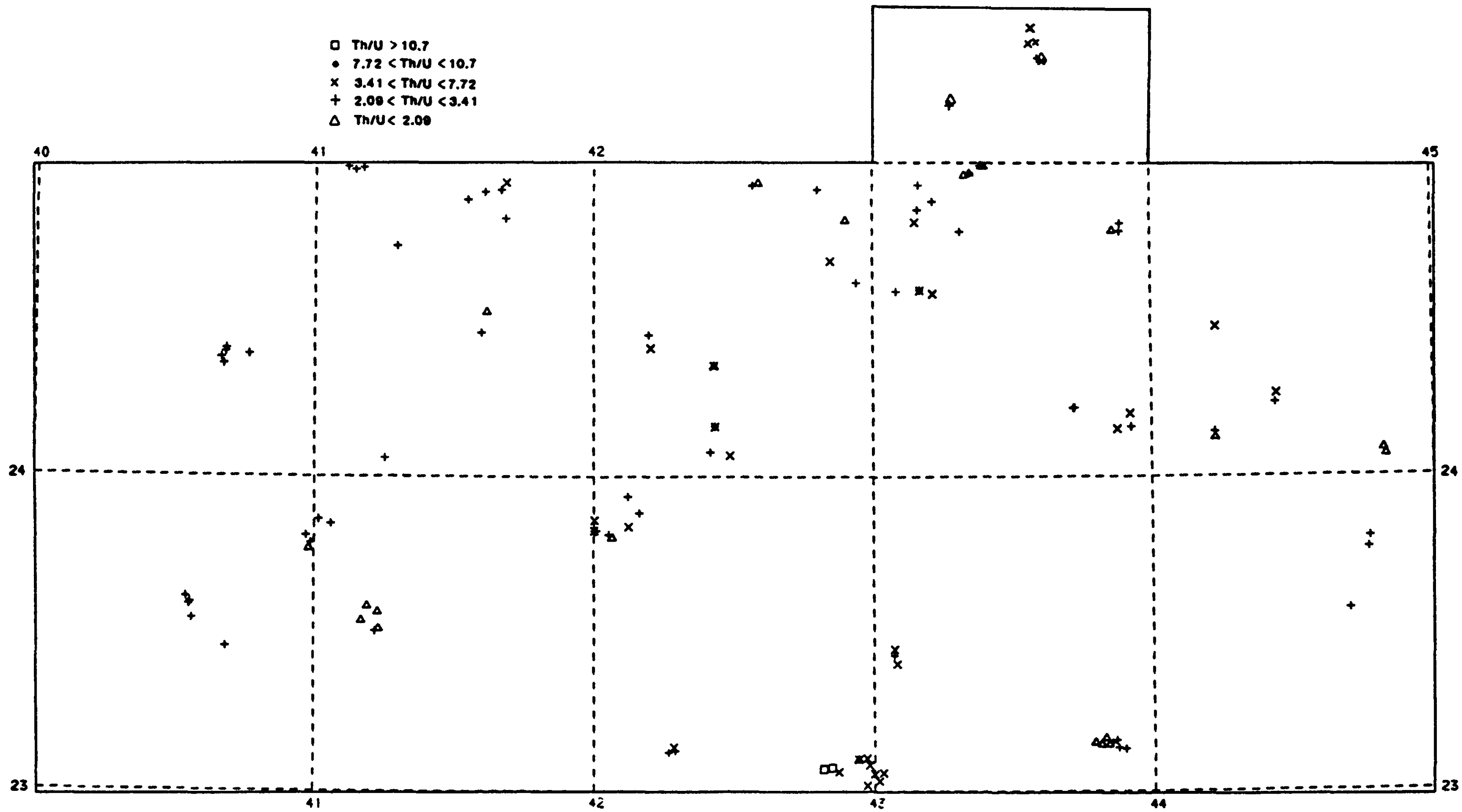

Figure 6.--*Map showing Th/U values for postorogenic samples from the east-central Shield relative to average granite (Stuckless and VanTrump, 1982). Classes represent plus or minus one-half sigma from the mean, plus or minus one-half to one sigma from the mean, and more than plus or minus one sigma from the mean.*

Table 5.--Selected correlation coefficients for samples of postorogenic rocks from the east-central Arabian Shield, Kingdom of Saudi Arabia.

Element pair	Correlation coefficient	Element pair	Correlation coefficient
U:Th	0.75	U:RaeU	0.96
U:Rb	.68	K:Rb	-.04
Fe:Zr	.53	Y:Nb	.54
Nb:Zr	.50	Sr:Mg	.95
Sr:Ca	.91	Sr:Si	-.87
Sr:Rb	-.31	Sr:Ti	.86

Rocks from which uranium has been leached within the last several thousand years generally have a pronounced disequilibrium within the uranium decay chain (Stuckless and Ferreira, 1976). This secular disequilibrium can be identified by comparing the values of uranium and radium-equivalent uranium (RaeU). The ratio RaeU/U should be between 1.1 and 0.9 if secular equilibrium has been established and maintained for the last several thousand years. The average RaeU/U for the postorogenic granites of the east-central Shield is well within this range, and furthermore the correlation coefficient between these two variables is very high (table 5). Therefore, recent leaching of uranium seems unlikely. Thus, both the Th/U and RaeU/U data suggest an extremely low probability for uranium deposits in the east-central Shield that formed from uranium leached out of granites.

