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Mineralogical determination of heavy minerals in beach sands, Cape Mountain district, Seward Peninsula, Alaska

by

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INTRODUCTION

Most of the tin that has been produced in the United States has come from the Seward Peninsula, Alaska. Streams in the Cape Mountain district produced 700 tons of tin concentrate from 1933 to 1941 (Heide and Sanford, 1948). At Cape Mountain, located at the westernmost tip of the Seward Peninsula, a 78.8 Ma, coarse-grained, biotite granite intruded a Mississippian limestone which is in thrust contact with Precambrian slates, silitites, and graywackes (Sainsbury, 1972). Village Creek, which flows along the granite-limestone contact, drains the eastern slope of Cape Mountain and has produced placer cassiterite originally derived from lodes near the limestone-granite contact. Placer deposits from Cape Creek produced coarse grained cassiterite and occasional cassiterite boulders that weigh more than 30 pounds (B. Reed, Written communication, 1988).

A barrier beach extends north, then northwest from Cape Mountain. The U.S. Bureau of Mines drilled the gravel bars in the district to evaluate the potential for finding new resources; they found some additional tin reserves along creeks of the northern slope of Cape Mountain (Heide and Sanford, 1948; Mulligan and Thorne, 1959). Samples analyzed in this study were collected at the mouth of Village Creek and along the beach or in the back-beach area of off-shore bars, as indicated in Table 1.

PROCEDURE

Six representative samples of beach sands were collected from the barrier beach that extends north from Cape Prince of Wales (fig. 1, table 1). Each sample contained approximately 0.22 cubic feet of sand (the content of two 14" gold pans, except sample 23298 which contained one panful, or 0.11 cubic feet). The heavy mineral portion of the sample was obtained by immersing the panned black sands in tetrabromoethane (specific gravity 2.95) and retaining the heavy portion for detailed study. Each heavy mineral concentrate was further separated into magnetic fractions using a Franz magnetic separator[1], and each magnetic fraction was given a letter designation a-f. The chute orientation and magnetic strength settings of the magnetic separator for each fraction, and the weight and weight percent of each fraction, are given in table 2 and fig. 2.

Mineralogical analyses of the samples were made by optical and x-ray identification. Minerals were handpicked, identified, and counted using a polarizing stereobinocular microscope. Identification of mineral species was confirmed by x-ray diffraction using powder and Gandolfi camera techniques. Between 400 and 1,000 grains of each magnetic fraction of each sample were identified and counted. Each sample included approximately 3,500 to 4,000 grains.

MINERALOGICAL IDENTIFICATION

The mineralogical identification of the components in each magnetically separated fraction of each sample is in Tables 3-8 and is summarized in Table 9. Data are in percent of total grains. Minerals were identified by species or mineral groups; they are discussed below with the abbreviations used to designate them in Tables 3-9. The grain size of all samples (Wentworth

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[1] The use of trade names is for descriptive purposes only. The U.S. Geological Survey does not endorse specific brands.

nonmenclature), is "very fine" except sample 23292, collected at the mouth of Village Creek, which was "fine" with 10-15% "medium-coarse" to "coarse." Samples 23961 and 23964 are better sorted than the other samples.

Magnetite (Mt)

Magnetite is the only mineral identified by its magnetic properties alone. Separation was done with a hand magnet.

Opaques (Op)

The group of minerals classified as opaques included those black, opaque minerals that were not further identified and separated. Pyrophanite is most abundant in fraction a; ilmenite is most abundant in fraction b; and chromite is most abundant in mineral fraction c. Chromite typically is enhedral and some are translucent and may appear red near the edges. Sample 23292 contains large, angular grains of wolframite in fraction e and ferberite in fractions d and e, and geikielite in trace amounts in fraction f. Sample 23966 includes some of the rare mineral galaxite in magnetic fraction f; it is charaterized by a blood-red reflection.

Leucoxene (Lx)

This mineral group includes all earthy to porcelaneous off-white, opaque, heavy minerals. The majority are rutile-quartz and anatase-quartz binary grains with varying amounts of iron staining. Some goethite and martitie is included, most notably in sample 23292.

Rutile (Rt)

Rutile is red, black, and honey yellow. Black rutile is distinguished from opaque minerals by its characteristic luster, prismatic form, and vertical striations.

Anatase, brookite, and rutile (Ana)

Sample 23292 contains anatase that has a fusiform crystal shape with step-like ridges on pyramidal faces. It is light bluish grey and is translucent.

Rutile-quartz (Rt-Q)

This group includes grey grains that appear to be rutilated quartz. Some may be recrystallized leucoxene.

Cassiterite (Cass)

Cassiterite is rare. In sample 23292, it is colorless to pink and has extremely weak pleochroism.

Titanite (Tit)

Titanite varies in color. Most is light honey-colored and smoky with an orange to ochrish tint, but it is also present in resinous red, brown, grey, and even colorless. Many smoky grey titanite grains are the yttrium variety.

Orthorhombic pyroxene (OPx)

The more magnetic fractions, a to c, tend to contain hypersthene that is distingusihed by red and green pleochroism. The relatively non-magnetic fractions contain chiefly colorless enstatite that is distinguished by its prismatic cleavage and parallel extinction. Minor quantities of forsterite are included in the OPX catagory.

Clinopyroxene (CPx)

Monoclinic pyroxenes are generally lath-shaped, sometimes with a distinct cleavage, and range widely in color, being orange, ochre, brown, honey yellow, green, grey, and black. Diopside is the most abundant variety but augite and pigeonite are present. Most clinopyroxene is in the fraction d. Sample 23292 contains abundant colorless diopside in fractions e and f that is notably larger, angular and tends to fluoresce faint white in ultraviolet light; this may be due to some binary scheelite or powellite.

Amphibole (Amp)

Green hornblende is the most abundant amphibole. Black hornblende is conspicuous by its cleavage and absorption colors in polarized light. Colorless tremolite, distinguished by its low extinction angle and color, is present in the non-magnetic fractions. Minor arfvedsonite is present in sample 23292.

Garnet (Gt)

Many varieties of garnet are present. Spessartite tends to be shades of pink and is more magnetic than the other garnets. Almandine is generally grey and is present as small, euhedral grains. Grossularite is colorless and non-magnetic.

Clinozoisite (CZo)

Clinozoisite is chiefly white, opaque, sometimes iron-stained, polycrystalline mineral aggregates which are generally well-rounded and frosted. Occasional translucent grains are present. Clinozoisite is characteristically non-magnetic and concentrated in the fractions c and d.

Epidot (Ep)

Epidote is yellow; it generally is present in fractions b, c, and d.

Chloritoid (Chtd)

Chloritoid is present as deep olive, bluish-green, brittle plates which generally are present in fraction c, but also in fraction a and b.

Vesuvianite (Ves)

Vesuvianite is present as colorless, euhedral crystals; x-ray diffraction indicates they are the ferroan variety. The crystals generally occur in fraction d, but are also present in fractions c and e.

