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CHEMICAL AND MINERAL COMPOSITION DATA ON OIL SHALE AND RETORTED OIL-SHALE WASTES FROM RULISON, COLORADO

by

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CONTENTS

	Page
Introduction	1
Sampling methods	2
Analytical methods	2
References cited	5

ILLUSTRATIONS

Page

Figure 1. Index map of the Piceance basin between the White and Colorado Rivers, showing the location of the Rulison experimental retorting site..... 7

2. Plan view of the Rulison experimental retorting site showing the location of selected plant facilities, waste pile, and drill holes..... 8

TABLES

Page

Table 1. Description of drill holes in retorted oil-shale waste and underlying material..... 9

2. Peak positions and chemical formulas for minerals identified by X-ray diffractometry..... 10

3. Chemical and mineral composition data for retorted oil-shale, oil shale, and standards..... 11

4. Comparison of literature values for oil-shale and retorted oil-shale standard samples with those values obtained during this study..... 28

Chemical and Mineral Composition Data on Oil Shale and Retorted Oil-Shale Wastes from Rulison, Colorado

by Michele L. Tuttle, Daniel J. Ackerman, Walter E. Dean, Paul H. Briggs, and Ardith J. Bartel

Introduction

In May of 1981, a retorted oil-shale waste pile and an oil-shale mine were sampled at Rulison, Colorado (fig. 1). The oil-shale mine and retort was operated by the U.S. Bureau of Mines from 1926 until 1929 (for a detailed description of the operations see Gavin and Desmond, 1930). In the Colorado-Utah-Wyoming region, the Rulison site contains the only sizeable area of retorted oil-shale waste representing retorting activities before 1950. The oil shale was mined above the plant and retorted by processes similar to those used for modern above-ground retorting. The objectives of this study were to investigate (1) the chemical and mineralogical changes during 50 years of weathering of spent shale and (2) differences between the chemical and mineral composition of the oil shale used in the retorts and the retorted oil-shale waste.

One hundred twelve samples from the waste pile, 11 samples of slope wash and (or) alluvium from the drill hole adjacent to the waste pile, and 13 samples of oil shale from the mine were collected. Three oil-shale and retorted oil-shale standard samples were also analyzed, in duplicate, producing a total suite of 142 samples, including 20 analytical replicates. The results of these analyses are tabulated in this report.

Sampling Methods

Samples from the waste pile and an area containing only slope wash and (or) alluvium adjacent to the waste pile were obtained from eight drill holes. The location of the drill holes with respect to the oil-shale plant site is shown on figure 2. Table 1 presents a brief description of each drill hole. The samples were taken by advancing a 0.5-meter split-spoon sampler ahead of a hollow-stem auger. All sample containers and sample-handling materials were cleaned with high-purity methylene chloride.

Oil-shale samples were collected from the mine wall at 0.3-meter intervals through the Mahogany zone. Two samples of leaner oil shale were collected from the adjacent quarry. All samples were crushed and ground to pass through a 100-mesh screen.

Analytical Methods

Mineral composition

Whole-rock mineral composition was determined using a Picker X-ray diffractometer with Ni-filtered, Cu-K radiation. Randomly oriented powder mounts were prepared by grinding the sample to approximately 5 μm and placing the powder in a sample packer with a gridded teflon frontpiece (Schultz, 1978). The result is a loosely-packed powder mount with a gridded surface. Intensities of specified peaks for each mineral (table 2) were measured on X-ray diffractograms and were used as measures of relative abundances of those minerals as tabulated in table 3. The mineral composition data are semiquantitative.

Chemical composition

Major-element oxide concentrations were determined with a Phillips PW1600 wavelength-dispersive simultaneous X-ray spectrometer[1/] with a rhodium target end-window tube (Taggart and others, 1981). In order to eliminate particle-size effects and to decrease matrix effects, samples were presented to the X-ray spectrometer as a lithium tetraborate fused glass disc. The glass discs were prepared by igniting the sample at 920°C, cooling it, and reweighing 0.8 grams. Eight grams of lithium tetraborate were mixed with the reweighed sample and 40 µL of concentrated lithium bromide solution added to prevent the disc sticking to the mold. The sample mixture, together with empty molds (Taggart and Wahlberg, 1979), were loaded into an automatic fluxer (Taggart and Wahlberg, 1980), and fused at 1120°C.

The loss in weight after the first ignition of the samples was reported as percent loss on ignition (LOI). These data represent the loss of water and carbon dioxide from the oxidation of organic carbon and decomposition of carbonate minerals, plus some or all of the volatile elements.

Semi-quantitative, induction-coupled, argon-plasma, optical-emission spectroscopy (Floyd and others, 1980) was used to analyze for arsenic, boron, barium, beryllium, cadmium, cerium, cobalt, chromium, copper, lead, lanthanum, lithium, manganese, molybdenum, neodynium, niobium, nickel, scandium, strontium, thorium, vanadium, yttrium, zinc, and zirconium. Boron and zirconium were determined by fusing 0.1 gram of sample with 1.0 grams potassium hydroxide at 400°C in a vitreous carbon crucible. The fusion cake was then dissolved in nitric acid and aspirated into the spectrophotometer.

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[1]Use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

The remainder of the trace elements were determined by decomposing 1.0 gram of sample with nitric, percholoric, and hydrofluoric acids. The acids were added to the sample and the solution evaporated to dryness. This procedure was repeated. The dryed salts were dissolved in water and concentrated nitric acid, brought to 50 mL, and aspirated into the spectrophotometer.

The analytical results are given in Table 3. The accuracy and precision of the methods was monitored by the analysts using internal standards and standard reference materials. In addition, known standard samples of oil shale and retorted oil shale were analyzed, in duplicate, with the sample suite. The average elemental concentrations in the standards computed from literature values and the average concentrations obtained from this study are compared in table 4.