Yttrium is geochemically similar to the heavier, middle rare-earth elements (Felsche and Hermann, 1978), and thus yttrium contents provide a means of assessing favorability for deposits of rare-earth elements. The average yttrium content of the postorogenic granites is slightly, though not significantly, low relative to an average granite (table 3); however, the large range of values and standard deviation show that at least some of the samples are markedly enriched in this element. Inspection of table 2 shows that the pluton at Jabal Minya has distinctly elevated contents of yttrium and that Suwaj (which is located just to the northwest), Jabal Habhab al Jissu, and Jabal Hadb ash Sharar are also somewhat anomalous. None of the anomalies seem large enough to merit detailed study, but the anomalous values at Jabal Minya indicate that this area, if it is chosen for detailed uranium studies, should be checked for rare-earth elements.

The average niobium content for the postorogenic granites is also similar to that of average granite, and it too has a large range and moderately large standard deviation. Two distinctly high values were noted at Hadb ad Dayahin, which may suggest some possibility for vein concentrations of niobium and tantalum in this area, but in general, the potential for deposits of these metals seem low.

Although the probability for yttrium (and associated rare-earth) deposits or niobium (and associated tantalum) deposits seems low, the data for samples from Baid al Jimalah and Jabal Silsilah suggest that these elements may be useful as pathfinder elements for other metals of interest. Contents of yttrium and niobium are elevated for most samples from these two mineralized plutons (table 2) and the average content for at least yttrium is high for the group of anomalously metalliferous plutons (table 4).

In addition to elevated yttrium and niobium contents, the average anomalously metalliferous samples exhibit several interesting features relative to average granite. In contrast to most of the postorogenic plutons, uranium, and to a lesser extent, thorium contents are anomalously high in the metalliferous plutons. This is shown graphically on figure 7<u>A</u> that shows that, compared to an average granite, most samples are enriched in uranium relative to both potassium and thorium, and enriched in thorium relative to potassium. Furthermore, the anomalously metalliferous samples also contrast with most samples of postorogenic granite in that they have RaeU/U values that are significantly different from 1 (0.86 ± 0.11). This feature suggests that the metalliferous plutons may have had some recent uranium mobility. Thus, in addition to the metals of interest identified in these plutons, they have some favorability for associated radioelement deposits. Alternatively, radioelements may be useful as pathfinder elements for metalliferous plutons; that is, anomalous radioelement contents and ratios may be used to select areas of exploration for several economically important metals.

The plutons grouped as anomalous have a distinctly low average K/Rb and a distinctly high average Rb/Sr. Both of these features are likely to develop as a result of a high degree of magma evolution (which is a low degree of partial melting, melting of an evolved protolith, a high degree of differentiation, or a combination of any of these mechanisms). This high degree of evolution is shown graphically (fig. 8<u>A</u>) by the tendency of data to plot along the K-Rb sideline and towards the Rb corner. Samples from four plutons of the east-central Shield plot in this same highly evolved region in the K-Rb-Sr diagram: Jabal Minya, Jabal Khinzir, Hadb ad Dayahin, and Jabal Khazaz (fig. 8<u>B</u>). The first three of these plutons are associated with geochemically anomalous wadi sediments (Moore, 1984), and the first two of these have been identified as anomalously radioactive as part of the current study. Although not identified by a separate symbol on figure 8B, samples from Suwaj (noted earlier because of their high yttrium contents) plot along the K-Rb sideline, just above the midpoint, and are therefore as evolved as many of the samples from the anomalous granites.

Stuckless, Hedge, and others (1984) have noted that K/Rb and Rb/Sr averages over seven and one-half minute areas form a regional pattern such that samples along the eastern margin of the Shield have generally higher Rb/Sr and lower K/Rb values than samples further west. Data for individual samples yield a somewhat equivocal pattern (figs. 9 and 10), but most of the high Rb/Sr values plot toward the east edge of the area studied, and most of the high K/Rb values plot towards the west of these samples. The degree of alumina saturation provides a more striking east-west pattern (fig. 11). All of the strongly peraluminous samples were collected east of longitude 43°15' E, and the peralkaline samples were all collected west of longitude 41°15' W. Most of the metaluminous samples were collected between these two longitudes, although some of the metaluminous granites were collected from the same plutons as the peralkaline granites, and thus there is no clear cut boundary between these two varieties.

