U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

GEOCHEMICAL DATA OF DRILL CORE SAMPLES OF CARBONATITES AND ASSOCIATED IGNEOUS ROCKS, MAGNET COVE COMPLEX, ARKANSAS

by

Marta J.K. Flohr[1] and J. Michael Howard[2]

Open-File Report 95-621

[1]National Center, MS 959
Reston, Virginia 22092

[2]Arkansas Geological Commission
Vardelle Parham Geology Center
3815 West Roosevelt Road
Little Rock, Arkansas 72204

1995

CONTENTS

TABLE

Introduction

Drill core M5 sampled carbonatites and alkaline igneous rocks of the Magnet Cove Complex, Hot Spring County, Arkansas. Representative samples of these rocks were obtained as part of a study of the Magnet Cove Complex and other alkaline igneous intrusions in the Southern Midcontinent of the United States. Recent detailed studies of the Magnet Cove Complex and its associated Ti-V-Nb mineralization were presented by Erickson and Blade (1963), Flohr and Ross (1989, 1990), Willis (1992), and Flohr (1994); earlier studies are cited by these authors. The Magnet Cove Complex is one of numerous igneous intrusions in the region, some of which crop out and others of which are not exposed at the surface, but which have been sampled by deep drilling and (or) identified by gravity and magnetic surveys (e.g., McKeown, 1982; Hendricks, 1988; see Fig. 1 of Flohr and Howard, 1994, for a sketch map of the region that shows the locations of these intrusions).

Drill core M5 was obtained by Molycorp, Inc. as part of their mineral exploration program. The drilling location was in the northwest corner of Sec. 19, TS3, R17W. The total depth of the core was 750 feet. The core is curated by the Arkansas Geological Commission in the Norman F. Williams Well Sample Depository, Little Rock, Arkansas. This report contains major-, minor-, and trace-element geochemical data of 33 rocks from the core. Short descriptions of the rock types sampled are included. Drill core samples other than those for which geochemical data were obtained were also collected, but these samples are not discussed here.

Analytical Methods

Samples were prepared for geochemical analysis using standard procedures (Arbogast, 1990) by USGS personnel. Outer surfaces of samples were removed before the samples were ground to ensure that no contamination by the coring equipment was present.

All analytical work was performed by USGS personnel. The following methods were used for the analyses reported in Table 1. Where a given element was determined by more than one method, all values are reported without attempting to evaluate the superiority of one method over another method. Si, Ti, Al, total Fe, Mn, Mg, Ca, Na, K, and P were analyzed using wavelength-dispersive X-ray fluorescence spectrometry (WDXRF; Taggart and others, 1987) by J. S. Mee and D. F. Siems and are reported as weight percent of the oxides. Ferrous iron, reported as FeO, was determined by H. Smith who used the colorimetric titration method of Peck (1964). Ferric iron, reported as Fe_2O_3, was calculated from the total iron as obtained by WDXRF and the measured ferrous iron content. F^- and Cl^- were determined by ion-selective electrode potentiometry using either the method of Kirschenbaum (1988) or of Bodkin (1977) for F and that of Aruscavage and Campbell (1983) for Cl (analysts: C.J. Skeen and N.H. Elsheimer). Total S was analyzed by first combusting the sample in a sulfur analyzer and then measuring the evolved sulfur dioxide by an infrared (IR) detector (Kirschenbaum, 1983; analysts: C.J. Skeen and N.H. Elsheimer). CO_2 was measured by first digesting the sample with $HClO_4$, a process during which CO_2 is evolved and carried into a coulometric cell. The CO_2 was then converted into a strong acid by ethanolamine and was titrated coulometrically (Engleman and others, 1985; analysts: C. Papp and H. Smith). H_2O^-, or nonessential water, was determined by weighing the sample before and after drying it for one hour at 100°C (Shapiro, 1975; analyst: H. Smith). Total water was determined by H. Smith who used the method of

Jackson and others (1987): the sample was mixed with a flux, heated to 950°C, and the evolved water was determined coulometrically by Karl-Fischer titration. H_2O^+, or bound water, is the difference between the total water and H_2O^-. Loss on ignition (LOI) was determined as part of the WDXRF analytical work-up and was determined by weighing the sample before and after heating at 925°C for 45 minutes. A large number of elements, including the rare-earth elements (REE), were determined by instrumental neutron activation analysis (INAA; Baedecker and McKown, 1987) by P. A. Baedecker and J.N. Grossman. Additional important trace elements were analyzed using inductively coupled plasma-atomic emission spectrometry (ICP-AES; Lichte and others, 1987) by M. W. Doughten or using energy-dispersive X-ray fluorescence spectrometry (EDXRF; Johnson, 1984; Johnson and King, 1987) by J. Kent.

Polished thin sections of all samples, except the altered clay-rich rocks, were obtained. Examination of these thin sections and limited X-ray powder diffraction (XRD) analysis provide the basis for the brief mineralogical descriptions presented in the next section.

Rock Types

Lithologies sampled by drill core M5 include a variety of carbonatites and altered rocks. Altered rocks include (1) rocks that contain abundant clay and may be the product of relatively late-stage hydrothermal alteration (these rocks are termed altered clay-rich rocks in Table 1) and (2) altered silicate rocks that are the products of intense metasomatism and reaction between silicate rocks and carbonatite. The following brief descriptions present only the gross characteristics of the rocks. Some of the carbonatites are complex and contain clasts of partly altered silicate rock or earlier-formed carbonatite. Within each of the following groups discussed below, the analyses (Table 1) are ordered from low to high Si content to emphasize the ranges of compositions present in each of these three broad and compositionally diverse groups.