Pumpelleyite (Pump)

Most pumpelleyite is jade-green or bi-colored, with one end of the grain ocher and the other end green. Most pumpelleyite is in fraction c, but it also occurs in fractions b and d some pumpelleyite is present as binary grains with quartz.

Tourmaline (Tm)

Tourmaline is commonly black to smoky-brown-black dravite. Sample 23292 is an exception because purple or blood-red colored uvite is twice as abundant as dravite.

Staurolite (St) and Aluminum silicates (Al-Si)

Staurolite and metamorphic aluminum-silicate minerals are present in trace amounts, but occur together. Kyanite is more abundant than sillimanite, which is more abundant than andalusite.

Scheelite and powellite (Sch-Pow)

Large, angular grains of colorless scheelite-powellite fluoresce bluish-white; the scheelite fluoresces more intensely than powellite. In many cases these minerals occur with wolframite and ferberite.

Apatite (Ap)

Most apatite is present as rounded, frosted, milky-white fluoro-apatite. Carbonate-apatite occurs as rounded, shiny, black to dark tan grains often with grey phosphorite. Some hydroxyl apatite is present. The apatites are concentrated in the nonmagnetic fraction f, but also occur in e.

Xenotime (Xm)

Xenotime occurs as translucent milk- to off-white, euhedral grains. They are characterized by the presence of two pyramids on a lens-or-square-shaped tetragonal crystal. The milky appearance may be due to the presence of uranium. Xenotime is present exclusively in fraction c.

Monazite (Mz)

Monazite grains are generally yellow to golden-yellow lath-shaped, and euhedral. They usually have a blunt pyramidal termination and concentrate in fractions c and d.

Zircon (Zr)

The hyacinth variety of zircon forms 25 to 30% of the zircon, and pink colored. The malacon variety forms 15% and occurs as well-rounded, translucent, honey-colored grains. Zircons in sample 23292 are almost entirely euhedral malacon prisms. Pure zircon is in the nonmagnetic fraction f, but owing to the common presence of magnetite inclusions, it is present in other fractions as well.

Micaceous Minerals (Micac)

Micaceous minerals are present almost exclusively in sample 23292. They occur as large flakes of biotite as well as minor quanities of muscovite and chlorite.

Others (Ot)

This catagory includes single and binary grains of quartz and feldspar that were not removed during heavy-liquid separation. It also includes unidentified particles lacking diagnostic criteria that can be readily used for identification. Grains that are present include trace amounts of prehnite, hedenbergite, richterite, cummingtonite, piedmontite, allanite, greenalite, chantalite, chondrodite, crandelite, siderite, hercynite, and volcanic glass.

Semiquantative emission spectrographic analyses were done on the suite of samples and the results are given in Table 10. The analyses were done on a representative split of the sample from which the minerals lighter than tetrabromoethane had been removed. The samples in table 10 were divided magnetically into 3 parts before analysis. The sample number suffix that ends in 200 is equivalent to the fraction a, 201 is equivalent to the combination of the b, c, and d fractions, and 202 is equivalent to the e and f fractions.

DISCUSSION

Detrital heavy minerals can provide information about source rocks and geologic processes, especially where the source rocks are covered or the geologic processes that supplied and concentrated the minerals are active intermittently or are no longer active. Heavy mineral suites may also provide information about potentially economic commodities.

Sample 23292 from Village Creek contains a suite of minerals that apparently reflects the contact metamorphic mineralogy of the rocks near the headwaters of the creek. It is the only sample containing more than a trace amount of cassiterite and high contents of tungsten. Diopside, scheelite, woldramite, powellite, vesuvianite and minor cassiterite suggest the presence of scheelite and cassiterite-bearing skarn mineralization. The euhedral zircon, monazite, apatite and micaceous minerals reflect the close proximity and provenance of the granite.

The economic considerations of only trace quanities of cassiterite in a stream draining a known cassiterite provenance should be considered. Although cassiterite is a resistant mineral in the surfacial environment, it may not be present, in a form or concentration that would be detected by mineralogical analysis of panned stream samples, at the mouth of a stream draining a known source or along a barrier beach formed in the down-current direction from the stream. In this case, it may be that the coarse size of the cassiterite crystals or aggregates of crystals (up to 20 cm diameter, Heide and Sanford, 1948), together with cassiterite's high density, inhibited movement far from the source. In addition, the very fine-grained nature and sorting of the samples from the barrier beach show that they have been extensively moved by wind and water, and probably cassiterite has been the least effected. Tin, however, is detectable in several of the samples by emission spectrographic analysis as shown in Table 10 and is most abundant in sample 23292. This suggests that spectrographic analysis may reveal tin to be a trace to minor constituent in magnetite or garnet as solid solution. Other minerals have significant changes in their abundance that correspond to the position of the sample site. Increases in titanite, epidote, and garnet northward from the stock, together with commensurate decreases in clinopyroxene and amphibole reflects the relative stabilities of these minerals in the placer and near-shore marine environments. The increase in pumpelleyite northward probably reflects its source in the Precambrian metamorphosed sedimentary rocks.

Table 11 lists the selected mineral contents of each sample with the corresponding analyzed chemical constituents and the approximate correlation is obvious. Based on the chemically analyzed tin value, sample 23292 contains 0.16 weight percent cassiterite. Calculated from mineral grain-count, the sample should yield 0.03 lbs. cassiterite, 0.2 lbs. scheelite-powellite, 0.04 lbs. xenotime, and 0.03 lbs. monazite. These figures have large statistical errors.

U.S. Bureau of Mines drill-data (Heide and Sanford, 1948, Mulligan and Thorne, 1959) estimate the following tin values in lbs/cu yd for mining sections: Goodwin Creek 0.0X to 0.X with a maximum 7.74, and Boulder Creek 0.X to 1.5 with a maximum 4.8. Only three holes were drilled in the Village Creek area and the tin values in the panned concentrates were not given and thus assumed to be low. If we use the overall average tin values in the concentrate of the adjacent Creek, the mining section in the headwaters of Village Creek should yield 0.0X-0.X lbs/cu yd tin with a maximum of 0.35 lb/cu yd.