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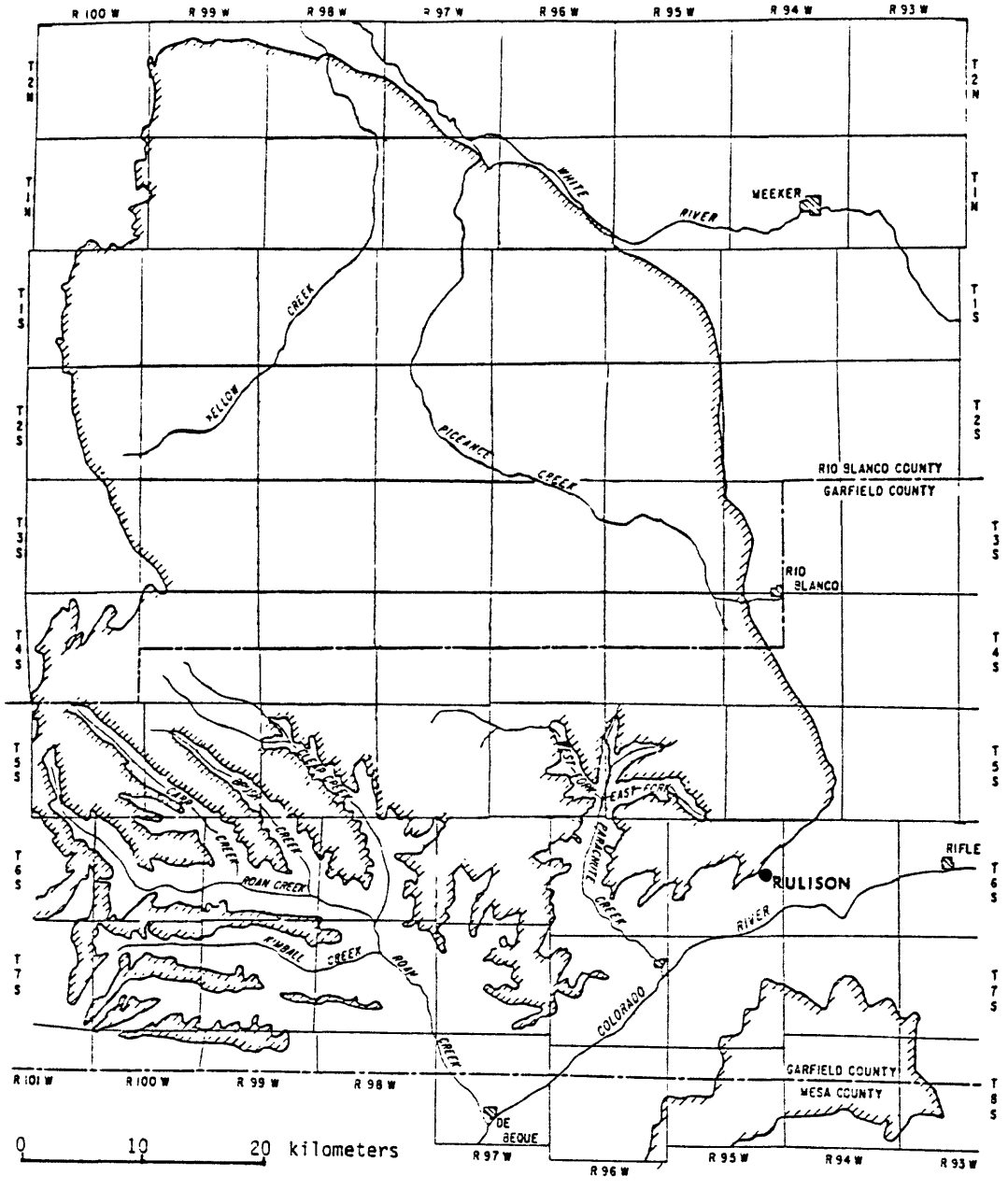

Figure 1. Index map of the Piceance basin between the White and Colorado Rivers, showing the location of the Rulison experimental retorting site (indicated as Rulison). Hachured area is underlain by the Green River Formation.

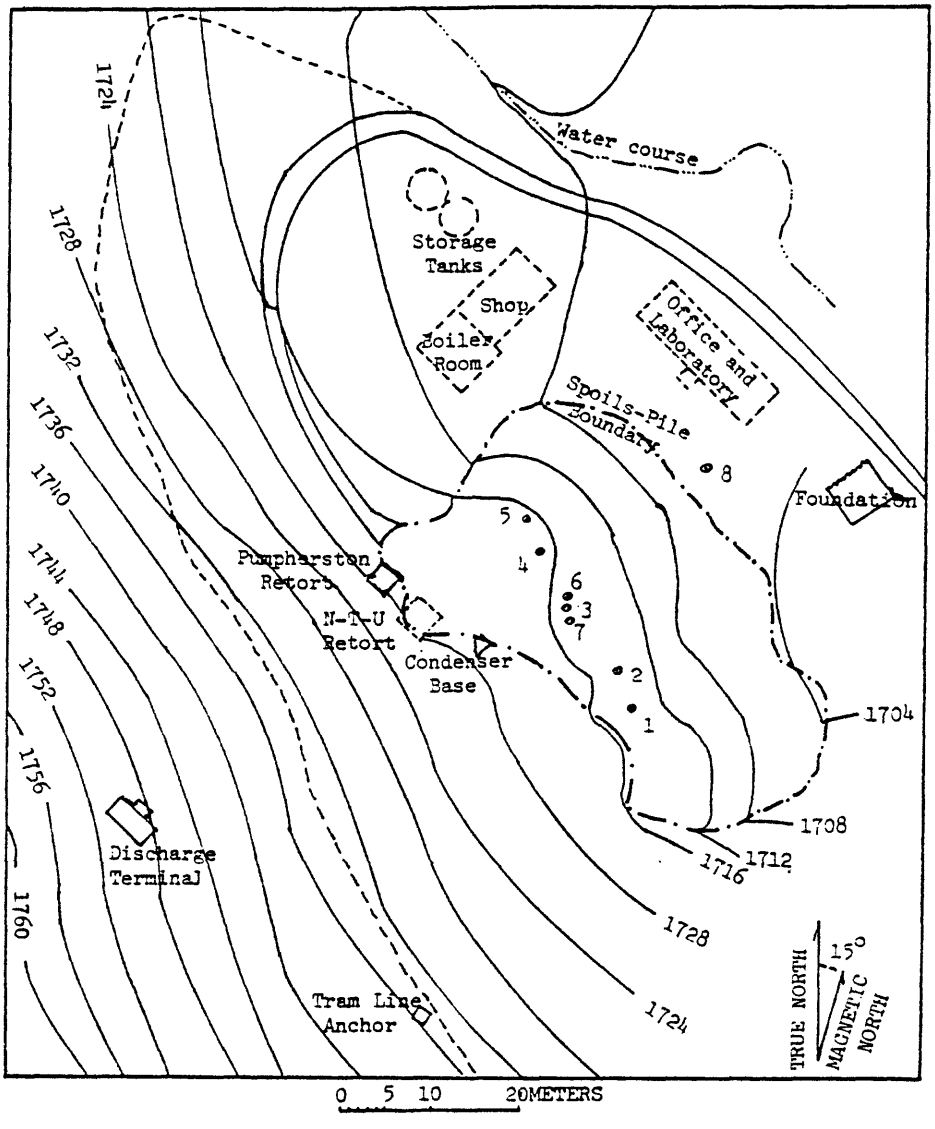

Figure 2. The Rulison experimental retorting site showing location of selected plant facilities, spoil pile, and sampling sites. Modified from Gavin and Desmond (1930). Facilities outlined by dashed lines are no longer in evidence.