Carbonatites. The dominant lithologies in the M5 drill core are coarse-to-medium-grained calcite carbonatites. These calcite carbonatites are readily distinguished in hand sample and in thin section on the basis of the abundance of accessory silicate, oxide, phosphate, and sulfide minerals. Intervals with concentrations of one or more of the accessory minerals are interspersed with zones of almost pure coarse-grained calcite (barren) carbonatite. The accessory mineral-bearing and barren carbonatite intervals range from a few feet to tens of feet in thickness. The most common accessory minerals are monticellite, apatite, magnetite, perovskite, and pyrite. Barren calcite, monticellite-rich, and apatite-rich carbonatites are the most common. Vuggy REE-mineralized coarse-grained carbonatite (e.g., sample M5-47, with bastnaesite and tentatively identified synchesite) forms a thin zone near the top of the core. Coarse-grained pyrite is most abundant in calcite carbonatite where the carbonatite is in contact with fine-grained mafic silicate rock. Phlogopitized coarse-grained calcite carbonatite (sample M5-549.8) contains masses of phlogopite with subordinate aegirine.

A distinct medium-grained calcite carbonatite contains accessory phlogopite, magnetite, apatite, and sulfide. In some occurrences, particularly in the 706 ft to 727 ft interval (e.g., samples M5-717, M5-721), this carbonatite is faintly laminated, with millimeter-wide bands rich in mica and magnetite. Medium-grained carbonatite is less common at shallower depths, where coarser-grained carbonatites are more common.

Ankeritic carbonatites, which contain calcite and ankerite, are not common in the M5 drill core. Accessory minerals include hematite, apatite, pyrite, quartz, and

arfvedsonite. A Ti-mineralized zone (represented by sample M5-387) contains, in addition to calcite and ankerite, rutile, feldspar, pyrite, mica, and a 14Å clay mineral, which is represented by several weak XRD peaks that are consistent with smectite group minerals.

Altered silicate rocks. Aphanitic mafic rock occurs at the bottom of the core at about 729 ft to 750 ft and at several shallower intervals. Pyroxene grains replaced by biotite and oxide minerals, fine-grained recrystallized groundmasses, and local development of abundant pyrite characterize these rocks. Other altered silicate rocks are more syenitic and contain abundant pyroxene and zoned red garnet. Mafic and felsic rocks that are in contact with carbonatite are the most altered.

Altered clay-rich rocks. Altered clay-rich rocks occur mainly in the interval from about 619 ft to 662 ft, although altered rocks are present at other depths. Smectite and subordinate kaolinite are the clay minerals present. Other minerals in these rocks include calcite, ankerite, siderite, orthoclase, biotite, and sulfide. Enrichments of Ti and REE are also found (e.g., samples M5-658.5 and M5-658.5, respectively).

Acknowledgements

The assistance of Mr. Jack D. Stephenson and Mr. Benjamin F. Clardy, recently retired, (Arkansas Geological Commission) during the first author's visit to Little Rock is gratefully acknowledged.

References Cited

Arbogast, B.F., ed., 1990, Quality assurance manual for the Branch of Geochemistry: U.S Geological Survey Open-File Report 90-668, 184 p.

Aruscavage, P.J. and Campbell, E.Y., 1983, An ion selective electrode method for the determination of chlorine in geological materials: Talanta, v. 30, p. 745-749.

Baedecker, P.A. and McKown, D.M., 1987, Instrumental neutron activation analysis of geochemical materials, *in* Baedecker, P.A., ed., Methods of geochemical analysis, U.S. Geological Survey Bulletin 1770, p. H1-H14.

Bodkin, J.B., 1977, Determination of fluorine in silicates by use of an ion-selective electrode following fusion with lithium metaborate: Analyst, v. 102, 409-413.

Engleman, E.E., Jackson, L.L., and Norton, D.R., 1985, Determination of carbonate carbon in geological materials by coulometric titration: Chemical Geology, v. 53, p. 125-128.

Erickson, R.L., and Blade, L.V., 1963, Geochemistry and petrology of the alkalic igneous complex at Magnet Cove, Arkansas: U.S. Geological Survey Professional Paper 425, 95 p.

Flohr, M.J.K., 1994, Titanium, vanadium, and niobium mineralization and alkali metasomatism from the Magnet Cove Complex, Arkansas: Economic Geology, v. 89, p. 105-130.

Flohr, M.J.K., and Ross, M., 1989, Alkaline igneous rocks of Magnet Cove Arkansas: Metasomatized ijolite xenoliths from Diamond Jo quarry: American Mineralogist, v. 74, p. 113-131.

Flohr, M.J.K., and Ross, M., 1990, Alkaline igneous rocks of Magnet Cove Arkansas: Mineralogy and geochemistry of syenites: Lithos, v. 26, p. 67-98.

Flohr, M.J.K., and Howard, J. M., 1994, Geochemical data of drill core samples of carbonatites and associated igneous rocks, Benton, Arkansas: U.S. Geological Survey Open-File Report 94-450, 21 p.

Hendricks, J.D., 1988, Bouguer gravity of Arkansas: U.S. Geological Survey Professional