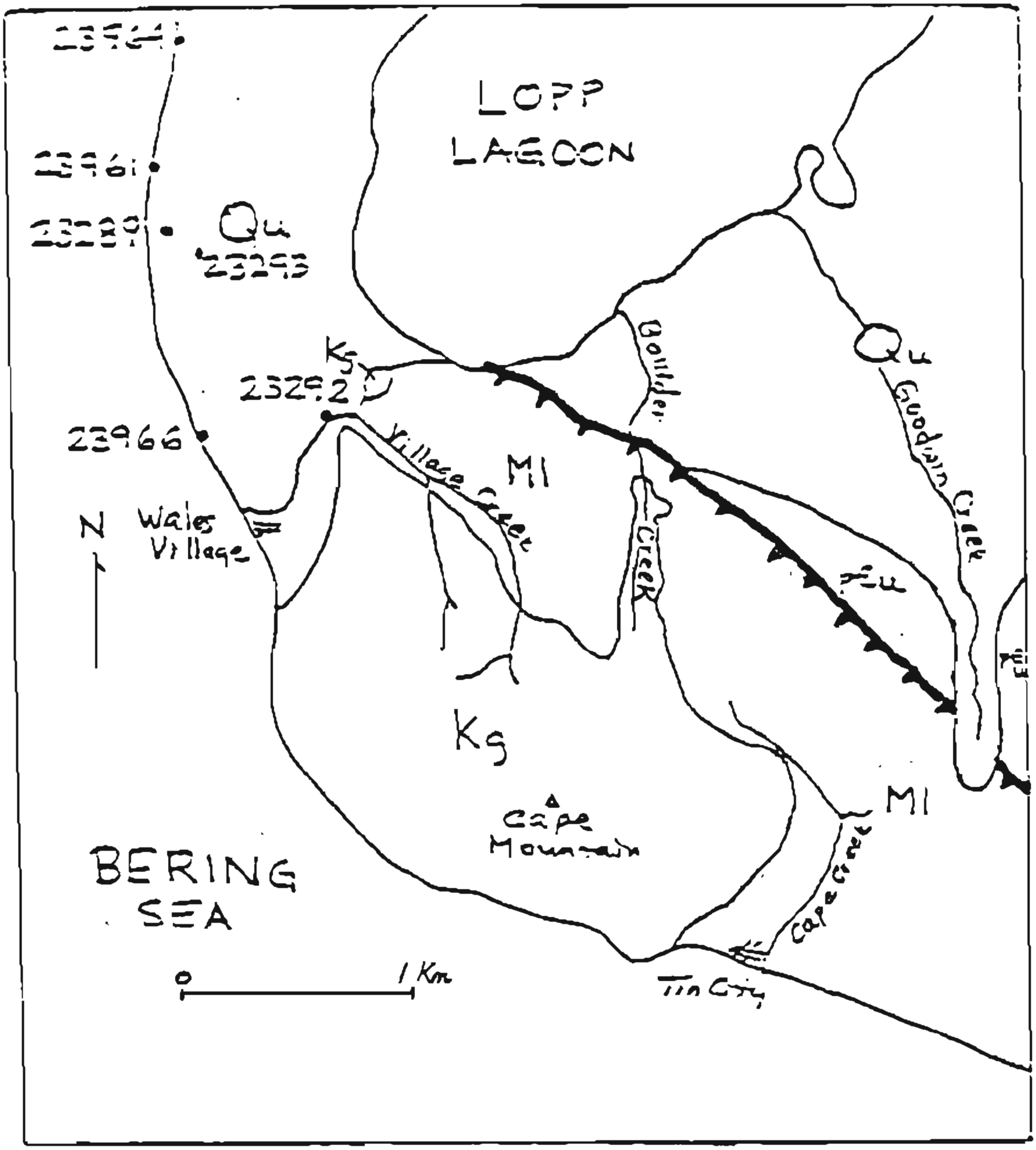

Figure 1.--Simplified geologic map showing sample locations at the western tip of the Seward Penisula. Modified from Heide and Sanford (1948) and Sainsbury (1972). Geologic symbols used are: pCu = Precambrian undivided, Ml = Mississippian limestone, Kg = Cretaceous granite, Qu = Quaternary undivided. The ticked line is the position of the Wales thrust fault; the ticks are on the upper plate.

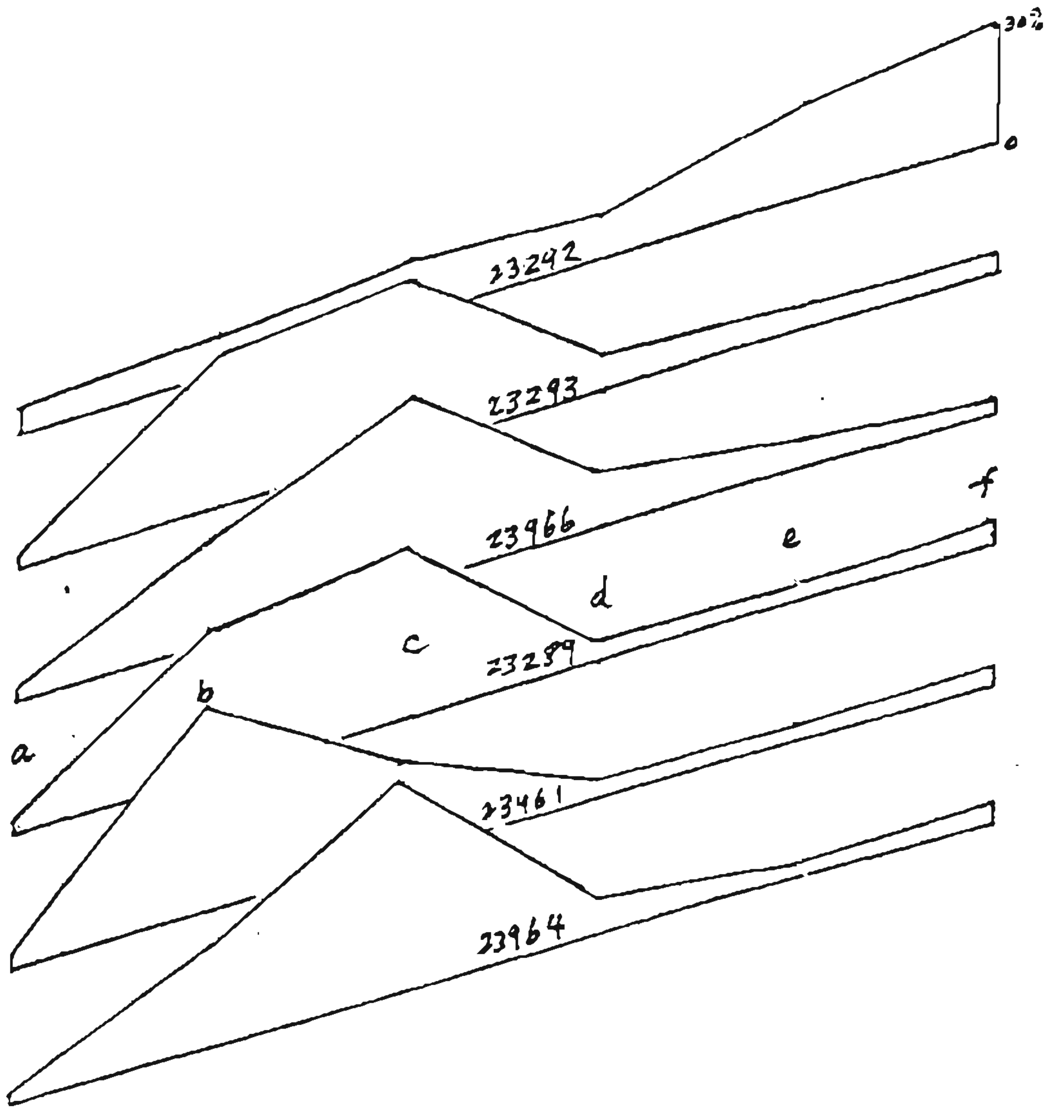

Figure 2. -- Weight percent diagram of magnetic separated fractions a to f; data from table 2.