Table 1.--Descriptions of drill holes in retorted oil-shale waste and underlying material at U.S. Bureau of Mines experimental retort site, Rulison, Colorado

[NGVD, National Geodetic Vertical Datum]

Drill hole Number (Figure 2)	Altitude above NGVD of 1929 (meters)	Total Depth (meters)	Depth to top of underlying material (meters)	Number of samples
1	1715.9	5.9	3.9	18
2	1715.9	6.3	5.1	20
3	1715.8	5.4	4.2	15
4	1716.1	2.9	0.4	8
5	1716.4	1.6	0	6
6	1715.9	6.6	5.6	22
7	1715.8	4.1	3.5	13
8	1705.1	2.0	0	8

Table 2.--Peak positions and chemical formulas for minerals identified by X-ray diffractometry

Mineral	Chemical formula[1]	Peak position (degrees 2θ)
Akermanite-----	$Ca_2[MgSi_2O_7]$	31.2
Analcime-------	$Na[AlSi_2O_6]\cdot H_2O$	26.0
Calcite--------	$CaCO_3$	29.4
Chlorite-------	$(Mg,Al,Fe)_{12}[(Si,Al)_8O_{20}](OH)_6$	12.4
Diopside-------	$CaMg[Si_2O_6]$	29.9
Dolomite-------	$CaMg(CO_3)_2$	30.8
Gypsum---------	$CaSO_4\cdot 2H_2O$	11.7
Illite---------	$K_{1-1.5}Al_4[Si_{7-6.5}Al_{1-1.5}O_{20}](OH)_4$	8.8
Montmorillonite (anhydride)--	$(\frac{1}{2}\,Ca,Na)_{0.7}(Al,Mg,Fe)_4[(Si,Al)_8O_{22}]$	9.1
Potassium feldspar-----	$KAlSi_3O_8$	27.5
Quartz---------	SiO_2	26.6
Sodium feldspar	$NaAlSi_3O_8$	27.9

[1]Deer and others, 1966.

Table 3.--Chemical and mineral composition data for 112 test hole samples from the Rulison retorted oil-shale waste pile,and adjacent area, 10 samples from the Rulison oil-shale mine, three oil-shale and retorted oil-shale standards, and 20 analytical replicates

[m, meters; pct, percent; ppm, parts per million; LOI, loss on ignition at 920°C; results for minerals are in relative X-ray diffraction intensities; results for major elements are reported as oxides; depth variable for oil-shale samples refers to the height, in meters, above the mine floor; samples 31001 and 31002 are Fisher assay standard FASS, samples 32001 and 32002 are spent-shale standard SS-1, samples 33001 and 33002 are oil-shale standard OS-1]

Chemical and Mineral Analyses

Sample	hole no.	depth(m)	Al_2O_3 pct	CaO pct	Fe_2O_3 pct	K_2O pct	MgO pct	MnO pct	Na_2O pct	P_2O_5 pct	SiO_2 pct	TiO_2 pct	LOI pct	As ppm
						Test Hole Samples								
11011	1	.23	9.05	18.9	3.81	1.80	8.16	.03	2.87	.26	41.2	.33	12.2	60
11021	1	.38	7.23	24.4	2.93	1.31	7.12	.03	2.14	.41	32.3	.25	19.9	60
11031	1	.53	6.28	23.8	2.66	1.31	6.34	.03	2.44	.37	28.1	.21	26.5	60
11041	1	.76	7.36	22.7	2.93	1.49	6.85	.03	2.22	.34	34.2	.25	19.6	60
11051	1	1.43	6.58	27.0	2.72	1.20	6.12	.03	1.71	.39	29.1	.22	22.7	50
11061	1	2.00	8.39	18.9	3.47	2.46	6.89	.04	2.07	.31	36.1	.30	19.2	70
11071	1	2.29	9.47	17.3	3.99	2.89	7.51	.04	2.31	.23	41.2	.35	12.4	60
11081	1	2.75	9.68	18.9	3.70	3.11	8.33	.04	1.93	.19	42.3	.34	9.45	60
11091	1	3.05	10.1	19.3	3.90	3.05	8.56	.05	2.32	.23	44.3	.35	6.02	50
11101	1	3.49	9.37	19.7	4.30	3.00	8.45	.05	2.08	.16	41.4	.34	9.64	30
11111	1	3.81	10.6	16.8	3.69	2.22	7.57	.04	3.90	.14	48.7	.33	6.08	30
11121	1	3.92	8.67	14.5	3.44	2.67	4.44	.05	1.74	.18	43.9	.37	19.0	30
11122	1	3.92	8.44	14.8	3.42	2.63	4.49	.05	1.69	.17	42.9	.34	19.5	20
11131	1	4.12	9.56	12.9	3.40	2.79	4.05	.04	1.73	.21	46.0	.38	17.5	10
11141	1	4.42	9.24	14.0	3.24	2.62	4.30	.04	1.97	.17	42.6	.35	19.8	30
11151	1	4.88	7.41	13.2	2.35	2.24	2.73	.04	1.31	.17	53.9	.29	15.0	20
11161	1	5.18	9.85	10.5	3.44	2.32	3.31	.05	1.63	.22	53.0	.39	14.7	20
11171	1	5.49	10.2	10.4	3.47	2.41	3.13	.05	1.53	.18	52.8	.40	14.4	20
11181	1	5.79	10.9	9.92	3.64	2.39	3.15	.06	1.55	.25	52.3	.44	14.3	20
12011	2	.23	8.82	19.5	3.61	2.15	8.07	.04	2.23	.25	38.3	.33	15.4	50
12021	2	.49	9.15	18.6	3.87	2.20	8.54	.04	2.12	.19	39.0	.33	13.9	40
12031	2	.76	9.61	20.0	3.72	2.44	9.73	.04	2.46	.26	41.9	.37	8.13	40
12041	2	1.28	8.22	24.9	3.26	1.75	8.78	.03	2.32	.19	36.9	.28	11.4	50
12042	2	1.28	8.02	25.6	3.17	1.65	8.61	.03	2.16	.19	36.0	.26	11.7	50
12051	2	1.59	8.16	22.7	3.39	1.68	7.49	.03	2.82	.37	36.1	.28	15.0	50
12061	2	2.10	7.94	22.1	3.08	1.71	5.93	.03	3.05	.46	32.8	.27	19.9	50
12071	2	2.41	7.32	24.7	2.86	1.43	7.59	.03	2.91	.34	33.9	.25	16.9	50
12081	2	2.90	8.06	17.4	3.24	2.18	6.31	.03	2.85	.29	35.3	.29	21.8	60
12091	2	3.20	9.18	21.7	3.72	2.28	8.07	.04	2.75	.46	39.7	.33	9.75	50
12101	2	3.66	9.84	21.3	4.07	2.52	7.77	.04	3.10	.35	42.2	.35	7.17	30
12111	2	3.96	9.03	21.5	3.60	2.43	7.44	.04	2.68	.39	38.3	.31	12.8	40
12121	2	4.27	8.79	20.5	3.64	2.28	7.67	.04	2.72	.43	37.6	.32	13.7	40
12122	2	4.27	8.77	20.3	3.55	2.29	7.45	.04	2.72	.40	37.2	.31	14.3	40
12123	2	4.27	8.70	20.5	3.57	2.27	7.67	.04	2.76	.45	37.1	.32	14.5	40
12131	2	4.89	9.25	17.8	3.65	1.98	6.54	.03	3.82	.37	41.9	.28	11.7	60
12132	2	4.89	9.36	17.4	3.48	1.98	6.55	.03	3.93	.38	42.3	.30	11.8	30
12141	2	5.06	8.62	15.9	3.93	1.95	6.56	.03	2.85	.23	38.2	.30	19.4	30
12151	2	5.21	9.10	12.7	3.32	2.79	4.16	.04	1.69	.21	46.4	.36	17.6	10
12161	2	5.58	8.08	16.2	2.84	2.26	4.04	.05	1.60	.15	43.6	.30	20.3	20
12171	2	5.93	9.96	12.8	3.43	2.72	4.09	.04	1.56	.18	45.6	.40	18.2	20