Paper 1474, 31 p.
Jackson, L.L., Brown, F.W., and Neil, S.T., 1987, Major and minor elements requiring individual determination, classical whole rock analysis, and rapid rock analysis, *in* Baedecker, P.A., ed., Methods of geochemical analysis, U.S. Geological Survey Bulletin 1770, p. G1-G23.
Johnson, R.G., 1984, Trace element analysis of silicates by means of energy-dispersive X-ray spectrometry: X-Ray Spectrometry, v. 13, p. 64-68.
Johnson, R.G. and King, B.-S.L., 1987, Energy-dispersive X-ray spectrometry, *in* Baedecker, P.A., ed., Methods of geochemical analysis, U.S. Geological Survey Bulletin 1770, p. F1-F5.
Kirschenbaum, H., 1983, The classical chemical analysis of rocks - the old and the new: U.S. Geological Survey Bulletin 1547, 55 p.
Kirschenbaum, H., 1988, The determination of fluoride in silicate rocks by ion selective electrode: an update: U.S. Geological Survey Open-File Report, 88-588, 5 p.
Lichte, F.E., Golightly, D.W., and Lamothe, P.J., 1987, Inductively coupled plasma-atomic emission spectrometry, *in* Baedecker, P.A., ed., Methods of geochemical analysis, U.S. Geological Survey Bulletin 1770, p. B1-B10.
McKeown, F.A., 1982, Overview and discussion, *in* McKeown, F.A. and Pakiser, L.C., eds., Investigations of the New Madrid, Missouri, earthquake region, U. S. Geological Survey Professional Paper 1236, p. 1-14.
Peck, L.C., 1964, Systematic analysis of silicates: U.S. Geological Survey Bulletin 1170, 89 p.
Shapiro, L., 1975, Rapid analysis of silicate, carbonate, and phosphate rocks - revised edition: U.S. Geological Survey Bulletin 1401, 76 p.
Taggart, J.E., Lindsey, J.R., Scott, B.A., Vivit, D.V., Bartell, A.J., and Stewart, K.C., 1987, Analysis of geological materials by wavelength dispersive X-ray fluorescence spectrometry, *in* Baedecker, P.A., ed., Methods of geochemical analysis, U.S. Geological Survey Bulletin 1770, p. E1-E19.
Willis, M.A., 1992, Calculation of thermodynamic properties of aqueous titanium species and constraints on the mobility of Ti in aqueous solution in geologic environments: Unpublished M.A. thesis, Washington University, St. Louis, 323 p.

Table 1. Geochemical data of M5 drill core samples, Magnet Cove Complex, Arkansas

[Sample - number following core number (M5) is depth in feet; Lab No. - USGS laboratory sample number; pct - percent; WDXRF - wavelength-dispersive X-ray fluorescence spectrometry; col. titra. - colorimetric titration; SIE - selective ion electrode; comb./IR - combustion/IR spectroscopy; coul. titra. - coulometric titration; diff. - by difference (methods for obtaining H_2O^+ and H_2O^- are given in the text); calc. - calculated; INAA - instrumental neutron activation analysis; LOI - loss on ignition; 925°C - LOI determined after heating sample to 925°C; EDXRF - energy-dispersive X-ray fluorescence; ICP-AES - inductively coupled plasma-atomic emission spectrometry; nd - not determined due to interference; ppm - parts per million; ppb - parts per billion; -- - not analyzed; ank - ankerite; cal - calcite; cbt - carbonatite; phlg - phlogopitized; alt sil rock - altered silicate rock; alt clay-rich - altered clay-rich rock]

			Sample	M5-288	M5-591.5	M5-722	M5-717	M5-721	M5-115.5	M5-47
			Lab No.	W257414	W257421	W257425	W257423	W257424	W257410	W257409
			Rock type	cal cbt	cal-ank cbt	cal cbt	cal cbt	cal cbt	cal cbt	cal cbt
SiO_2	pct	WDXRF		0.46	1.02	1.39	1.88	2.37	2.96	3.51
TiO_2	pct	WDXRF		<0.2	<0.2	0.12	0.11	0.05	<0.2	<0.2
Al_2O_3	pct	WDXRF		<0.10	0.25	0.34	0.44	0.67	0.77	1.25
Fe_2O_3	pct	calc.		0.02	0.64	0.79	1.39	0.64	1.12	0.82
FeO	pct	col. titra		0.05	0.40	0.40	0.99	1.44	0.10	0.36
MnO	pct	WDXRF		0.06	0.26	0.25	0.11	0.07	0.87	0.35
MgO	pct	WDXRF		0.13	0.49	0.18	1.18	1.3	0.62	0.3
CaO	pct	WDXRF		54.6	52.8	52.8	51.4	50.6	50.8	49.3
Na_2O	pct	WDXRF		<0.15	<0.15	<0.05	<0.15	<0.15	<0.15	<0.15
K_2O	pct	WDXRF		0.02	0.07	0.05	0.12	0.51	0.30	0.02
P_2O_5	pct	WDXRF		1.73	2.58	0.11	1.84	0.82	2.52	<0.05
F^-	pct	SIE		0.14	0.25	0.04	0.12	0.12	0.41	0.28
Cl^-	pct	SIE		0.008	0.014	0.010	0.002	0.001	0.004	0.024
Total S	pct	comb./IR		0.01	0.46	0.46	0.73	0.77	<0.01	0.20
CO_2	pct	coul. titra.		42.0	39.6	42.9	38.9	39.9	38.7	40.4
H_2O^+	pct	diff.		0.02	0.04	0.03	0.13	0.22	0.41	0.65
H_2O^-	pct	diff.		0.03	0.09	0.09	0.09	0.08	0.29	0.68
-F≡oxy	pct	calc.		0.06	0.11	0.02	0.05	0.05	0.17	0.12
-Cl≡oxy	pct	calc.		0.002	0.003	0.002	0	0	0.001	0.005
-S≡oxy	pct	calc.		0.005	0.23	0.23	0.365	0.385	0	0.10
Sum	pct	calc.		99.3	99.3	100.2	99.8	100.0	100.0	98.4
LOI	pct	925°C		41.2	39.1	41.1	37.2	38.0	38.6	40.9
Na	pct	INAA		0.034	0.060	0.123	0.024	0.025	0.046	<3
K	pct	INAA		<0.2	<0.2	<0.8	<0.2	0.40	0.36	--
Ca	pct	INAA		38.1	37.4	39.4	33.7	37.2	35.8	38.9
Fe	pct	INAA		0.043	0.771	0.925	1.73	1.62	0.927	0.936
V	ppm	ICP		62	35	43	76	38	78	21
Li	ppm	ICP		10	7.0	<5	6.8	<5	169	29
Ba	ppm	EDXRF		450	355	192	750	550	510	134

Table 1. Geochemical data of M5 drill core samples, Magnet Cove Complex, Arkansas - Continued