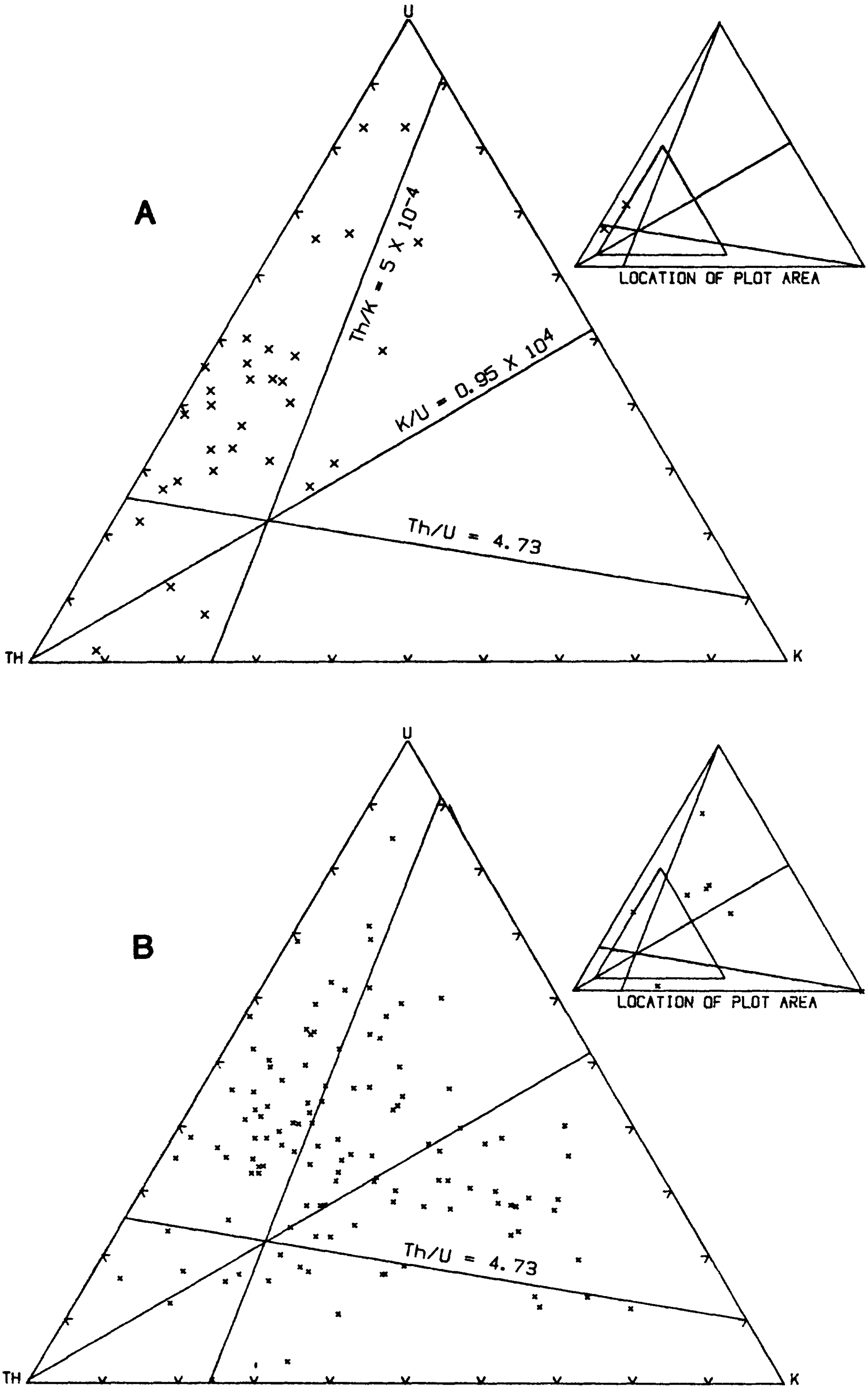

Figure 7.--*Ternary diagram showing relative proportions of uranium, thorium, and potassium relative to average granite (Stuckless and VanTrump, 1982) for anomalously metalliferous granites (A) and postorogenic samples from the east-central Shield (B). Insets show the expanded portion of the diagram as well as data points that plot outside the expanded portion.*