Sample	B ppm	Ba ppm	Be ppm	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cu ppm	La ppm	Li ppm	Mn ppm	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm
Test Hole Samples																
11011	70	510	1	4	26	11	69	57	29	130	300	26	12	15	50	40
11021	50	570	1	2	40	9	34	47	29	72	390	21	6	18	30	40
11031	<50	460	<1	<2	23	7	25	37	24	72	280	20	8	14	23	30
11041	50	530	1	4	27	9	34	43	33	81	400	18	10	17	27	40
11051	60	540	1	3	24	7	31	35	21	55	290	20	5	11	23	30
11061	80	560	1	3	36	8	39	41	25	93	290	22	8	7	27	40
11071	120	550	2	5	44	11	53	54	28	120	330	27	8	20	39	50
11081	110	610	2	4	47	9	52	52	35	110	460	25	11	13	34	40
11091	120	560	1	3	45	9	41	48	29	110	370	20	11	25	33	30
11101	110	570	2	3	43	9	74	51	31	110	380	16	10	25	43	30
11111	80	2,000	2	4	45	11	64	46	29	150	360	19	9	25	47	20
11121	80	500	1	3	44	6	38	26	29	71	370	9	8	30	21	20
11122	80	470	1	3	31	5	32	25	29	64	400	8	9	13	18	20
11131	90	500	1	3	42	7	29	27	29	75	330	8	8	19	21	20
11141	90	470	1	3	36	6	30	24	26	64	330	9	7	12	20	20
11151	70	830	<1	3	30	5	34	18	23	41	320	<4	<5	16	20	20
11161	60	470	1	2	49	7	23	20	26	51	330	<4	<5	13	22	30
11171	70	460	<1	2	90	7	33	23	27	47	390	<4	7	90	18	20
11181	80	570	1	4	39	8	41	24	29	53	430	4	7	24	21	20
12011	100	620	1	4	33	9	36	47	29	100	320	22	9	26	22	40
12021	100	590	1	4	33	8	35	40	26	110	320	20	8	18	22	30
12031	80	600	1	4	41	12	29	41	28	170	310	21	6	20	23	40
12041	<50	540	1	3	35	10	27	37	29	120	310	25	9	11	27	40
12042	70	520	1	4	27	9	40	38	24	110	300	24	8	18	30	40
12051	70	550	1	3	27	10	34	55	23	100	270	27	6	18	30	40
12061	<50	500	1	3	30	9	29	44	27	74	370	24	6	19	25	30
12071	<50	490	1	<2	22	8	30	35	22	89	260	23	<5	<5	20	20
12081	80	470	1	4	29	9	39	50	28	100	290	29	8	20	26	40
12091	60	590	1	3	33	9	31	41	30	96	350	22	9	13	25	40
12101	70	610	1	3	41	9	46	48	30	140	340	22	8	16	39	30
12111	90	590	1	3	40	10	53	37	29	110	330	20	8	14	29	30
12121	80	610	1	3	36	9	50	45	31	140	410	26	9	26	32	30
12122	100	670	1	4	37	9	41	46	26	160	320	26	5	19	29	30
12123	70	630	1	2	27	8	42	42	27	130	290	22	5	6	23	40
12131	80	780	2	6	64	17	92	72	54	230	580	40	12	27	56	50
12132	80	510	1	3	36	11	51	47	35	140	380	24	7	26	32	30
12141	80	500	1	3	36	8	32	43	28	81	300	22	8	21	20	30
12151	90	460	1	4	41	6	31	21	24	65	340	9	6	25	18	20
12161	<50	410	1	3	28	5	29	18	28	57	360	5	6	13	17	20
12171	80	670	1	3	37	9	38	32	31	73	430	7	9	16	22	20