		Sample	M5-288	M5-591.5	M5-722	M5-717	M5-721	M5-115.5	M5-47
Cu	ppm	EDXRF	<10	16	10	144	24	<10	17
Ni	ppm	EDXRF	<10	<10	<10	<10	<10	<10	10
Zn	ppm	EDXRF	<10	<10	<10	32	13	<10	12
Sc	ppm	INAA	0.19	2.34	11.13	0.52	0.29	4.79	6.63
Cr	ppm	INAA	<0.6	<1	3.8	<1	<0.7	4.3	4.6
Co	ppm	INAA	0.20	2.66	0.68	18.63	9.65	2.11	2.78
Ni	ppm	INAA	<6	<12	<20	<10	<11	<14	30
Zn	ppm	INAA	<2	<4	<5	34.4	16.7	8.5	9.4
As	ppm	INAA	3.66	7.2	19.6	9.7	2.00	5.3	<26
Rb	ppm	INAA	1.9	<2	<3	5.1	25.7	15.6	<8
Sr	ppm	INAA	5642	5503	2401	5875	7229	2134	2108
Zr	ppm	INAA	<14	<5	<60	31	<23	<50	<190
Mo	ppm	INAA	<2	<4	8	<0.3	<1	5	<15
Sb	ppm	INAA	0.171	0.096	1.72	0.219	<0.05	0.237	1.33
Cs	ppm	INAA	<0.04	0.137	<0.1	0.186	0.443	0.172	1.90
Ba	ppm	INAA	487	392	197	704	577	545	147
La	ppm	INAA	184	133	358	113	54.0	137	4521
Ce	ppm	INAA	174	157.7	549	104.6	48.8	211	5425
Nd	ppm	INAA	40.1	59.9	201	22.1	11.6	102	1463
Sm	ppm	INAA	8.06	20.1	36.7	3.68	1.68	33.2	206
Eu	ppm	INAA	2.66	7.21	9.21	1.19	0.481	11.24	48.3
Tb	ppm	INAA	1.035	4.11	2.38	0.392	0.150	5.53	1137
Ho	ppm	INAA	1.17	4.59	<3	<1	<0.4	6.2	<90
Yb	ppm	INAA	2.29	7.62	11.0	1.05	0.41	10.8	11.2
Lu	ppm	INAA	0.26	0.91	1.55	0.13	0.06	1.29	1.37
Hf	ppm	INAA	<0.03	<0.1	<0.09	0.238	<0.08	0.116	0.38
Ta	ppm	INAA	<0.03	0.102	0.155	0.160	0.058	0.069	<0.1
Th	ppm	INAA	1.08	55.4	73.2	1.37	0.713	39.4	387
U	ppm	INAA	0.82	3.62	0.42	1.73	0.60	1.74	6.7
Au	ppb	INAA	<5	<5	<8	<5	3.4	<9	<40

		Lab No.	W258893	W258900	W258904	W258902	W258903	W258889	W258888
Y	ppm	ICP	23	120	45	11	2.6	140	97
Sr	ppm	ICP	4700	6100	2000	5800	6400	2100	1700
Zr	ppm	ICP	8.7	12	13	39	13	16	36
Ba	ppm	ICP	450	520	210	870	640	670	130
Mo	ppm	ICP	<1	<1	3.7	3.8	<1	3.3	2.2
Nb	ppm	ICP	<1	10	37	83	6.8	3.1	4.7

Table 1. Geochemical data of M5 drill core samples, Magnet Cove Complex, Arkansas - Continued

		Sample	M5-387	M5-374	M5-394	M5-436.5	M5-207	M5-125.5	M5-689
		Lab No.	W257416	W257418	W257417	W257419	W257412	W257411	W257422
		Rock type	cal-ank cbt	cal cbt	cal-ank cbt	cal cbt	cal cbt	cal-ank cbt	cal cbt
SiO_2	pct	WDXRF	4.04	4.74	6.15	7.61	8.89	9.12	9.16
TiO_2	pct	WDXRF	2.60	0.19	0.16	0.74	1.06	0.04	0.1
Al_2O_3	pct	WDXRF	0.83	0.65	0.44	1.45	2.22	0.51	0.47
Fe_2O_3	pct	calc.	0.24	3.93	3.31	0.82	0.14	0.42	4.60
FeO	pct	col. titra	3.11	1.20	0.95	1.49	1.27	1.32	1.60
MnO	pct	WDXRF	0.78	0.31	0.26	0.51	1.46	0.48	0.54
MgO	pct	WDXRF	6.36	3.11	1.43	3.78	5.83	4.23	6.05
CaO	pct	WDXRF	39.4	47.8	47.0	42.7	38.3	42.8	44.9
Na_2O	pct	WDXRF	<0.15	<0.15	<0.15	0.17	<0.15	<0.15	<0.15
K_2O	pct	WDXRF	0.08	0.10	0.12	1.48	1.94	0.40	0.08
P_2O_5	pct	WDXRF	<0.05	8.67	9.80	9.13	0.53	0.59	9.58
F^-	pct	SIE	0.13	0.47	0.52	1.36	0.98	0.61	0.57
Cl^-	pct	SIE	0.010	0.006	0.005	0.010	0.018	0.005	0.008
Total S	pct	comb./IR	0.14	0.11	0.14	0.11	0.18	0.01	0.14
CO_2	pct	coul. titra.	39.9	26.1	27.2	27.2	32.8	37.2	21.0
H_2O^+	pct	diff.	0.26	0.29	0.26	0.18	0.30	0.19	0.29
H_2O^-	pct	diff.	0.32	0.14	0.09	0.09	0.08	0.18	0.10
-F≡oxy	pct	calc.	0.05	0.20	0.22	0.57	0.41	0.26	0.24
-Cl≡oxy	pct	calc.	0.002	0.001	0.001	0.002	0.004	0.001	0.002
-S≡oxy	pct	calc.	0.07	0.055	0.07	0.055	0.09	0.005	0.07
Sum	pct	calc.	98.3	98.1	98.1	99.5	96.5	98.4	99.5
LOI	pct	925°C	40.0	26.9	27.7	27.5	33.9	38.6	20.6
Na	pct	INAA	0.098	0.077	0.100	0.158	0.121	0.041	0.056
K	pct	INAA	<2	<2	<2	1.7	<0.6	0.33	<2
Ca	pct	INAA	28.8	34.6	35.4	32.6	26.8	32.0	33.0
Fe	pct	INAA	2.66	3.81	3.20	1.87	1.206	1.400	4.83
V	ppm	ICP	192	497	571	248	95	197	730
Li	ppm	ICP	37	19	73	438	340	364	46
Ba	ppm	EDXRF	198	500	415	520	>5000	335	380
Cu	ppm	EDXRF	<10	15	16	11	<10	<10	<10
Ni	ppm	EDXRF	<10	<10	10	<10	<10	<10	<10
Zn	ppm	EDXRF	29	60	53	63	59	22	66
Sc	ppm	INAA	12.81	2.12	2.21	1.16	1.29	3.94	2.73
Cr	ppm	INAA	10.9	<1	<1	<2	2.4	1.2	<1
Co	ppm	INAA	6.67	9.89	3.99	6.79	2.95	5.43	13.68