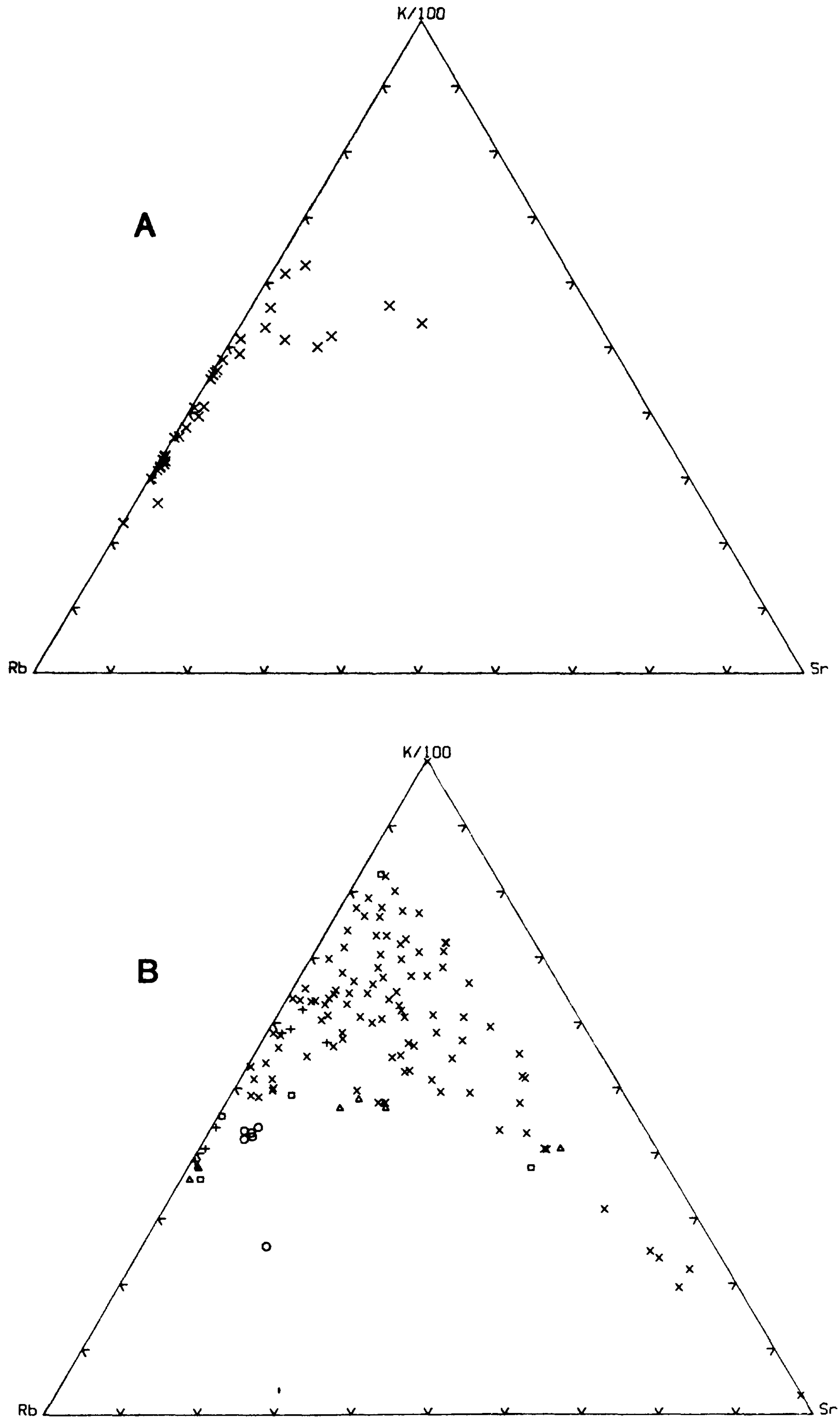

Figure 8.--*Ternary diagram showing relative proportions of potassium, rubidium, and strontium for anomalously metalliferous samples (A) and postorogenic samples from the east-central Shield (B). Symbols in part B indicate samples from Hadb ad Dayahin (squares), Jabal Minya (circles), Jabal Khinzir (triangles), and Jabal Khazaz (plusses).*

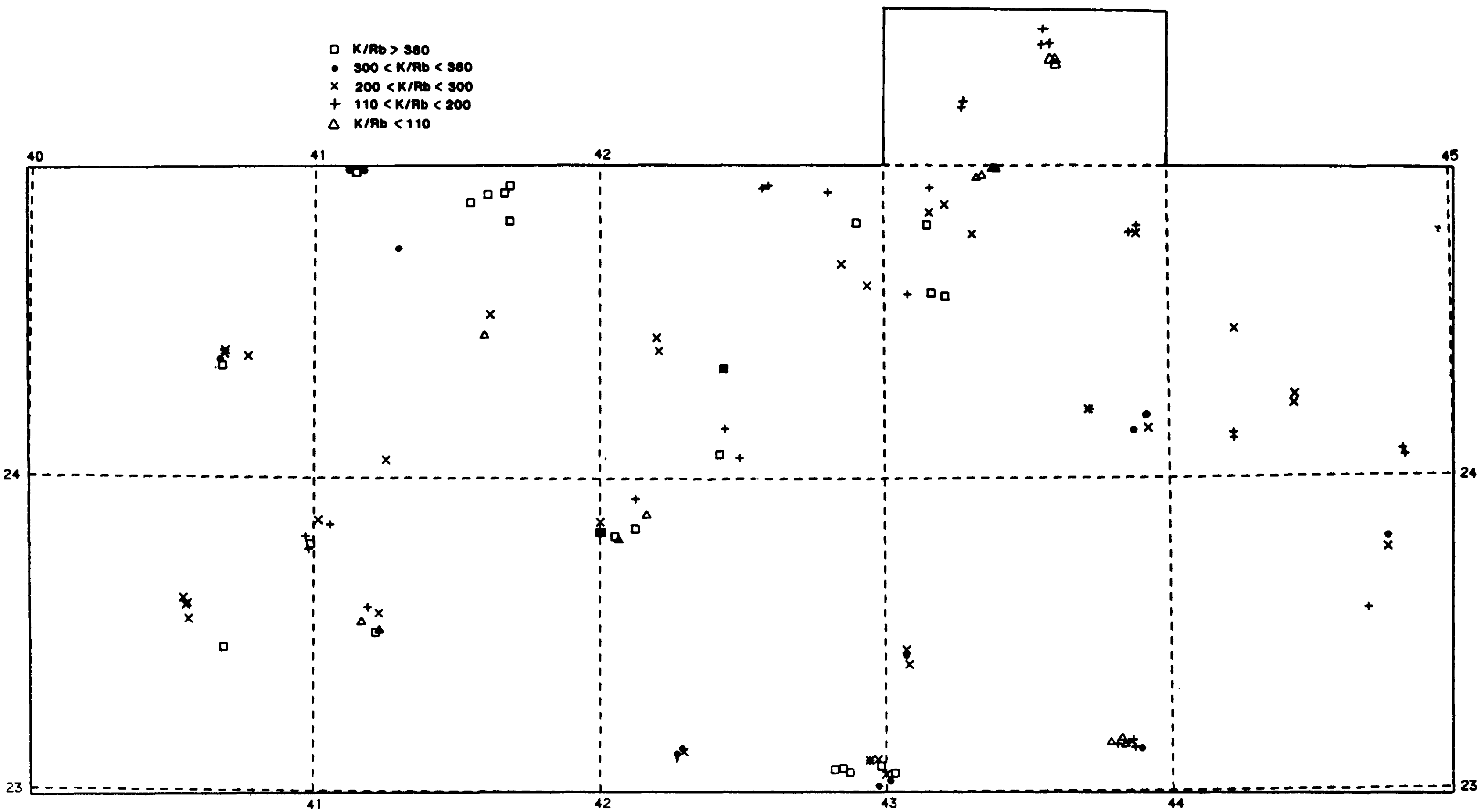

Figure 9.--*Map showing the distribution of K/Rb values for postorogenic samples from the east-central Shield.*