Chemical and Mineral Analyses

Sample	Sc ppm	Sr ppm	Th ppm	V ppm	Y ppm	Zn ppm	Zr ppm	akerman	analcime	calcite	chlorite	diopside	dolomite	gypsum	illite
							Test Hole Samples								
11011	5	770	9	130	10	69	60	20	--	33	--	16	--	--	--
11021	6	1,100	12	100	10	59	50	15	--	50	--	9	--	3	--
11031	<4	980	4	85	8	47	30	8	--	90	--	6	22	--	3
11041	6	970	9	96	10	59	70	18	3	44	--	10	14	2	2
11051	<4	1,100	8	75	8	14	30	14	--	36	--	8	11	4	--
11061	7	790	7	95	11	57	60	20	3	25	--	12	20	--	--
11071	7	770	12	120	12	73	50	17	5	17	--	15	--	--	13
11081	8	830	9	110	14	72	60	25	5	10	--	20	N	5	--
11091	7	850	13	110	14	68	50	33	6	11	--	25	11	6	2
11101	8	850	14	100	15	59	50	26	8	20	--	24	N	2	1
11111	5	780	12	95	12	19	70	26	3	10	--	29	--	--	--
11121	7	520	16	72	11	71	80	--	9	46	--	--	51	--	7
11122	6	520	<4	68	13	15	90	--	6	42	--	--	55	--	6
11131	7	440	7	74	14	53	80	--	6	38	3	--	40	--	8
11141	6	470	6	70	12	11	70	--	11	43	--	--	48	--	6
11151	4	380	7	52	11	<4	60	--	5	87	1	--	31	--	8
11161	7	390	7	68	13	55	90	--	5	35	5	--	28	--	8
11171	7	330	5	65	12	50	100	--	6	42	5	--	33	--	7
11181	8	380	14	82	15	25	100	--	7	36	7	--	36	--	10
12011	6	870	12	100	12	60	50	18	6	36	--	14	10	--	--
12021	6	820	4	96	11	20	50	16	6	28	--	12	10	--	2
12031	6	910	14	87	11	59	70	33	5	12	--	17	--	--	--
12041	5	1,100	4	95	9	63	60	39	3	20	--	13	--	3	2
12042	6	1,000	6	89	9	23	40	38	--	22	--	10	--	3	--
12051	5	960	4	110	9	68	50	23	--	42	--	11	8	--	5
12061	5	910	11	89	9	58	50	13	3	45	--	7	7	7	--
12071	<4	1,000	<4	77	8	52	40	18	--	32	--	9	--	3	--
12081	5	740	9	100	10	63	50	14	5	38	--	13	24	3	3
12091	5	910	7	100	12	69	70	41	5	16	--	15	--	3	--
12101	6	920	10	99	12	73	70	45	6	17	--	14	--	--	--
12111	8	930	12	87	13	59	70	--	8	27	--	--	--	--	--
12121	9	880	17	91	13	57	60	23	7	31	--	16	--	--	1
12122	6	970	13	97	13	27	50	21	8	31	--	15	--	--	--
12123	6	900	5	89	11	59	80	22	6	32	--	15	--	--	2
12131	10	1,200	16	160	16	100	70	17	5	30	--	16	--	N	--
12132	6	780	10	110	11	58	70	17	4	29	--	17	--	--	--
12141	7	650	10	100	13	20	60	9	16	19	--	13	41	--	2
12151	6	450	11	71	13	11	80	--	7	41	3	--	53	--	7
12161	5	490	8	58	10	41	80	--	12	74	--	--	45	--	5
12171	7	430	8	79	13	59	110	--	6	35	3	--	39	--	7

Sample	K-spar	mont-anh	Na-spar	quartz
			Test Hole Samples	
11011	12	--	22	31
11021	9	--	9	14
11031	10	--	45	20
11041	8	--	28	27
11051	6	4	26	13
11061	10	2	21	20
11071	12	2	20	19
11081	10	2	12	15
11091	12	2	9	13
11101	11	4	8	17
11111	12	--	14	20
11121	12	5	22	94
11122	12	5	21	98
11131	16	7	26	90
11141	14	7	39	86
11151	22	3	64	220
11161	16	--	38	120
11171	12	--	36	140
11181	13	--	26	120
12011	10	--	21	22
12021	10	--	14	25
12031	7	--	9	19
12041	7	--	13	10
12042	6	--	13	8
12051	11	--	31	15
12061	9	--	46	16
12071	9	--	25	11
12081	10	4	47	37
12091	8	1	14	14
12101	6	--	9	14
12111	7	2	9	16
12121	8	2	11	18
12122	7	3	9	15
12123	6	2	13	16
12131	12	5	15	17
12132	12	5	16	18
12141	11	3	19	45
12151	14	9	28	100
12161	28	3	23	120
12171	13	2	26	100