Table 1. Geochemical data of M5 drill core samples, Magnet Cove Complex, Arkansas - Continued

			Sample	M5-387	M5-374	M5-394	M5-436.5	M5-207	M5-125.5	M5-689
Ni	ppm	INAA		<22	<17	<18	<20	<12	<7	<16
Zn	ppm	INAA		26.6	78.7	63.4	56.4	64.2	24.9	93.7
As	ppm	INAA		<2	22.1	25.7	5.0	<3	2.46	49.1
Rb	ppm	INAA		5.6	5.3	5.8	63.6	76.5	25.1	6.6
Sr	ppm	INAA		2247	4557	4265	4262	3179	4323	4041
Zr	ppm	INAA		<60	--	--	<4	<60	<30	<20
Mo	ppm	INAA		506	--	<12	<5	<12	<0.5	<0.9
Sb	ppm	INAA		6.12	0.17	0.68	0.500	0.887	0.414	0.24
Cs	ppm	INAA		0.26	0.24	0.40	0.68	1.05	0.192	0.266
Ba	ppm	INAA		181	488	428	554	7430	352	372
La	ppm	INAA		975	665	754	671	1435	78.2	664
Ce	ppm	INAA		1352	721	805	776	1845	78.6	651
Nd	ppm	INAA		354	167	186	226	432	20.5	138
Sm	ppm	INAA		52.1	29.5	33.4	53.4	44.9	4.26	23.5
Eu	ppm	INAA		12.79	9.85	11.18	17.8	9.34	1.5	8.15
Tb	ppm	INAA		3.33	3.63	4.25	7.72	2.27	0.753	3.02
Ho	ppm	INAA		3.6	4.6	6.7	9.3	<10	1.20	4.0
Yb	ppm	INAA		7.69	7.13	9.41	13.8	9.40	4.37	8.34
Lu	ppm	INAA		1.05	0.86	1.18	1.52	1.28	0.61	1.08
Hf	ppm	INAA		0.22	<0.3	0.60	0.50	<0.07	0.538	0.160
Ta	ppm	INAA		12.52	0.142	0.115	1.52	2.34	0.078	<0.07
Th	ppm	INAA		97.1	0.44	0.66	8.01	12.46	2.03	0.59
U	ppm	INAA		2.36	6.22	5.8	5.82	<1	1.76	4.5
Au	ppb	INAA		<14	<11	<12	<9	<17	<4	<9
			Lab No.	W258895	W258897	W258896	W258898	W258891	W258890	W258901
Y	ppm	ICP		39	90	130	190	50	36	94
Sr	ppm	ICP		1900	4000	4300	3700	2600	5200	3700
Zr	ppm	ICP		17	30	38	20	7	24	20
Ba	ppm	ICP		200	510	460	560	8000	480	390
Mo	ppm	ICP		608	<1	<1	<1	<1	<1	<1
Nb	ppm	ICP		1170	199	149	211	218	17	20

Table 1. Geochemical data of M5 drill core samples, Magnet Cove Complex, Arkansas - Continued