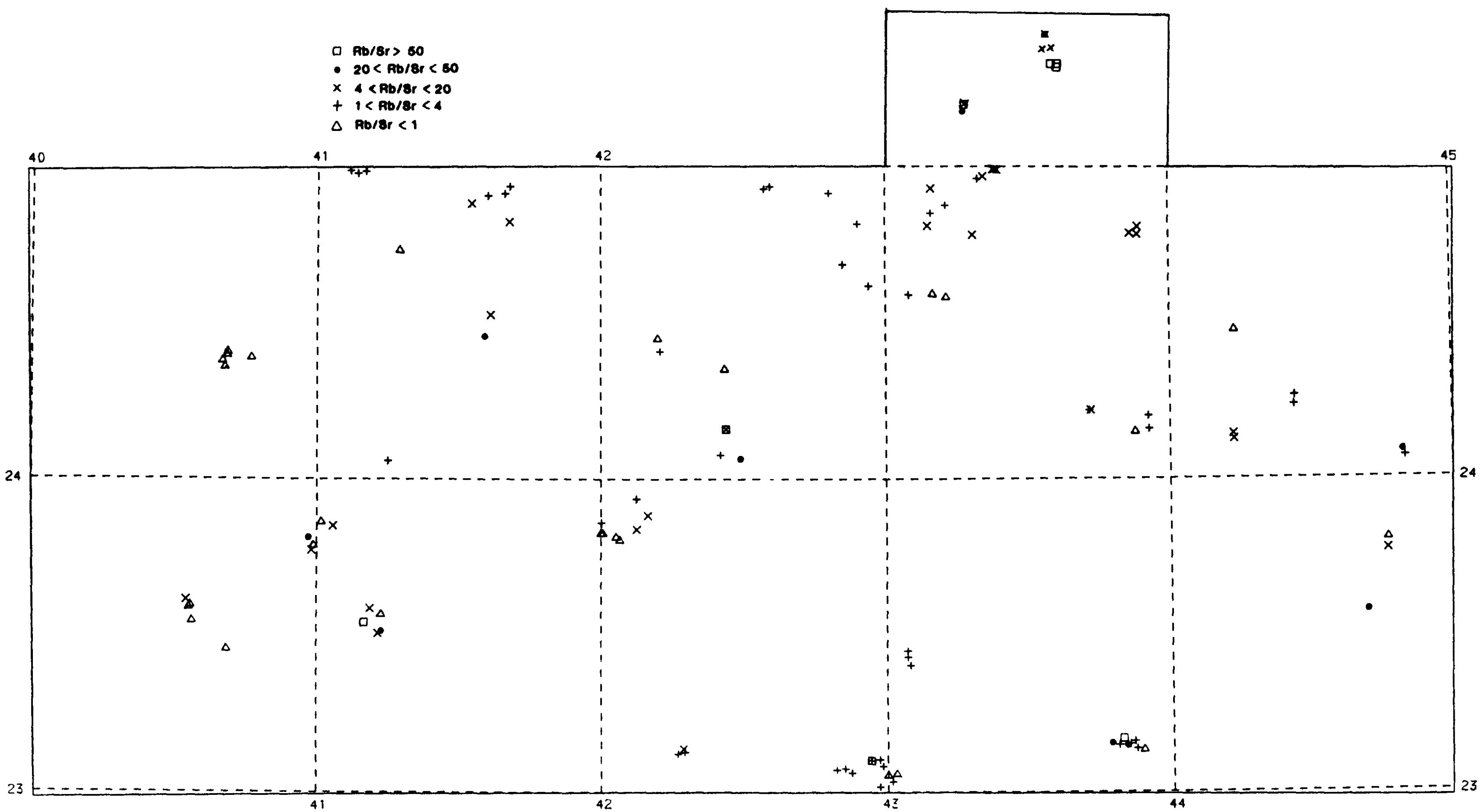

Figure 10.--*Map showing the distribution of Rb/Sr values for postorogenic samples from the east-central Shield.*