Table 1.--Location of samples selected for detailed mineralogical analysis. Sample locations are on the westernmost tip of the Seward Peninsula, Alaska.

Sample No.	Latitude	Longitude	Heavy mineral %	Elevation/field notes
23292	65.223N	168.022W	0.2	~ 10 ft. above sea level, mouth of Village Creek/left limit of Village Creek before entering a gravel pit
23293	65.227N	168.038W	0.3	0.4 km in back of beach, 3.1 km N of Cape/ 3.5' cut above frozen ground
23966	65.223N	168.022W	0.5	On upper beach, 2.2 km N of Cape/upper beach at depth 1.5' from a back lagoon outlet
23289	65.222N	168.042W	0.8	0.2 km in back of beach, 3.6 km N of Cape/ below 6" of eolian sand at the storm wash line
23961	65.233N	168.044W	0.5	On back beach, 5.3 km N. of Cape/between back beach and dune
23964	65.238N	168.041W	1.5	On upper beach, 7.4 km N of Cape/channel cut between 6" to 18" depth including a 3" black sand strip

Table 2.--Weight and weight percent of magnetic fractions of heavy mineral samples. Sample portion "a" was the grains adhered to the wall of a vertical glass tube at maximum magnetic strength. Those free fall grains were further separated with the Franz separator having a tilt of 19° and a slope of 20° into b, c, d, e, and f. Upper number is weight in grams; lower number is weight percent.

Sample No.	Magnetic fractions						Totals
	a	b	c	d	e	f	
Cutting edge magnetic strength in amp.		0.2	0.4	0.6	1.8		
23292[1]	0.33 8.27	0.41 10.27	0.58 14.54	0.45 11.28	0.99 24.81	1.23 30.83	3.99 100.0
23293	0.26 2.61	3.94 39.6	4.15 41.71	0.65 6.53	0.50 5.03	0.45 4.52	9.95 100.0
23966[2]	0.47 3.17	4.11 27.75	7.28 49.16	1.54 10.4	0.77 5.2	0.64 4.32	14.81 100.0
23289[3]	0.55 4.4	4.75 37.97	5.59 44.68	0.53 4.24	0.5 4.00	0.59 4.72	12.51 100.1
23961	0.73 4.37	9.14 54.67	4.58 27.39	0.78 4.66	0.62 3.71	0.87 5.2	16.72 100.0
23964	1.48 3.5	11.09 26.4	21.23 50.5	3.82 9.1	2.00 4.7	2.42 5.8	42.05 100.0

[1] 0.14 >18 mesh not included

[2] 0.58 gm >18 mesh not included

[3] 0.37 gm >20 mesh not included

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Table 10.--Emission spectrographic analyses of magnetic fractions of heavy beach sands from the western most tip of the Seward Peninsula, Alaska. See text for sample preparation information. Analyst is C. Skeen, Plate Recorder is W. B. Crandell, and Project Leader is A. F. Dorrzape, USGS.

SAMPLE NO	A 23961	2-6	1.8-7.1B	23964			23966		
FIELD #	SP23961-200	SP23961-201	SP23961-202	SP23964-200	SP23964-201	SP23964-202	SP23966-200	SP23966-201	SP23966-202
SAMPLE	W-235497	W-235498	W-235499	W-235500	W-235501	W-235502	W-235503	W-235504	W-235505
SPECTRUM	4	5	6	7	8	9	10	11	12
SI %	7.1	9.5	7.6	3.9	8.6	10	3.7	7.0	10
AL %	3.2	2.3	1.1	1.3	2.1	2.4	1.9	2.4	1.6
FE %	5.0	5.2	0.46	12	5.3	0.61	11	5.4	0.71
MG %	1.7	3.2	0.38	0.47	2.8	0.55	0.57	2.3	0.79
CA %	2.5	4.6	4.7	0.77	3.8	4.7	0.91	2.1	7.9
NA %	< 0.15	0.069	0.086	< 0.15	0.073	0.11	< 0.15	0.079	0.085
K %	< 0.15	0.11	0.17	< 0.15	< 0.15	0.13	< 0.15	< 0.15	0.10
TI %	2.4	0.44	6.4	2.7	0.40	4.9	4.6	0.64	4.9
P %	< 0.068	< 0.068	0.31	< 0.068	< 0.068	0.19	< 0.068	< 0.068	0.32
MN %	1.4	0.52	0.013	0.76	0.76	0.029	0.91	0.78	0.023
AG PPM	2.4	0.50	4.1	1.1	0.85	1.6	1.6	0.91	2.2
AS PPM	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 150
AU PPM	< 6.8	< 6.8	< 6.8	< 6.8	< 6.8	< 6.8	< 6.8	< 6.8	< 6.8
B PPM	< 6.8	68	< 3.2	5.5	49	25	< 6.8	42	37
BA PPM	14	16	650	12	17	480	14	11	370
BE PPM	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	6.7
BI PPM	< 10	< 10	67	< 10	< 10	< 10	< 10	< 10	< 10
CD PPM	< 32	< 32	< 32	< 32	< 32	< 32	< 32	< 32	< 32
CE PPM	240	590	500	< 43	460	510	< 43	500	530
CO PPM	33	22	6.9	20	18	4.1	29	20	4.9
CR PPM	> 6800	2700	160	1900	2900	300	2800	2300	240
CU PPM	5.0	4.2	3.1	4.2	4.0	4.2	5.8	4.2	4.5
DY PPM	< 22	< 22	N	< 22	< 22	N	< 22	< 22	N
ER PPM	< 4.6	< 4.6	N	< 4.6	< 4.6	N	< 4.6	< 4.6	N
EU PPM	< 2.2	< 2.2	11	< 2.2	7.2	12	< 2.2	< 2.2	13
GA PPM	7.2	7.4	1.5	< 1.5	7.4	2.6	1.8	6.5	3.5
GD PPM	< 32	< 32	< 68	< 32	< 32	85	< 32	< 32	97
GE PPM	< 4.6	< 4.6	< 4.6	< 4.6	< 4.6	< 4.6	< 4.6	< 4.6	< 4.6
HF PPM	< 15	< 15	2000	< 15	< 15	1100	< 15	< 15	820
HO PPM	< 6.8	< 6.8	40	< 6.8	< 6.8	27	< 6.8	< 6.8	< 10
IN PPM	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
IR PPM	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15
LA PPM	77	250	160	< 10	240	220	28	210	210
LI PPM	< 68	100	< 68	< 68	< 68	< 68	< 68	< 68	< 68
LU PPM	< 15	< 15	< 150	< 15	< 15	< 15	< 15	< 15	< 15
MN PPM	14000	5240	130	7600	7600	290	9100	7800	230
MO PPM	4.3	< 1.0	< 1.0	7.0	< 1.0	< 1.0	8.7	< 1.0	< 1.0
NB PPM	21	41	610	52	11	340	88	12	330
ND PPM	83	210	210	< 68	240	270	< 68	260	270
NI PPM	61	79	17	39	62	17	52	61	21