Chemical and Mineral Analyses--continued

Sample	hole no.	depth(m)	Al_2O_3 pct	CaO pct	Fe_2O_3 pct	K_2O pct	MgO pct	MnO pct	Na_2O pct	P_2O_5 pct	SiO_2 pct	TiO_2 pct	LOI pct	As ppm
12172	2	5.93	9.71	12.8	3.39	2.74	4.28	.04	1.51	.19	45.6	.39	18.7	30
12181	2	6.13	8.82	15.2	3.20	2.37	5.40	.04	1.88	.16	41.3	.34	20.7	20
12191	2	6.31	9.68	12.7	3.45	2.51	4.93	.05	1.96	.16	45.2	.37	18.0	40
13011	3	.28	10.6	11.4	3.59	2.11	4.05	.03	1.36	.20	47.8	.40	17.1	30
13021	3	.58	10.2	15.2	4.19	2.11	6.23	.04	2.78	.33	45.6	.37	11.9	40
13031	3	1.34	10.4	16.8	4.02	2.03	6.70	.04	2.62	.23	45.2	.36	10.2	30
13041	3	1.73	9.65	20.7	3.72	2.19	7.86	.04	2.61	.32	41.9	.33	9.43	30
13042	3	1.73	9.60	21.1	3.92	2.18	8.01	.04	2.75	.32	42.0	.33	8.80	30
13051	3	2.47	10.1	19.6	4.13	2.16	7.57	.04	3.21	.51	42.9	.35	7.95	50
13061	3	2.78	8.58	20.6	3.83	2.04	8.70	.04	2.38	.32	37.3	.31	14.8	40
13071	3	3.26	8.02	16.8	3.23	2.23	7.39	.03	2.25	.30	34.3	.29	23.6	30
13081	3	3.57	8.11	19.7	3.30	2.26	8.24	.03	2.26	.25	35.0	.30	18.8	30
13082	3	3.57	8.15	20.1	3.23	2.30	8.54	.03	2.23	.23	34.9	.30	18.3	20
13091	3	4.07	8.12	21.9	3.26	2.46	7.95	.03	1.97	.16	34.9	.29	18.0	30
13101	3	4.23	17.8	1.78	7.18	2.82	1.91	<.02	.61	.18	56.9	.68	9.45	30
13111	3	4.42	17.8	1.09	5.54	2.71	1.49	<.02	.55	.14	61.4	.68	8.65	20
13121	3	4.84	16.4	2.97	5.01	2.49	1.71	<.02	.74	.15	60.1	.62	9.40	30
13131	3	4.96	15.1	4.11	5.11	2.56	1.96	.02	.83	.18	58.4	.59	10.1	20
13141	3	5.11	11.9	4.93	4.07	2.37	2.20	.04	1.24	.18	61.3	.49	10.5	20
13151	3	5.31	10.1	8.59	3.33	2.47	2.92	.04	1.33	.14	56.3	.41	13.6	30
14011	4	.32	7.53	21.2	3.09	1.72	6.73	.03	2.45	.48	32.8	.25	22.2	50
14021	4	.55	6.63	25.4	2.78	1.30	6.53	.03	2.36	.59	28.9	.22	24.1	40
14031	4	1.10	15.0	4.25	4.78	2.64	2.18	<.02	.80	.18	59.1	.60	10.2	30
14041	4	1.71	8.99	17.0	3.69	2.15	5.89	.03	2.83	.33	37.0	.31	20.0	30
14051	4	1.89	13.1	7.89	4.60	2.39	3.44	<.02	1.45	.23	53.1	.52	12.3	30
14061	4	2.09	7.57	21.5	3.09	1.55	6.05	.03	2.54	.39	32.7	.27	21.9	50
14071	4	2.41	7.34	22.3	3.15	1.41	6.53	.03	2.81	.36	32.7	.26	20.9	70
14081	4	2.72	5.39	29.1	2.19	1.19	5.96	.03	2.47	.55	24.7	.18	26.2	50
15011	5	.31	7.54	20.9	2.99	1.75	6.48	.02	2.22	.23	33.4	.27	23.4	30
15012	5	.31	7.49	20.8	2.95	1.74	6.46	.02	2.19	.23	33.2	.26	23.6	30
15021	5	.54	7.40	22.0	3.05	1.63	6.25	.03	2.88	.38	31.7	.25	22.6	50
15031	5	.92	6.69	22.5	2.88	1.47	6.69	.03	2.65	.31	29.7	.23	24.1	50
15041	5	1.19	6.90	23.8	2.70	1.67	6.07	.03	2.58	.30	29.6	.23	24.5	50
15051	5	1.37	7.16	21.0	3.06	1.81	7.22	.04	2.23	.22	31.7	.25	24.1	30
15061	5	1.54	8.03	19.7	3.15	1.82	6.55	.03	2.91	.30	34.6	.27	20.8	60
16011	6	.17	9.07	19.8	3.70	2.12	6.82	.04	2.82	.41	40.0	.32	13.3	50
16012	6	.17	9.06	20.4	3.73	2.11	6.90	.04	2.88	.47	40.3	.33	12.5	50
16021	6	.43	9.00	20.1	3.68	1.98	7.34	.04	3.26	.24	41.1	.32	11.8	50
16031	6	.67	8.59	19.2	3.28	1.83	6.87	.03	2.34	.27	37.0	.30	18.9	40
16041	6	1.06	8.51	20.3	3.39	2.06	7.49	.03	2.42	.29	38.0	.30	16.6	50
16051	6	1.37	7.10	20.3	2.74	1.83	7.28	.03	2.22	.30	31.5	.23	25.5	30
16061	6	1.68	6.38	20.5	2.37	1.72	7.36	<.02	2.09	.20	29.0	.20	29.4	30
16071	6	1.98	6.52	21.9	2.92	1.70	8.09	.03	1.96	.20	29.2	.22	26.3	40
16081	6	2.32	6.84	19.4	3.92	1.64	7.14	.03	2.32	.24	31.0	.24	25.9	30
16091	6	2.62	8.67	17.4	3.37	2.12	6.85	.03	2.06	.22	36.5	.31	20.6	30

Chemical and Mineral Analyses--continued

Sample	B ppm	Ba ppm	Be ppm	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cu ppm	La ppm	Li ppm	Mn ppm	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm
12172	70	450	1	2	31	7	26	22	28	69	310	<4	8	9	18	20
12181	60	470	1	2	31	6	34	19	28	63	330	<4	8	18	17	30
12191	80	770	3	6	74	11	64	59	55	110	820	9	18	34	37	70
13011	60	440	1	4	40	7	38	30	28	67	240	9	7	14	26	40
13021	80	490	2	4	37	12	100	58	28	110	310	22	10	19	66	40
13031	70	530	1	3	38	11	98	50	29	130	290	23	8	14	59	30
13041	70	610	1	3	42	11	31	46	29	140	320	17	11	17	30	30
13042	80	600	1	4	37	12	90	51	29	140	330	17	8	17	56	30
13051	70	520	1	3	35	13	120	60	33	150	450	29	10	23	70	20
13061	80	520	1	3	34	9	80	45	27	120	340	24	7	19	48	20
13071	80	500	1	2	38	9	26	35	26	140	250	32	7	13	22	30
13081	90	590	1	3	35	9	48	41	26	180	280	24	10	16	34	30
13082	80	570	1	4	25	9	42	40	28	180	360	25	7	15	23	20
13091	80	540	1	3	33	7	46	34	26	140	280	14	7	12	25	30
13101	70	360	2	5	69	8	55	25	38	52	92	9	16	22	23	60
13111	80	540	2	7	57	6	62	34	37	53	44	5	9	22	21	40
13121	80	370	2	4	53	7	37	19	35	52	140	8	17	18	26	40
13131	<50	370	2	3	65	11	37	18	34	47	160	4	12	26	39	30
13141	70	440	2	3	51	9	32	17	31	41	310	7	12	13	24	40
13151	60	670	2	4	57	10	55	32	42	76	560	6	13	32	30	30
14011	50	420	1	2	29	10	26	46	24	61	280	22	6	18	26	30
14021	<50	470	1	3	28	8	25	36	28	50	360	21	7	7	23	20
14031	<50	450	2	4	62	8	38	20	35	54	160	5	14	28	26	40
14041	<50	370	1	<2	34	9	26	37	24	75	220	20	6	8	21	30
14051	60	520	2	4	51	10	55	39	33	64	140	14	10	23	26	30
14061	<50	470	1	3	27	9	26	40	19	69	240	23	<5	16	21	30
14071	<50	410	1	<2	24	8	17	43	24	65	260	30	5	12	24	30
14081	<50	520	<1	2	20	6	21	30	16	63	290	20	<5	15	17	20
15011	60	480	1	3	30	9	29	37	24	110	230	21	7	15	23	30
15012	<50	520	1	3	28	9	24	38	24	120	230	22	5	17	25	30
15021	<50	480	1	<2	30	8	29	49	27	78	330	25	5	11	28	30
15031	60	450	<1	2	27	9	26	45	32	100	350	28	7	15	22	30
15041	<50	430	<1	3	26	6	26	43	27	71	290	25	8	16	20	30
15051	50	530	1	3	26	6	34	32	24	63	310	19	7	13	15	20
15061	60	460	1	4	29	9	30	46	24	99	280	29	8	26	23	30
16011	70	580	1	4	36	11	76	50	24	120	290	13	<5	25	49	30
16012	70	590	1	4	41	11	82	52	26	130	320	16	7	20	52	110
16021	50	550	1	3	28	11	56	45	25	110	300	14	5	12	63	30
16031	60	560	1	2	33	8	25	37	22	90	230	15	<5	5	30	40
16041	60	520	1	3	33	9	42	47	26	120	290	16	6	25	28	30
16051	60	480	1	2	21	9	28	35	21	98	250	18	6	13	25	20
16061	60	480	<1	3	28	9	23	33	24	82	220	16	7	14	22	20
16071	60	480	1	2	25	8	25	33	25	100	260	24	7	15	18	20
16081	70	470	1	4	25	9	33	36	23	87	280	28	8	18	25	50
16091	70	520	1	3	33	8	34	36	22	100	250	20	<5	20	26	40