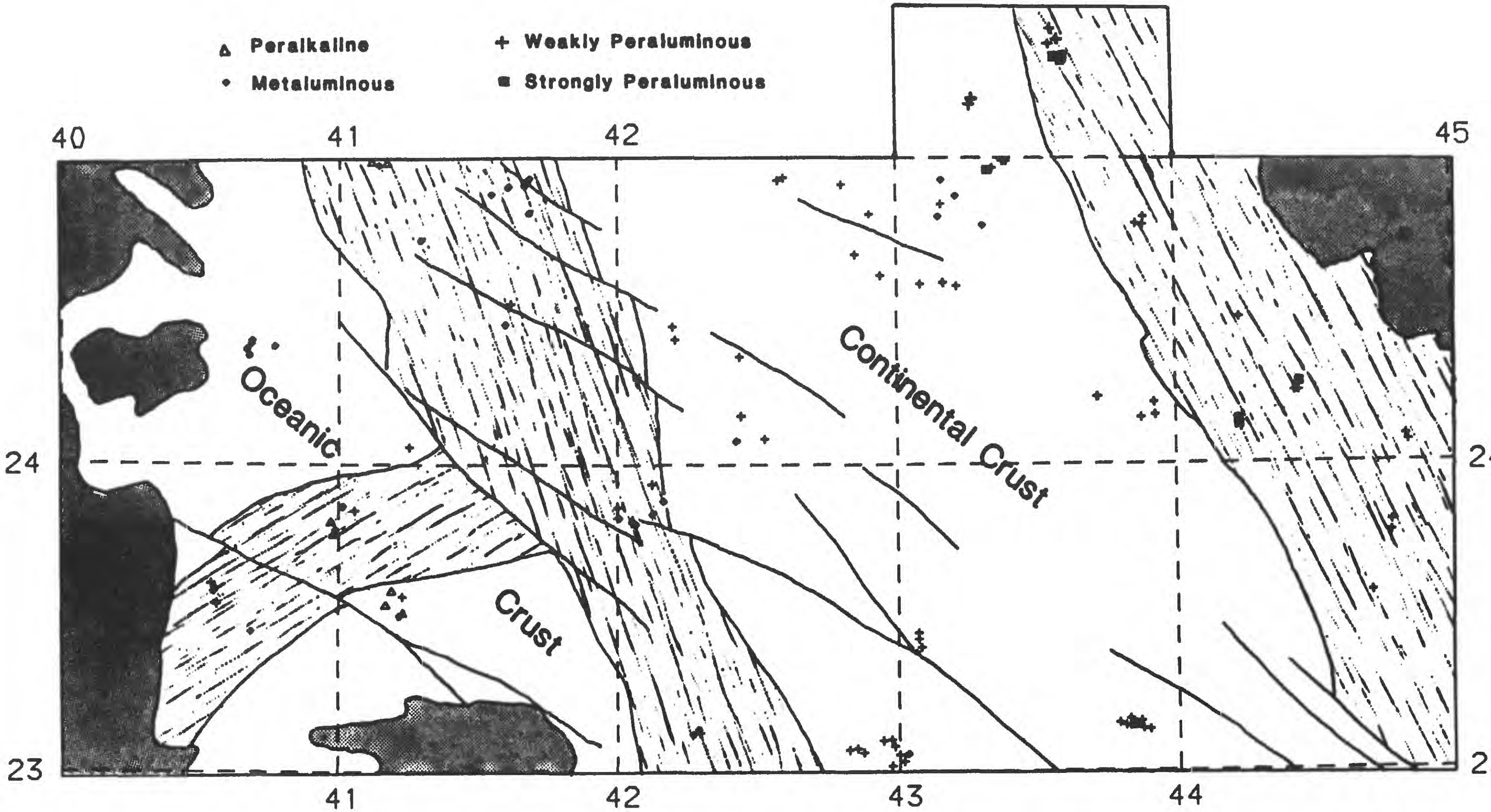

Figure 11.--*Map showing degree of alumina saturation for samples from the east-central Shield relative to the position of accretionary terranes of Stoeser and Camp (1985). Phanerozoic cover rocks are shown by grey stipple pattern; orogenic belts are shown by grained pattern; and accreted terranes are unpatterned.*

Stuckless, Hedge, and others (1984) have suggested that the general east-west patterns reflect gradational changes in the protolith of the postorogenic granites. The gradational change is attributed to the mixing of sediments that were dominantly of continental affinity to the east and dominantly of oceanic affinity to the west. Alternatively, the changes in protolith chemistry may have developed by microplate accretion as proposed by Stoeser and Camp (1985). The data obtained in the current study do not provide a clear distinction between these two models. Both models call for continental materials to the east, and such materials might well be pelitic or other peraluminous material, thereby accounting for the limited distribution of strongly peraluminous, postorogenic plutons (fig. 11). Both models place oceanic materials to the west, and these materials might well give rise to the postorogenic rocks that have high K/Rb values (fig. 9). However, the rest of the data seem more consistent with a gradational change as opposed to the relatively sharp boundaries that might reasonably develop as a consequence of an accretionary model.

The degree of alumina saturation is compared with the accretionary terranes proposed by Stoeser and Camp (1985) on figure 11. The strongly peraluminous samples are restricted to terranes of continental material or the suture between two continental blocks, but there is a considerable area underlain by continental material that did not produce any strongly peraluminous granites. The metaluminous samples would have been derived from oceanic terrane, a mixed terrane, and part of the continental terrane; however, they were not derived from other parts of the continental terrane. Finally, the peralkaline rocks would have been derived from oceanic terrane, the suture between two oceanic terranes, and the suture between oceanic terranes. Because all of the peralkaline localities are near terrane boundaries, appropriate assumptions about dips of terrane boundaries and depth of magma generation might allow all of the peralkaline rocks to be derived from a single terrane. However, peralkaline rocks crop out just north of the study area at Jabal Aban al Ahmar ($42^{o}45'$ E and $25^{o}45'$ N, Stuckless, VanTrump, and others, 1982) and these would have to be derived from a purely continental source. Thus, if the chemistry of the postorogenic granites is a reflection of protolith chemistry, an accretionary model, as currently proposed, does not seem to explain regional chemical variations as well as the model that calls for a mixing of sediments derived from two contrasting terranes.