			Sample	M5-251	M5-365	M5-549.8	M5-704.5B	M5-547.5	M5-750	M5-740.5
			Lab No.	W257413	W257415	W257420	W257450	W257444	W257452	W257451
			Rock type	cal cbt	cal cbt	cal cbt	alt sil rock	alt sil rock	alt sil rock	alt sil rock
SiO_2	pct	WDXRF		12.7	15.7	19.3	35.0	38.2	41.5	42.8
TiO_2	pct	WDXRF		0.04	0.16	0.65	0.09	1.03	3.12	2.86
Al_2O_3	pct	WDXRF		0.13	0.42	5.25	13.8	14.3	18.3	19.4
Fe_2O_3	pct	calc.		0.94	2.87	2.97	1.69	3.71	1.28	2.52
FeO	pct	col. titra		1.24	1.26	1.19	0.48	0.27	7.72	6.08
MnO	pct	WDXRF		0.42	0.67	0.27	0.32	0.19	0.28	0.29
MgO	pct	WDXRF		7.57	10.7	7.74	1.96	2.54	3.69	2.49
CaO	pct	WDXRF		46.6	32.7	29.5	19.0	20.4	8.41	8.98
Na_2O	pct	WDXRF		<0.15	1.76	1.23	5.94	4.35	3.54	4.10
K_2O	pct	WDXRF		0.02	0.53	2.92	2.57	1.05	4.45	4.97
P_2O_5	pct	WDXRF		0.34	1.47	7.73	0.06	0.29	0.72	0.48
F^-	pct	SIE		0.10	0.54	1.89	0.27	0.31	0.38	0.42
Cl^-	pct	SIE		0.007	0.002	0.003	0.007	0.007	0.006	0.038
Total S	pct	comb./IR		0.07	0.01	0.19	0.31	0.39	2.93	0.52
CO_2	pct	coul. titra.		28.8	30.3	15.7	13.5	6.59	1.02	0.72
H_2O^+	pct	diff.		0.42	0.82	0.96	3.99	5.18	2.76	2.21
H_2O^-	pct	diff.		0.12	0.29	0.40	0.26	0.75	0.25	0.20
-F≡oxy	pct	calc.		0.04	0.23	0.80	0.11	0.13	0.16	0.18
-Cl≡oxy	pct	calc.		0.002	0	0.001	0.002	0.002	0.001	0.009
-S≡oxy	pct	calc.		0.035	0.005	0.095	0.16	0.20	1.47	0.26
Sum	pct	calc.		99.6	100.4	98.8	99.0	99.2	98.7	98.6
LOI	pct	925°C		29.0	30.3	16.7	16.9	11.3	2.76	2.07
Na	pct	INAA		0.024	1.40	0.953	4.66	3.44	2.71	3.20
K	pct	INAA		<0.1	0.65	2.41	3.1	1.02	4.2	4.5
Ca	pct	INAA		32.2	22.6	21.3	13.5	14.8	6.6	7.53
Fe	pct	INAA		1.64	3.21	3.19	1.6	2.94	7.21	6.76
V	ppm	ICP		25	174	986	97	212	418	336
Li	ppm	ICP		9.6	61	354	79	24	33	18
Ba	ppm	EDXRF		350	260	>5000	790	520	2600	2800
Cu	ppm	EDXRF		12	10	12	26	32	65	36
Ni	ppm	EDXRF		<10	<10	<10	<10	<10	<10	10
Zn	ppm	EDXRF		34	52	80	28	164	148	130
Sc	ppm	INAA		1.504	3.28	18.41	0.287	2.18	6.86	5.11
Cr	ppm	INAA		1	0.9	4	<2	2.12	3.3	6.4
Co	ppm	INAA		11.35	18.09	6.57	3.78	8.29	20	19.5
Ni	ppm	INAA		<10	<14	<21	<8	<15	25	<26

Table 1. Geochemical data of M5 drill core samples, Magnet Cove Complex, Arkansas - Continued

	Sample	M5-251	M5-365	M5-549.8	M5-704.5B	M5-547.5	M5-750	M5-740.5
Zn ..... ppm ..	INAA	37.6	66.3	75.8	34.2	162	146	135
As ..... ppm ..	INAA	2.08	14	16.1	3.3	8.9	12.4	9.6
Rb ..... ppm ..	INAA	<2	7.3	153	60.8	32.9	168	179
Sr ..... ppm ..	INAA	4026	2532	3395	2002	2390	2391	2830
Zr ..... ppm ..	INAA	<60	90	<197	263	246	349	384
Mo ..... ppm ..	INAA	<2	<1	<7	6.9	12.1	7.5	<9
Sb ..... ppm ..	INAA	0.138	0.64	0.28	0.282	0.76	3.38	3.03
Cs ..... ppm ..	INAA	0.13	0.65	3.22	12.37	1.18	3.95	7.82
Ba ..... ppm ..	INAA	348	284	9787	784	520	2616	2826
La ..... ppm ..	INAA	66.8	167	256	35.3	105.2	147	136
Ce ..... ppm ..	INAA	65.9	188	298	40.2	131.3	264	232
Nd ..... ppm ..	INAA	16.6	42.3	81	8.9	34.1	94	78.6
Sm ..... ppm ..	INAA	3.94	8.53	15.9	1.87	6.31	16.4	14
Eu ..... ppm ..	INAA	1.52	2.86	5.03	0.643	1.96	4.31	3.77
Tb ..... ppm ..	INAA	0.929	1.31	2.39	0.383	0.873	1.53	1.41
Ho ..... ppm ..	INAA	1.79	1.99	3.3	--	--	--	--
Yb ..... ppm ..	INAA	7.29	6.79	6.49	2.38	3.52	3.37	3.4
Lu ..... ppm ..	INAA	1.05	1.07	0.72	0.321	0.467	0.425	0.421
Hf ..... ppm ..	INAA	<0.05	6.15	4.52	3.59	4.66	6.68	6.08
Ta ..... ppm ..	INAA	0.039	0.108	3.01	1.50	6.16	18.2	17.9
Th ..... ppm ..	INAA	<0.1	0.369	13.75	2.84	12.02	21.2	18.7
U ..... ppm ..	INAA	0.44	1.41	20.3	3.97	7.8	5.62	5.93
Au ..... ppb ...	INAA	<3	<7	<8	15.4	7.9	<7	22.9

	Lab No.	W258892	W258894	W25899	W258929	W258923	W258931	W258930
Y ..... ppm ..	ICP	45	43	85	21	35	47	30
Sr ..... ppm ..	ICP	3900	2200	3100	1900	2100	2900	2300
Zr ..... ppm ..	ICP	11	99	130	240	320	510	330
Ba ..... ppm ..	ICP	370	320	9900	840	460	3800	5700
Mo ..... ppm ..	ICP	<1	<1	<1	5.8	12	5.5	3.5
Nb ..... ppm ..	ICP	46	121	227	191	220	290	317

Table 1. Geochemical data of M5 drill core samples, Magnet Cove Complex, Arkansas - Continued