Table 10 - continued

	Sample # 23961			23964			23966		
FIELD #	SP23961-200	SP23961-201	SP23961-202	SP23964-200	SP23964-201	SP23964-202	SP23966-200	SP23966-201	SP23966-202
SAMPLE	W-235497	W-235498	W-235499	W-235500	W-235501	W-235502	W-235503	W-235504	W-235505
SPECTRUM	4	5	6	7	8	9	10	11	12
OS PPM	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15
PB PPM	17	8.8	10	< 6.8	9.7	9.4	9.9	8.4	11
PD PPM	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
PR PPM	< 100	< 150	< 150	< 100	< 100	< 150	< 100	< 150	< 150
PT PPM	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 6.8	< 2.2	< 2.2	< 2.2
RE PPM	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
RH PPM	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2
RU PPM	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2
SB PPM	< 68	< 68	< 68	< 68	< 68	< 68	< 68	< 68	< 68
SC PPM	30	22	29	18	30	24	19	21	22
SE PPM	< 10	36	< 46	< 10	28	< 32	< 10	30	< 32
SM PPM	20	100	620	< 68	7.0	820	21	9.2	1800
SR PPM	16	70	55	3.8	60	< 150	5.2	36	< 150
TA PPM	< 320	< 320	< 320	< 320	< 320	< 320	< 320	< 320	< 320
TB PPM	< 32	< 32	< 32	< 46	< 32	< 32	< 32	< 32	< 32
TE PPM	< 46	< 100	830	< 46	< 100	1100	< 46	< 100	1000
TL PPM	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TM PPM	< 4.6	< 4.6	23	< 4.6	< 4.6	16	< 4.6	< 4.6	13
U PPM	< 460	< 220	< 220	< 220	< 220	< 460	< 220	< 220	< 220
V PPM	120	130	170	130	91	140	160	87	150
W PPM	< 15	< 15	120	< 15	< 15	< 15	< 15	< 15	810
Y PPM	99	68	H	50	54	H	38	54	220
YB PPM	15	14	94	6.3	10	67	10	7.5	55
ZN PPM	190	110	H	180	120	H	190	130	H
ZR PPM	160	210	> 22000	130	120	> 22000	190	79	> 22000

MAJORS RECALCULATED AS OXIDES

SIO2 %	15	20	16	8.4	18	21	7.9	15	21
AL2O3 %	6.1	4.4	2.1	2.5	4.0	4.5	3.6	4.5	3.0
FE2O3 %	13	7.4	0.66	17	7.6	0.87	16	7.7	1.0
MGO %	2.8	3.3	0.63	0.78	4.6	0.91	0.95	3.8	1.3
CAO %	3.5	6.4	6.6	1.1	5.3	6.6	1.3	2.9	11
NA2O %	< 0.20	0.093	0.12	< 0.20	0.098	0.15	< 0.20	0.11	0.12
K2O %	< 0.18	0.13	0.20	< 0.18	< 0.18	0.16	< 0.18	< 0.18	0.12
TIO2 %	4.0	0.73	11	4.5	0.67	8.2	7.7	1.1	8.2
P2O5 %	< 0.16	< 0.16	0.71	< 0.16	< 0.16	0.44	< 0.16	< 0.16	0.73
MNO %	1.8	0.67	0.017	0.98	0.98	0.037	1.2	1.0	0.030

1. THE RELATIVE STANDARD DEVIATION FOR EACH REPORTED CONCENTRATION IS PLUS 50% AND MINUS 33%.
2. 'H' DENOTES THE OCCURRENCE OF AN UNRESOLVED INTERFERENCE.
3. '*' DENOTES USE OF A SAMPLE WEIGHT LESS THAN 15 MG. REPORTED RESULTS ARE BASED ON THE ACTUAL SAMPLE WEIGHT.

Table 10.--Continued.

SAMPLE No.	23289			23292			23293		
FIELD # SAMPLE	SP23289-200	SP23289-201	SP23289-202	SP23292-200	SP23292-201	SP23292-202	SP23293-200	SP23293-201	SP23293-202
	W-235506	W-235507	W-235508	W-235509	W-235510	W-235511	W-235512	W-235513	W-235514
SPECTRUM	13	14	15	16	17	18	19	20	21
SI %	3.6	8.3	7.7	3.9	7.8	14	6.8	11	10
AL %	1.4	1.7	1.3	1.6	1.5	1.5	1.2	1.6	2.3
FE %	13	6.1	0.63	13	3.1	0.89	10	4.9	0.69
MG %	0.52	1.7	0.54	0.74	2.7	11	1.9	3.0	0.72
CA %	1.1	1.7	6.6	1.2	3.2	9.2	2.3	4.0	7.4
NA %	< 0.15	0.065	0.11	< 0.15	< 0.15	0.039	< 0.15	0.13	0.10
K %	< 0.15	< 0.15	0.17	0.35	0.22	0.17	< 0.15	< 0.15	0.088
TI %	3.7	0.29	7.0	7.7	1.0	0.54	3.2	0.37	7.4
P %	< 0.068	0.092	0.33	0.27	0.32	< 0.068	< 0.068	< 0.068	0.57
MN %	0.90	0.68	0.014	1.8	0.62	0.029	1.1	0.60	0.019
AG PPM	1.4	< 0.10	3.6	3.5	0.67	1.4	1.8	< 0.10	3.9
AS PPM	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100
AU PPM	< 6.8	< 6.8	< 6.8	< 15	< 6.8	< 6.8	< 6.8	< 6.8	< 6.8
B PPM	< 6.8	75	5.5	61	300	90	9.3	110	65
BA PPM	15	7.4	1900	25	26	60	16	15	320
BE PPM	< 1.0	< 1.0	< 1.0	< 1.0	7.2	15	< 1.0	< 1.0	< 1.0
BI PPM	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
CD PPM	< 32	< 32	< 32	< 32	< 32	< 32	< 32	< 32	< 32
CE PPM	< 43	670	750	410	< 3300	720	< 43	120	550
CO PPM	24	14	6.8	16	7.1	< 1.0	28	12	5.5
CR PPM	2200	2300	270	1300	700	31	2200	1400	220
CU PPM	3.1	5.8	3.5	8.6	5.2	4.3	7.2	4.0	4.4
DY PPM	< 22	37	N	< 22	190	57	< 22	< 22	N
ER PPM	< 4.6	< 100	N	< 4.6	190	30	< 4.6	< 4.6	N
EU PPM	< 2.2	< 2.2	12	< 2.2	3.5	3.9	< 2.2	2.8	11
GA PPM	2.1	4.4	< 1.5	< 1.5	7.3	1.7	5.1	9.3	3.7
GD PPM	< 32	< 32	< 68	36	150	< 32	< 32	< 32	81
GE PPM	< 4.6	< 4.6	< 4.6	< 4.6	< 4.6	< 4.6	< 4.6	< 4.6	< 4.6
HF PPM	< 15	< 15	2700	< 150	< 15	510	< 15	< 15	510
HO PPM	< 6.8	< 6.8	44	< 10	54	26	< 6.8	< 6.8	20
IN PPM	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
IR PPM	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15
LA PPM	< 10	290	280	180	1100	120	30	66	230
LI PPM	< 68	< 68	< 68	< 68	N	N	< 68	N	< 68
LU PPM	< 15	< 15	< 150	< 150	< 15	< 15	< 15	< 15	< 15
MN PPM	9000	6800	140	18000	6200	290	11000	6000	190
MO PPM	10	< 1.0	< 1.0	11	< 1.0	6.3	6.6	< 1.0	< 1.4
NB PPM	110	8.9	900	> 1000	150	330	48	8.4	600
ND PPM	< 68	350	310	210	1200	250	< 32	41	250
NI PPM	51	50	19	28	16	11	59	34	17