PETROGENIC CONSIDERATIONS

The position of data points in the Q-Ab-Or system scatter widely (fig. 2), but if the compositions can be interpreted as equilibrium cotectic liquids, some of the less evolved samples may represent melts that formed at a pressure of about 10 kb. Because most of the points plot to the right of the polybarric minimum, these primitive melts must have been water-undersaturated (Luth, 1969). Most of the more evolved samples appear to have re-equilibrated at much lower pressures and at or near water-saturated conditions (figs. 2 and 3). Pressure estimates of 0.5 to 2 kb suggest shallow depths of emplacement, which is consistent with these plutons as a source for the late Precambrian silicic volcanic rocks.

If the initial melts were water undersaturated, they must have been fairly hot relative to typical crystallization temperatures of granites (Luth, 1969). Recent experimental work by Watson and Harrison (1983) has shown that zirconium saturation is a function of temperature and bulk chemistry. The chemical variable is expressed as the cation ratio M, which is defined as (Na+K+2xCa)/(AlxSi). The value of M for samples analyzed in the current study (table 1) is plotted against zirconium concentrations (table 2) on figure 12. Isotherms, which are based on the solubility of of zirconium, are superimposed on the plot. One sample (which is off the scale of fig. 12) plots near the 1020-degree isotherm, but most of the samples indicate a maximum equilibration temperature of 920° C.

Collins and others (1982) have postulated that A-type (anorogenic) granites are derived from a source material that has yielded granitic materials during an earlier event and that as such, melting temperatures should be in excess of 850° C. However, more than half of the samples (80 of 127) suggest equilibration below a temperature of 800° C. Samples from Jabal Silsilah and Baid al Jimalah, which from both major- and trace-element element data appear to represent end-stage products of extensive differentiation, plot near the solidus temperature of a water-saturated granite at low pressure. Thus, the temperatures of less than 800° C probably do not represent initial melt temperatures, but rather they reflect partial to complete re-equilibration at the temperature of the granite solidus under water-saturated conditions. This type of reequilibration is probably responsible for most of the spectrum of temperatures indicated on figure 12, and thus, most of the initial melts may have been as hot as 920° C.

There is a great volume of postorogenic granite in the eastern Arabian Shield. This volume and the very high temperatures postulated here to make those granites indicate that a very large amount of heat was transferred into the lower crust. Some of the heat may have been provided by decay of radioactive elements in the source region, and the generally elevated uranium contents of the postorogenic granites suggest that the source region may have been enriched in that element; however, this heat source alone could probably not have caused such extensive melting. Most of the heat needed to form the postorogenic granites may have been introduced by the intrusion of magma from the mantle.

Mantle intrusions may have occurred in response to relaxation and consequent tension following the orogenic period. A rift environment existed several hundred kilometers to the west (in Egypt) during the time of intrusion of the postorogenic granites (Stern and others, 1984), and within the rift, mantle-derived igneous rock is abundant. Although not common, young gabbroic intrusions are known throughout the eastern Shield (Fleck and others, 1980), and gabbro is intimately associated with the intrusion at Jabal Abha (sample 184374, table 1). Thus, the heat needed to drive the postorogenic event may have been mantle derived.

The fact that the postorogenic granites formed and evolved under similar physical conditions does not imply that all of the plutons have a simple genetic relationship to one another. In fact, an accretionary model could be consistent with abrupt changes in the character of the protolith at points that roughly correspond to the change from strongly peraluminous to metaluminous granites and in the region where peralkaline rocks occur. Such boundaries would obviously be different from those shown on figure 11, and their existence would preclude any type of common genesis that might relate all of the plutons to each other. In contrast, a mixed-sediment source would allow an indirect genetic relationship. If pressures and temperatures, at which magmas were formed, were fairly uniform throughout the source region, the resulting magmas would be part of a continuum that would approximate a two end-member system.

Stuckless, Nkomo, and Wenner (1982) reported that results of Q-mode analysis were consistent with a genetic relationship for 17 plutons in the north-eastern Shield. High correlation coefficients for several element pairs (table 5) suggest that a similar relationship for plutons from the east-central Shield is allowed. Good correlations between major elements does not constitute evidence for a genetic relationship because it can be documented that the plutons formed and evolved under similar physical conditions, and the variations in major elements are strongly controlled by intensive variables. However, variations of trace elements are controlled by partitioning coefficients for specific mineral phases. Thus the good correlation coefficients between certain major and trace elements, such as CaO or MgO and Sr or between seemingly unrelated trace elements such as rubidium and uranium (table 5) suggest some sort of genetic link amongst the various plutons. A protolith formed by the mixing of two sedimentary components (one continental derived and the other oceanic) would be consistent with this interpretation.