Chemical and Mineral Analyses--continued

Sample	Sc ppm	Sr ppm	Th ppm	V ppm	Y ppm	Zn ppm	Zr ppm	skerman	analcime	calcite	chlorite	diopside	dolomite	gypsum	illite
12172	6	430	7	75	12	55	90	--	6	37	2	--	41	--	8
12181	6	540	6	66	11	46	100	--	10	38	2	--	54	--	5
12191	12	790	12	130	21	91	90	--	7	27	2	--	52	--	5
13011	7	480	7	95	12	32	80	--	--	39	7	--	15	--	8
13021	7	640	10	130	12	81	70	14	--	28	--	24	--	--	4
13031	7	730	9	120	12	27	80	26	3	20	--	22	--	--	3
13041	6	890	10	110	13	26	60	38	--	22	--	20	--	--	3
13042	6	910	8	100	11	60	70	43	--	19	--	24	--	--	3
13051	6	800	12	130	13	62	80	37	--	18	1	20	--	--	2
13061	7	880	13	120	12	56	50	29	5	23	--	20	22	--	3
13071	5	750	8	83	10	50	60	--	27	42	--	--	24	--	4
13081	5	930	12	85	10	50	40	17	14	36	--	12	20	--	2
13082	9	910	12	81	10	52	50	24	12	34	--	13	13	--	2
13091	6	930	8	87	10	57	60	24	8	36	--	11	16	--	3
13101	15	310	19	190	19	91	160	--	--	6	15	--	6	--	19
13111	15	280	10	170	14	45	130	--	--	7	21	--	--	--	19
13121	12	220	7	150	22	95	160	--	7	13	17	--	4	--	17
13131	12	230	10	130	29	120	150	--	5	21	15	--	--	--	18
13141	9	230	11	92	17	79	140	--	--	29	12	--	17	--	13
13151	9	410	14	110	18	83	100	--	7	36	7	--	27	--	9
14011	5	900	14	95	9	57	40	4	--	84	--	6	6	--	2
14021	4	1,000	6	87	10	45	40	--	--	88	--	--	2	2	2
14031	12	260	8	140	18	91	140	--	--	15	12	--	--	--	17
14041	6	670	10	110	10	61	60	--	--	48	--	--	34	--	3
14051	11	410	11	140	17	86	100	--	--	32	8	--	10	4	12
14061	5	930	11	91	9	18	40	--	--	60	--	--	8	4	3
14071	<4	840	<4	100	8	55	50	--	--	45	--	--	--	4	2
14081	<4	1,100	4	67	7	<4	30	--	--	120	--	--	--	2	--
15011	4	890	9	90	10	53	50	--	--	76	--	--	35	--	3
15012	5	910	9	90	9	67	50	--	--	81	--	--	36	--	4
15021	5	870	<4	91	9	59	50	--	--	83	--	--	17	--	--
15031	5	900	8	87	8	53	70	--	--	75	--	--	24	5	2
15041	5	890	8	85	9	48	30	--	--	87	--	--	22	3	2
15051	6	900	12	97	10	42	40	--	2	57	--	--	54	--	2
15061	5	800	12	100	9	57	40	--	7	65	--	--	16	4	3
16011	6	890	12	120	12	32	60	31	4	29	--	16	--	--	2
16012	7	920	9	110	12	34	60	36	--	25	--	16	--	--	1
16021	6	770	10	100	9	78	60	23	3	24	--	21	--	--	--
16031	5	820	5	97	11	61	70	13	--	46	--	14	11	--	3
16041	5	870	12	95	10	58	50	19	5	33	--	19	--	--	2
16051	<4	960	7	84	8	48	40	8	--	60	--	11	29	--	3
16061	<4	930	7	81	7	49	30	--	--	71	--	--	41	--	1
16071	<4	1,000	9	88	8	44	30	--	--	62	--	--	19	--	1
16081	6	850	7	93	9	15	40	9	--	63	--	13	25	--	2
16091	6	800	4	96	11	24	50	8	3	53	--	10	--	--	3

Chemical and Mineral Analyses--continued

Sample	K-spar	mont-anh	Na-spar	quartz
12172	18	3	32	98
12181	13	--	23	78
12191	14	--	35	82
13011	10	--	28	110
13021	16	--	20	46
13031	8	--	12	44
13041	6	--	14	30
13042	8	--	12	24
13051	7	--	12	21
13061	8	2	10	20
13071	10	--	23	43
13081	7	2	14	28
13082	8	--	14	23
13091	8	--	14	25
13101	9	--	7	130
13111	10	5	14	180
13121	12	3	17	170
13131	14	9	17	160
13141	13	3	27	170
13151	18	1	24	180
14011	13	6	58	21
14021	9	--	48	15
14031	8	--	13	160
14041	10	--	55	44
14051	12	--	37	120
14061	9	--	53	28
14071	10	--	51	20
14081	10	--	48	15
15011	10	--	51	44
15012	10	--	51	40
15021	11	5	68	27
15031	9	9	54	36
15041	11	--	50	29
15051	9	--	47	37
15061	10	2	52	30
16011	11	--	26	35
16012	9	--	23	24
16021	9	--	16	23
16031	12	--	29	35
16041	11	--	18	20
16051	13	--	42	32
16061	9	--	45	38
16071	10	--	40	30
16081	13	1	50	31
16091	9	2	40	40