Table [illegible] - Continued

SAMPLE No.	23289			23292			23293		
FIELD #	SP23289-200	SP23289-201	SP23289-202	SP23292-200	SP23292-201	SP23292-202	SP23293-200	SP23293-201	SP23293-202
SAMPLE	W-235506	W-235507	W-235508	W-235509	W-235510	W-235511	W-235512	W-235513	W-235514
SPECTRUM	13	14	15	16	17	18	19	20	21
OS PPM	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15
PB PPM	9.7	7.5	320	14	11	8.0	11	7.9	12
PD PPM	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
PR PPM	< 100	< 150	< 150	< 100	400	< 100	< 100	< 100	< 150
PT PPM	< 2.2	< 6.8	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2
RE PPM	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
RH PPM	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2
RU PPM	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2	< 2.2
SB PPM	< 68	< 68	< 68	< 68	< 68	< 68	< 68	< 68	< 68
SC PPM	22	17	30	17	28	9.5	25	18	24
SM PPM	< 10	40	< 32	24	250	< 32	< 10	< 10	< 32
SN PPM	200	< 4.6	4200	78	290	2100	22	< 4.6	550
SR PPM	6.8	30	69	15	45	46	16	62	370
TA PPM	< 320	< 320	< 320	< 320	< 320	< 320	< 320	< 320	< 320
TB PPM	< 46	< 32	< 32	< 32	< 32	< 46	< 32	< 32	< 32
TH PPM	< 46	< 150	< 150	< 100	< 1000	< 150	< 46	< 46	< 150
TL PPM	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
TM PPM	< 4.6	< 4.6	21	20	25	< 4.6	< 4.6	< 1.6	17
U PPM	< 220	< 220	< 220	< 220	< 220	< 220	< 220	< 220	< 220
V PPM	200	110	200	120	61	84	170	93	180
W PPM	< 15	< 15	4100	6200	5500	> 10000	< 15	< 15	< 68
Y PPM	38	130	H	< 460	940	120	36	31	H
YB PPM	7.7	17	82	38	130	16	6.6	6.6	57
ZN PPM	230	190	H	390	180	110	220	84	H
ZR PPM	380	67	> 22000	360	190	15000	180	140	> 22000
MAJORS RECALCULATED AS OXIDES									
SIO2 %	7.7	18	17	8.4	17	30	15	24	21
AL2O3 %	2.7	3.2	2.9	3.0	2.8	2.8	2.3	3.0	4.4
FE2O3 %	19	8.7	0.50	19	4.4	1.3	14	7.0	0.99
MGO %	0.86	2.8	0.90	1.2	4.5	18	3.2	5.0	1.2
CAO %	1.5	2.4	9.2	1.7	4.5	13	3.2	5.6	10
NA2O %	< 0.20	0.088	0.13	< 0.20	< 0.20	0.053	< 0.20	0.18	0.14
K2O %	< 0.18	< 0.18	0.20	0.42	0.27	0.20	< 0.18	< 0.18	0.11
TIO2 %	6.2	0.48	12	13	1.7	0.90	3.3	0.62	12
P2O5 %	< 0.16	0.21	0.76	0.62	0.73	< 0.16	< 0.16	< 0.16	1.3
MNO %	1.2	0.80	0.018	2.3	0.80	0.037	1.4	0.78	0.025

1. THE RELATIVE STANDARD DEVIATION FOR EACH REPORTED CONCENTRATION IS PLUS 50% AND MINUS 33%.
2. 'H' DENOTES THE OCCURRENCE OF AN UNRESOLVED INTERFERENCE.
3. '*' DENOTES USE OF A SAMPLE WEIGHT LESS THAN 15 MG. REPORTED RESULTS ARE BASED ON THE ACTUAL SAMPLE WEIGHT.

able 10.--Continued

CONCENTRATION RANGES FOR ELEMENTS DETERMINED
BY COMPUTERIZED SPECTROGRAPHIC ANALYSIS OF SILICATE ROCKS

OXIDE [illegible] (MAJORS)	CONCENTRATION RANGE (%)	ELEMENT (TRACE)	CONCENTRATION RANGE (PPM)	ELEMENT (TRACE)	CONCENTRATION RANGE (PPM)	ELEMENT (TRACE)	CONCENTRATION RANGE (PPM)
SIO2	0.0099 - 73	AG	0.10 - 10,000	IN	10 - 10,000	SN	10 - 1,000
AL2O3	0.088 - 60	AS	100. - 10,000	IR	15 - 10,000	SR	4.6 - 10,000
FE2O3	0.111 - 31	AU	6.8 - 1,500	LA	10 - 10,000	TA	1.0 - 320,000
MGO	0.0076 - 50	B	3.2 - 460	LI	68 - 32,000	TE	320 - 10,000
CAO	0.0014 - 44	BA	1.5 - 32,000	LU	15 - 1,000	TB	32 - 1,000
NA2O	0.0129 - 11	BE	1.0 - 400	MN	1.0 - 460,000	TH	46 - 10,000
K2O	0.302 - 13	BI	10 - 6,400	MO	1.4 - 1,000	TL	10 - 10,000
TIO2	0.0053 - 77	CD	32 - 10,000	NB	6.8 - 1,000	TM	4.6 - 1,000
P2O5	0.16 - 16	CE	43 - 20,000	ND	32 - 10,000	U	220 - 10,000
MNO	0.00013 - 60	CO	1.9 - 22,000	NI	1.9 - 15,000	V	1.0 - 1,000
		CR	1.0 - 6,800	OS	15 - 6,800	W	15 - 10,000
		CU	1.0 - 1,300	PB	6.8 - 1,000	Y	1.5 - 10,000
		DY	22 - 1,000	PD	1.0 - 4,600	YB	0.15 - 1,000
		ER	4.6 - 1,000	PR	100 - 1,000	ZN	15 - 10,000
		EU	2.2 - 1,000	PT	2.2 - 10,000	ZR	3.2 - 22,000
SYMBOLS USED IN REPORT:		GA	1.8 - 1,000	RE	10 - 10,000		
LESS THAN LOWER LIMIT (L)		GD	32 - 1,000	RH	2.2 - 10,000		
GREATER THAN UPPER LIMIT (G)		GE	4.6 - 10,000	RU	2.2 - 10,000		
NOTE 2		HF	15 - 10,000	SB	68 - 10,000		
NOTE 3		HO	6.8 - 1,000	SC	1.0 - 1,000		