			Sample	M5-567	M5-616.5	M5-626	M5-583	M5-704.5A	M5-658.5	M5-533
			Lab No.	W257445	W257447	W257448	W257446	W257449	W257480	W257477
			Rock type	alt sil rock	alt sil rock	alt sil rock	alt sil rock	alt sil rock	alt clay-rich	alt clay-rich
SiO_2	pct	WDXRF		46.0	46.6	48.0	48.1	49.9	34.3	39.2
TiO_2	pct	WDXRF		2.65	0.96	2.17	1.58	0.22	3.85	0.75
Al_2O_3	pct	WDXRF		18.5	17.9	17.7	17.9	20.9	7.51	14.9
Fe_2O_3	pct	calc.		1.88	5.57	2.91	3.93	2.25	5.9	2.1
FeO	pct	col. titra		6.61	1.45	4.40	1.86	0.82	3.5	1.9
MnO	pct	WDXRF		0.24	0.39	0.21	0.19	0.23	0.37	0.31
MgO	pct	WDXRF		2.74	0.99	2.02	1.40	0.60	4.05	3.65
CaO	pct	WDXRF		7.29	7.65	7.47	6.04	4.72	9.79	12.5
Na_2O	pct	WDXRF		3.56	4.65	6.00	7.49	6.13	0.76	2.07
K_2O	pct	WDXRF		5.66	6.63	4.23	6.39	6.70	0.07	2.07
P_2O_5	pct	WDXRF		0.64	0.28	0.49	0.35	0.14	<0.05	0.32
F^-	pct	SIE		0.42	0.13	0.25	0.14	0.05	1.1	0.48
Cl^-	pct	SIE		0.016	0.042	0.016	0.268	0.007	0.011	0.012
Total S	pct	comb./IR		0.93	0.21	0.76	0.60	0.11	2.5	0.28
CO_2	pct	coul. titra.		0.47	1.27	0.62	1.11	1.6	14.7	12.7
H_2O^+	pct	diff.		1.88	2.85	1.90	1.30	3.94	3.2	3.3
H_2O^-	pct	diff.		0.27	0.80	0.20	0.17	0.43	2.9	2.4
-F≡oxy	pct	calc.		0.18	0.05	0.11	0.06	0.02	0.46	0.20
-Cl≡oxy	pct	calc.		0.004	0.009	0.004	0.061	0.002	0.002	0.003
-S≡oxy	pct	calc.		0.47	0.11	0.38	0.30	0.06	1.25	0.14
Sum	pct	calc.		99.1	98.2	98.9	98.4	98.7	92.8[1]	98.6
LOI	pct	925°C		1.42	4.26	1.95	1.80	5.55	17.1	18.1
Na	pct	INAA		2.72	3.64	4.74	5.95	4.85	<19	1.66
K	pct	INAA		4.9	6.0	3.7	5.8	6.2	<100	2.01
Ca	pct	INAA		6.4	5.2	6.2	4.57	3.58	<15	9.0
Fe	pct	INAA		6.74	5.29	5.66	4.38	2.33	6.16	3.13
V	ppm	ICP		260	398	263	186	142	290	346
Li	ppm	ICP		25	19	6.4	7.6	144	113	163
Ba	ppm	EDXRF		1350	4100	1350	1850	1900	nd	395
Cu	ppm	EDXRF		36	<10	38	21	<10	12	63
Ni	ppm	EDXRF		14	<10	<10	16	<10	26	<10
Zn	ppm	EDXRF		116	205	108	95	124	170	94
Sc	ppm	INAA		5.29	0.744	5.03	3.05	0.072	4.13	8.2
Cr	ppm	INAA		4.0	1.5	9.3	2.8	<1	<11	6.1
Co	ppm	INAA		19.2	5.34	17.8	11.38	0.918	20.7	6.71
Ni	ppm	INAA		20	<19	<24	<14	<8	<140	<23

Table 1. Geochemical data of M5 drill core samples, Magnet Cove Complex, Arkansas - Continued

	Sample	M5-567	M5-616.5	M5-626	M5-583	M5-704.5A	M5-658.5	M5-533
Zn ..... ppm ..	INAA	113	209	110	97.4	121	265	74.1
As ..... ppm ..	INAA	12.8	8.9	6.2	4.5	4.4	<120	4.89
Rb ..... ppm ..	INAA	199	207	127	183	134	<40	58
Sr ..... ppm ..	INAA	1567	2823	1499	1474	1378	2020	1670
Zr ..... ppm ..	INAA	348	349	333	323	294	<600	99
Mo ..... ppm ..	INAA	8.1	10.1	3.1	3.4	5.8	<70	4.5
Sb ..... ppm ..	INAA	2.18	2.07	1.12	0.92	0.5	1.76	1.38
Cs ..... ppm ..	INAA	2.61	3.67	0.98	5.47	4.61	4.1	4.42
Ba ..... ppm ..	INAA	1345	4073	1375	1859	1932	<190	421
La ..... ppm ..	INAA	128	175	110	101.2	137	17800	67.2
Ce ..... ppm ..	INAA	231	268	189	166	151	14350	91.1
Nd ..... ppm ..	INAA	82.6	54	67	54	20.8	2920	32.7
Sm ..... ppm ..	INAA	14.09	5.9	11.2	8.73	1.69	511	8.67
Eu ..... ppm ..	INAA	3.58	1.44	2.8	2.28	0.368	138.2	2.63
Tb ..... ppm ..	INAA	1.32	0.498	1.015	0.847	0.109	29.6	1.13
Yb ..... ppm ..	INAA	2.95	1.78	2.56	2.33	0.44	5.9	2.91
Lu ..... ppm ..	INAA	0.378	0.231	0.337	0.308	0.063	0.80	0.395
Hf ..... ppm ..	INAA	6.58	3.99	6.68	6.36	3.65	0.84	1.60
Ta ..... ppm ..	INAA	16.3	4.23	10.15	8.27	1.42	11.8	3.65
Th ..... ppm ..	INAA	20.2	23.8	20.5	21.3	19.2	839	8.36
U ..... ppm ..	INAA	5.27	19.23	6.16	7.53	5.01	8.2	1.78
Au ..... ppb ...	INAA	59	16.4	<8	<7	<5	<140	4.7