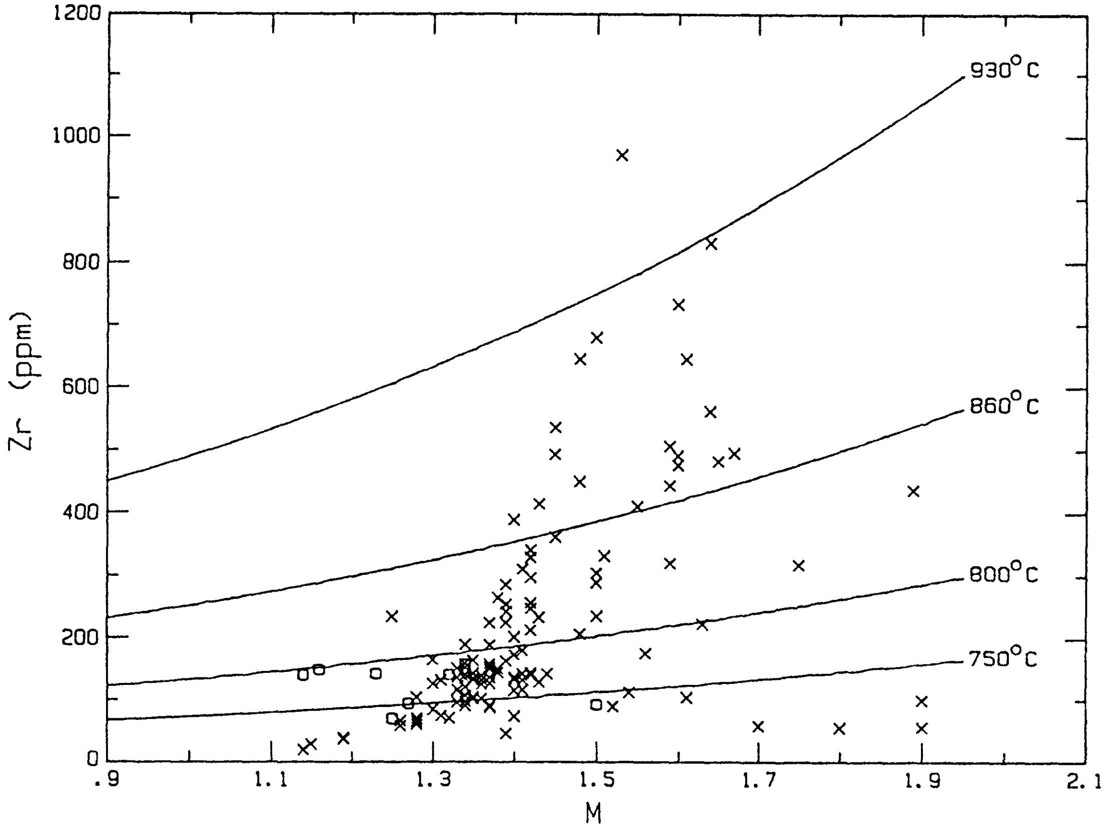

Figure 12.--*Plot of the cation ratio M [(Na+K+2xCa)/AlxSi] versus zirconium content for postorogenic samples from the east-central Shield with superimposed isotherms from Watson and Harrison (1983). Samples from Baid al Jimalah and Jabal Silsilah are represented by squares.*

SUMMARY AND CONCLUSIONS

Major- and trace-element data presented in this report show that four of the postorogenic plutons in the east-central Arabian Shield are similar to known metalliferous plutons elsewhere in Saudi Arabia. We recommend that Jabal Minya, Jabal Khinzir, Jabal Khazaz, and Hadb ad Dayahin be studied in detail. Inasmuch as current investigations have not found areas of strong mineralization, we further recommend that examination of these areas include geophysical techniques capable of examining the subsurface. Cupolas associated with these highly evolved granites would be the most favorable environment for deposits of several different metals of interest, and such cupolas may not be exposed at the current level of erosion.

Regionally high uranium values for the postorogenic granites suggest that the east-central Shield is within a uranium province. The plutons at Jabal Minya and Jabal Khinzir are particularly enriched in uranium relative to an average granite; however, no samples were collected as part of the current study that approached economic grade. Secular equilibrium between uranium and RaeU and low Th/U values suggest that uranium has not been mobilized since crystallization of the granites, and therefore the probability for secondary uranium deposits associated with the postorogenic granites is low. The enrichment of uranium relative to thorium further suggests that uranium distribution is magmatically controlled and that pegmatitic or hydrothermal concentrations of uranium would be the most likely forms of mineralization. Such types of mineralization would most likely be associated with the four highly evolved plutons noted above.

If the compositions of the rocks are interpreted as approximating equilibrium liquids, some of the samples preserve evidence of melting at high pressure (-10 kb), moderate temperature (-900^{o} C), and water-undersaturated conditions. Alternatively, melting may have proceeded past the disappearance of a sodium phase, in which case lower pressures may have prevailed. Other samples indicate final conditions of crystallization at low pressure (0.5 to 1 kb), low temperature (-700^{o} C), and water-saturated conditions. The latter are the most evolved and include plutons with known mineralization. The introduction of basaltic magma from the mantle seems like the best source of heat for generating the postorogenic plutons.

In spite of modifications to the chemistry of individual samples that must have occurred as a result of differentiation, regional trends are preserved that are interpreted to be the result of lateral variations in the protolith. Such variations are best explained by the mixing of sediments that formed the protolith such that peraluminous and evolved rocks in the east were formed by partial melting of dominantly continental-derived sediments whereas unevolved rocks and peralkaline rocks in the west were formed by partial melting of dominantly oceanic-derived sediments. This interpretation suggest that the paleoenvironment of the east-central Shield was similar to a back arc rather than accreted terranes.

DATA STORAGE

Data and work materials used in preparation of this report are archived as data-file USGS-DF-05-8, which is stored at the office of the U.S. Geological Survey Mission in Jeddah, Saudi Arabia. No Mineral Occurrence Documentation System (MODS) localities were established in connection with work on this report.

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