NOTES:

THE RELATIVE STANDARD DEVIATION FOR EACH REPORTED CONCENTRATION IS PLUS 50%, AND MINUS 33%.

'H' DENOTES THE OCCURRENCE OF AN UNRESOLVED INTERFERENCE.

'+' DENOTES USE OF A SAMPLE WEIGHT LESS THAN 15 MG. REPORTED RESULTS ARE BASED ON THE ACTUAL SAMPLE WEIGHT.

THE ABOVE RANGES APPLY FOR INITIAL CALIBRATION CONDITIONS. IN SOME CASES INTERFERENCES WILL NARROW THE RANGE.

Table 3.--Percent of total grains in magnetically-separated fractions of sample 23292. See text for abbreviations and identity of minerals included in each grouping. The t symbol indicates the mineral is present in trace amounts. Total indicates percent of mineral grains in the entire sample.

Magnetic fraction	Mineral or mineral group																							
	Mt	Op	Lx	Ana	Cass	Tit	OPx	CPx	Amp	Gt	CZo	Ep	Chtd	Ves	Pump	Sch-Pow	Tm	Ap	Zr	Xm	Mz	Micac	Ot	Tot
a	6.7	84.7					0.3	0.6	0.6	2.3	0.3		1.1		0.6							2.6	0.2	100.0
b		69.9						4.4	0.6	10.4			3.3						1.1			9.8	0.5	100.0
c		10.6	6.5			3.0	t	34.3	3.9	7.6	8.0	2.6	4.1	1.3	2.0		1.1		0.9	5.0	1.5	7.6		100.0
d		1.4	0.9	0.5				88.0	0.5	1.4	0.9	2.0		1.9			0.9		0.9		0.7			100.0
e		2.0	1.3				0.5	82.0	1.9	0.5								2.8	4.9				4.1	100.0
f		1.2			0.5			86.7								5.6		0.2	5.8					100.0
Total	0.5	16.6	1.2	0.2	0.2	0.4	0.2	62.5	1.2	2.6	1.3	0.6	1.0	0.4	0.3	1.7	0.3	0.8	3.3	0.7	0.3	2.4	1.1	99.9

Table 4.--Percent of total grains in magnetically-separated fractions of sample 23293. See text for abbreviations and identity of minerals included in each grouping. The t symbol indicates the mineral is present in trace amounts. Total indicates the percent of mineral grains in the entire sample.

Magnetic fraction	Mineral or mineral group																				
	Mt	Op	Lx	Rt-Q	Rt	Tit	OPx	CPx	Amp	Gt	CZo	Ep	Chtd	Ves	Pump	St	Tm	Al-Si	Ap	Zr	Ot	Tot
a	11.1	59.9	3.8				1.9	15.1	1.2	4.7		1.0	1.0				0.1		0.6	0.4		99.9
b		49.9	0.3			0.1	0.8	1.4	3.6	37.3	0.3	0.3	4.9		0.1	0.1	0.5		0.5			100.1
c		6.8	2.0	1.8		1.9	2.1	46.7	3.2	8.2	3.4	12.8	2.0		1.1	4.1	1.6			0.3	2.0	100.0
d			5.4	2.0	1.1	8.7		40.2		1.5	13.9	9.6			13.5		1.1			0.2	2.8	100.0
e			19.1	14.0	10.5	15.4		32.4						0.3	0.2		0.5	0.2	0.2	0.8	6.5	100.1
f			13.4	7.7	6.5	15.3		5.4			1.8							10.4	9.0	26.9	3.8	99.9
Total	0.3	24.2	3.0	1.9	0.9	2.9	1.2	24.8	2.8	18.4	2.5	6.1	2.8	t	1.4	1.7	1.0	0.5	0.7	1.4	1.5	100.1

Table 5.--Percent of total grains in magnetically-separated fractions of sample 23966. See text for abbreviations and identity of minerals included in each grouping. The t symbol indicates the mineral is present in trace amounts. Total indicates percent of mineral grains in the entire sample.

Magnetic fraction	Mineral or mineral group																				
	Mt	Op	Lx	Rt-Q	Rt	Cass	Tit	OPx	CPx	Amp	Gt	CZo	Ep	Chtd	Ves	Pump	Tm	Sch-Pow	Ap	Zr	Ot	Tot
a	32.1	60.0	0.4					3.5	1.9	0.4	1.0								0.1	0.4	0.1	99.9
b		53.1					3.4	0.5	3.9		31.6		2.3	3.1			1.5			0.5		99.9
c		22.4	2.1		2.0			1.4	11.8	1.0	34.8	1.0	6.0	16.5			0.8		0.2			100.0
d		1.1	6.2				14.5	22.5	30.7	0.2	0.5	16.1			0.3	5.6	0.7		0.1		1.5	100.0
e		0.2	20.9	8.7	6.5		17.5	3.8	17.1			10.8				0.4	0.1	0.1	1.0	11.5	1.0	100.0
f			4.9		6.2	t	20.7		11.6		0.2	2.0							5.2	48.7	0.5	100.0
Total	1	27.8	3.0	0.9	1.6	t	3.8	3.4	11.5	0.5	26.0	2.8	3.6	9.0	0.1	0.6	0.9		0.3	2.8	0.3	100.1

Table 7.--Percent of total grains in magnetically-separated fractions of sample 23961. See text for abbreviations and identity of minerals included in each grouping. Total indicates percent of mineral grains in the entier sample.