	Lab No.	W258924	W258926	W258927	W258925	W258928	W258959	W258956
Y ..... ppm ..	ICP	41	29	34	24	3.3	180	26
Sr ..... ppm ..	ICP	1900	4100	1800	1400	1100	1900	1500
Zr ..... ppm ..	ICP	520	660	510	430	320	77	90
Ba ..... ppm ..	ICP	2100	7100	2100	2400	1800	140	450
Mo ..... ppm ..	ICP	9.4	9.5	1.5	4.3	5.6	8.3	4.6
Nb ..... ppm ..	ICP	271	267	179	157	101	952	177

Table 1. Geochemical data of M5 drill core samples, Magnet Cove Complex, Arkansas - Continued

			Sample	M5-657.5	M5-728	M5-656.5	M5-619	M5-662
			Lab No.	W257479	W257483	W257478	W257481	W257482
			Rock type	alt clay-rich	alt clay-rich	alt clay-rich	alt clay-rich	alt clay-rich
SiO_2	pct	WDXRF		40.0	41.6	43.8	44.0	45.4
TiO_2	pct	WDXRF		3.16	1.03	3.24	1.73	3.61
Al_2O_3	pct	WDXRF		15.0	19.5	17.2	19.8	19.5
Fe_2O_3	pct	calc.		5.9	4.4	5.0	0.85	2.8
FeO	pct	col. titra		4.8	3.2	2.3	0.88	1.2
MnO	pct	WDXRF		0.46	0.2	0.18	0.14	0.09
MgO	pct	WDXRF		3.81	4.14	1.75	1.21	1.64
CaO	pct	WDXRF		5.97	6.36	5.19	8.13	4.07
Na_2O	pct	WDXRF		1.11	1.93	1.12	1.21	1.41
K_2O	pct	WDXRF		1.57	2.60	4.80	4.33	2.17
P_2O_5	pct	WDXRF		0.49	0.3	0.78	0.52	0.75
F^-	pct	SIE		1.3	0.69	0.49	0.38	0.35
Cl^-	pct	SIE		0.019	0.014	0.005	0.005	0.005
Total S	pct	comb./IR		0.82	0.25	2.0	0.18	1.6
CO_2	pct	coul. titra.		9.4	5.3	5.0	6.1	2.8
H_2O^+	pct	diff.		3.7	4.9	3.2	4.2	4.6
H_2O^-	pct	diff.		5.0	3.9	3.0	3.3	5.0
-F≡oxy	pct	calc.		0.55	0.29	0.21	0.16	0.15
-Cl≡oxy	pct	calc.		0.004	0.003	0.001	0.001	0.001
-S≡oxy	pct	calc.		0.41	0.13	1.0	0.09	0.8
Sum	pct	calc.		101.6	99.9	97.8	96.7	96
LOI	pct	925°C		17.6	14.4	11.3	14.1	13.8
Na	pct	INAA		0.879	1.52	0.884	0.941	1.10
K	pct	INAA		1.62	2.33	4.41	4.02	2.08
Ca	pct	INAA		3.91	4.57	4.40	6.22	2.82
Fe	pct	INAA		5.92	5.0	5.28	2.23	3.65
V	ppm	ICP		323	542	395	493	440
Li	ppm	ICP		57	174	127	154	45
Ba	ppm	EDXRF		770	1100	2100	2300	1400
Cu	ppm	EDXRF		32	23	49	32	30
Ni	ppm	EDXRF		10	<10	<10	<10	<10
Zn	ppm	EDXRF		44	46	27	260	530
Sc	ppm	INAA		5.76	2.78	7.51	2.54	6.09
Cr	ppm	INAA		7.1	2.1	9.3	<1	5
Co	ppm	INAA		28.9	6.22	31.1	6.97	28.7
Ni	ppm	INAA		<60	<21	<28	<18	<27

Table 1. Geochemical data of M5 drill core samples, Magnet Cove Complex, Arkansas - Continued

			Sample	M5-657.5	M5-728	M5-656.5	M5-619	M5-662
Zn	ppm	INAA		37.7	45.2	31.1	219	572
As	ppm	INAA		7.9	2.55	20.9	9.4	11.7
Rb	ppm	INAA		36.6	108	125	91	37.2
Sr	ppm	INAA		1240	870	2250	1970	1340
Zr	ppm	INAA		210	345	300	429	440
Mo	ppm	INAA		14.3	3.1	11.4	5.2	12.3
Sb	ppm	INAA		2.16	0.72	2.78	1.3	4.66
Cs	ppm	INAA		1.33	13.1	3.48	2.19	2.07
Ba	ppm	INAA		810	1120	2160	2330	1470
La	ppm	INAA		109	49.9	164	83.3	122
Ce	ppm	INAA		145	55	258	97.4	182
Nd	ppm	INAA		46.9	13.6	85.9	28	62.1
Sm	ppm	INAA		10.67	2.81	14.33	5.72	10.2
Eu	ppm	INAA		3.44	0.95	3.37	1.77	2.46
Tb	ppm	INAA		1.7	0.531	1.14	0.788	0.752
Yb	ppm	INAA		2.81	3.00	2.99	2.02	1.42
Lu	ppm	INAA		0.375	0.417	0.407	0.276	0.196
Hf	ppm	INAA		4.34	4.73	6.45	5.19	8.25
Ta	ppm	INAA		14.66	3.44	15.22	5.58	17.7
Th	ppm	INAA		22.1	4.54	18.8	9.34	22.8
U	ppm	INAA		9.64	2.99	3.8	4.43	6.54
Au	ppb	INAA		<4	<3	<5	11.5	12.5
			Lab No.	W258958	W258962	W258957	W258960	W258961
Y	ppm	ICP		31	21	19	22	11
Sr	ppm	ICP		1200	950	1900	2100	1100
Zr	ppm	ICP		240	300	350	650	430
Ba	ppm	ICP		900	1400	2300	3100	1500
Mo	ppm	ICP		16	3.6	13	5.9	13
Nb	ppm	ICP		411	192	251	273	251

[1] low sum attributed to high concentrations of REE and other elements that are commonly considered trace elements in many igneous rocks