Magnetic fraction	Mineral or mineral group																			
	Mt	Op	Lx	Rt-Q	Rt	Tit	OPx	CPx	Amp	Gt	CZo	Ep	Chtd	Pump	St	Tm	Al-Si	Ap	Zr	Ot	Tot
a	42.1	42.1	0.6				1.7	7.1		6.4											
b		36.9	0.8		0.8	2.5		1.8		50.9	0.3	0.2	5.3	0.2					0.2	0.2	100.1
c		9.3	3.6	10.3	0.3	8.0		22.5		10.1	4.1	13.7	8.0	0.6	0.3	0.3		9.0		0.3	100.1
d			6.8		5.8	3.2	0.2	63.9	5.6	0.6	6.4	2.2		0.2				4.6			99.9
e		10.8	25.5	0.2	4.1	22.4		12.0		0.2	13.2							6.2	5.2	0.2	100.0
f		7.1	10.6	4.5	10.5			8.6			3.2						1.5	11.0	42.4	0.7	100.1
Total	1.8	25.3	3.2	3.0	1.5	4.5	0.1	11.3	0.3	30.9	2.2	4.0	5.1	0.3	0.1	0.1	0.1	3.5	2.5	0.2	100.0

Table 8.--Percent of total grains in magnetically-separated fractions of sample 23964. See text for abbreviations and identity of minerals included in each grouping. Total indicates percent of mineral grains in the entire sample.

Magnetic fraction	Mineral or mineral group																	
	Mt	Op	Lx	Rt-Q	Rt	Tit	OPx	CPx	Amp	Gt	CZo	Ep	Chtd	Tm	Ap	Zr	Ot	Tot
a	47.3	43.3			0.3		4.1	1.7		2.7		0.1						100.1
b		62.3					0.9	2.5		31.9	0.3	0.1	1.8			0.1		99.9
c		14.7	1.5		1.2	15.4		9.3	1.9	38.9		8.1	8.9	0.1				100.0
d		2.4	8.3			18.4	6.8	37.1		1.2	4.1	9.2	10.1		2.4			100.0
e			28.9	8.0	10.7	12.2		27.2							11.6	1.4		100.0
f			12.9	10.3	8.6										8.2	30.1	29.0	100.0
Total	1.6	25.6	3.6	1.0	1.6	10.1	1.0	10.1	1.0	28.3	0.5	5.0	5.9	0.1	1.2	1.8	1.7	100.0

Table 9.—Summary of percent of total grains in magnetically-separated fractions of samples. See text for abbreviations and identity of minerals included in each grouping. The t symbol indicates the mineral is present in trace amounts.

Sample No.	Mineral or mineral group																											
	Mt	Op	Lx	Rt	Rt-Q	Ana	Cass	Tit	OPx	CPx	Amp	Gt	CZo-Zo	Ep	Chtd	Visu	Pump	Tm	St	Al-Si	Sch-Pow	Ap	Xm	Mz	Zr	Micac	Ot	Tot
23292	0.5	16.6	1.2			0.2	0.2	0.4	0.2	62.5	1.2	2.6	1.3	0.6	1.0	0.4	0.3	0.3			1.7	0.8	0.7	0.3	3.3	2.4	0.2	100.0
23293	0.3	24.2	3.0	0.9	1.9			2.9	1.2	24.8	2.8	18.4	2.5	6.1	2.8	t	1.4	1.0	1.7	0.5		0.7			1.4		1.5	100.1
23966	1	27.8	3.0	1.6	0.9		t	3.9	3.4	11.5	0.5	26.0	2.8	3.6	9.0	0.1	0.6	0.9			t	0.3			2.8		0.3	100.1
23289	2.9	38.4	3.2	2.3	0.1			1.0	1.0	18.7	0.3	19.5	2.0	1.9	2.6	0.1	1.5	0.8	0.1			0.4	0.1		3.1			100.0
23961	1.8	25.3	3.2	1.5	3.0			4.5	0.1	11.3	0.3	30.9	2.2	4.0	5.1		0.3	0.1	0.1	0.1		3.5			2.5		0.2	100.0
23964	1.6	25.6	3.6	1.6	1.0			10.1	1.0	10.1	1.0	28.3	0.5	5.0	5.9			0.1				1.2			1.8		1.7	100.0

Table 11.--Continued

Sample 23966

	Mt	Op	Lx	Rt+Q	Rt	Tit	Cass	Sch-Pow	Xm	Mz	Ap	Zr
200	32.1	60.0	0.4								0.1	0.4
201		29.6	1.9		1.1	2.9				0.1	0.1	0.2
202		0.1	13.4	4.6	6.2	18.7	T	0.1	0.1		2.9	28.1

	Fe_2O_5	MnO	TiO_2	Cr	Sn	W	Mo	Y	U	Ce	Th	P_2O_5	Zr	Hf
200	13	1.2	7.7	2800	21	<15	8.7	38	<220	<43	<46	<0.16	190	<15
201	7.7	1.0	1.1	2500	9.2	<15	<1.0	54	<220	500	<100	<0.16	79	<15
202	1.0	0.03	8.2	240	1800	810	<1.0	220	<220	530	1000	0.72	>22000	820

Sample 23289

	Mt	Op	Lx	Rt+Q	Rt	Tit	Cass	Sch-Pow	Xm	Mz	Ap	Zr
200	66.9	25.3	0.7									
201		42.5	2.3	0.1	1.6	0.5			0.5			1.3
202			12.7		10.4	6.0					4.3	22.3

	Fe_2O_3	MnO	TiO_2	Cr	Sn	W	Mo	Y	U	Ce	Th	P_2O_5	Zr	Hf
200	19	1.2	6.2	2200	200	<15	10	200	<43	<43	<46	<0.16	380	<15
201	8.7	0.88	0.48	2500	<4.6	<15	<1.0	110	670	670	<150	0.26	67	<15
202	0.9	0.018	12	270	4200	4100	<1.0	200	750	750	<150	0.76	<22000	2700

Table 11.--Continued

Sample 23293

	Mt	Op	Lx	Rt+Q	Rt	Tit	Cass	Sch-Pow	Xm	Mz	Ap	Zr
200	11.1	59.9	3.8								0.6	0.4
201		25.8	1.5	1.0	0.1	1.6					0.2	0.1
202			16.3	11.0	8.6	15.2					4.3	13.0

	Fe_2O_3	MnO	TiO_2	Sn	W	Mo	Y	U	Ce	P_2O_5	Zr	Hf
200	14	1.4	5.3	22	<15	6.6	36	<220	<43	<0.16	180	<15
201	7	0.78	0.62	<4.6	<15	<1.0	31	<220	120	<0.16	140	<15
202	0.99	0.025	12	550	<68	<1.0	H	<220	550	1.3	<22000	510

Sample 23292

	Mt	Op	Lx	Ana	Tit	Cass	Sch-Pow	Xm	Mz	Ap	Zr
200	6.7	84.7									
201		24.6	2.9	0.1	1.2			2.0	0.8		1.0
202		1.5	0.6			0.3	5.6			1.3	5.5

	Fe_2O_3	MnO	TiO_2	Cr	Sn	W	Mo	Y	U	Ce	Th	P_2O_5	Zr	Hf
200	19	2.3	13	1300	186	200	11	<460	<220	410	<100	0.62	360	<150
201	4.4	0.8	1.7	700	2505	500	<1.0	940	<220	3300	1000	0.73	190	<150
202	1.3	0.037	0.9	31	21001	0000	6.3	120	<220	720	<150	0.16	15000	510