Chemical and Mineral Analyses--continued

Sample	hole no.	depth(m)	Al_2O_3pct	CaO pct	Fe_2O_3pct	K_2O pct	MgO pct	MnO pct	Na_2O pct	P_2O_5 pct	SiO_2 pct	TiO_2 pct	LOI pct	As ppm
16101	6	2.93	8.66	19.2	3.39	2.34	7.93	.04	2.01	.23	37.5	.32	16.4	30
16111	6	3.23	8.53	19.1	3.29	2.13	7.23	.03	2.58	.19	37.9	.29	17.3	30
16112	6	3.23	8.80	19.0	3.30	2.15	7.15	.03	2.63	.18	38.4	.28	17.1	30
16121	6	3.54	8.21	16.2	3.99	2.57	7.49	.03	2.02	.18	35.7	.30	21.6	30
16131	6	3.78	8.88	14.3	3.57	3.07	7.35	.03	2.23	.19	37.5	.32	20.9	40
16141	6	4.36	8.41	18.6	3.45	2.69	7.91	.03	2.39	.24	36.6	.30	17.6	50
16151	6	4.67	7.50	21.5	3.08	2.44	7.47	.03	1.94	.20	32.3	.27	21.9	50
16161	6	4.97	15.3	4.95	4.92	2.60	3.04	<.02	1.51	.15	58.7	.58	7.45	20
16171	6	5.21	16.4	3.07	5.00	2.63	2.19	<.02	.81	.18	59.2	.63	8.98	30
16181	6	5.49	16.7	2.70	5.32	2.74	2.09	<.02	.73	.16	59.2	.63	9.24	20
16191	6	5.79	9.96	11.9	3.39	2.96	4.27	.04	1.56	.14	45.8	.40	18.5	20
16201	6	5.99	13.7	4.88	4.44	2.55	2.35	.03	.93	.16	58.9	.53	10.9	20
16211	6	6.19	9.96	7.60	3.35	2.15	2.24	.04	1.22	.16	60.5	.41	11.5	10
16221	6	6.49	10.5	7.78	3.46	2.19	2.49	.04	1.37	.18	58.3	.44	12.3	<10
17011	7	.25	8.59	21.7	3.48	2.01	8.84	.04	2.16	.15	38.5	.31	12.6	40
17021	7	.55	8.73	21.2	3.62	1.98	8.76	.04	2.38	.25	38.6	.31	12.3	60
17031	7	.86	8.48	21.1	3.18	1.78	7.86	.03	2.67	.21	38.9	.29	14.1	50
17041	7	1.16	9.02	21.4	3.47	1.96	7.30	.04	3.03	.77	40.3	.31	10.2	70
17051	7	1.59	9.59	21.2	3.90	2.18	9.11	.04	3.03	.32	41.2	.33	7.35	60
17061	7	1.89	8.87	20.6	3.60	2.12	8.39	.03	2.69	.36	38.8	.32	12.3	50
17071	7	2.23	9.28	21.4	3.96	2.14	7.81	.04	3.29	.38	41.5	.33	8.03	50
17081	7	2.53	8.70	20.5	3.65	1.97	8.17	.04	2.83	.26	40.0	.29	11.5	60
17091	7	2.96	8.50	16.9	3.33	2.74	6.61	.03	2.40	.24	35.7	.32	21.2	30
17101	7	3.26	8.18	21.8	2.96	1.83	8.12	.03	2.91	.60	34.8	.25	16.6	30
17111	7	3.44	8.09	22.9	3.17	1.87	8.42	.03	2.73	.31	35.8	.27	14.5	30
17121	7	3.60	17.4	2.04	5.14	2.77	1.93	<.02	.81	.16	59.3	.66	8.84	30
17131	7	3.96	18.2	1.06	6.30	2.98	1.72	<.02	.63	.18	59.1	.67	8.14	20
18011	8	.08	9.30	9.60	2.86	2.46	3.03	.04	1.06	.14	53.8	.40	16.8	<10
18021	8	.31	9.37	10.5	3.05	2.44	3.11	.04	1.13	.15	53.0	.39	15.8	10
18031	8	.61	9.14	10.8	3.08	2.39	3.32	.04	1.09	.13	53.5	.39	15.5	<10
18041	8	.92	9.32	11.6	3.16	2.50	3.85	.05	1.22	.13	50.3	.39	17.2	20
18042	8	.92	9.26	11.6	3.17	2.52	3.77	.05	1.13	.13	50.4	.39	17.1	10
18043	8	.92	8.86	12.3	3.03	2.51	4.06	.05	1.28	.12	49.1	.38	17.8	20
18051	8	1.22	8.81	11.4	3.08	2.44	3.60	.04	1.19	.14	50.1	.39	17.8	20
18061	8	1.53	8.79	13.5	2.99	2.68	4.49	.04	1.26	.13	45.5	.35	19.5	10
18071	8	1.82	8.47	12.4	2.82	2.60	3.69	.04	1.30	.12	51.3	.35	16.7	10
18081	8	2.00	9.27	10.7	3.15	2.53	3.57	.04	1.18	.16	52.3	.40	16.2	20
18082	8	2.00	9.19	10.3	3.12	2.49	3.32	.04	1.19	.15	52.9	.38	15.5	10
Oil-shale Samples														
21001	--	--	4.79	23.2	1.79	1.41	5.26	<.02	1.52	.15	21.2	.17	39.0	20
21002	--	--	4.63	23.1	1.76	1.42	5.22	<.02	1.43	.14	21.0	.16	39.2	20
21011	--	.30	4.03	24.7	1.59	1.14	4.69	<.02	1.22	.14	18.0	.13	42.8	20
21021	--	.61	5.18	18.9	2.14	1.37	5.25	<.02	1.81	.14	22.5	.18	40.8	20
21022	--	.61	5.17	19.0	2.10	1.39	5.26	.02	1.70	.14	22.2	.18	40.9	20

Chemical and Mineral Analyses--continued

Sample	B ppm	Ba ppm	Be ppm	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cu ppm	La ppm	Li ppm	Mn ppm	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm
16101	110	540	1	3	40	8	40	38	23	110	310	21	6	23	29	30
16111	80	520	1	3	35	7	27	32	28	100	270	18	7	13	27	40
16112	80	620	1	3	32	9	44	35	30	110	300	18	9	11	27	30
16121	110	500	1	3	38	10	32	40	29	180	280	31	10	23	20	30
16131	160	440	1	<2	34	8	23	32	27	200	240	32	9	10	22	30
16141	110	560	1	3	33	11	48	42	25	160	300	27	8	16	34	40
16151	100	530	1	3	26	9	30	37	27	110	310	21	9	17	24	20
16161	80	400	2	5	59	9	65	37	37	100	170	12	21	29	33	40
16171	60	390	2	5	59	8	53	19	37	55	95	5	11	28	30	40
16181	50	420	2	4	59	7	47	21	36	56	100	8	15	25	27	40
16191	90	490	1	3	42	7	36	24	31	68	340	6	10	26	21	30
16201	70	430	2	4	52	7	32	19	34	49	210	5	13	22	26	40
16211	70	520	1	4	42	8	37	23	30	45	320	<4	9	27	28	20
16221	70	1,100	1	4	44	7	37	21	26	46	300	4	6	19	20	20
17011	80	530	1	4	31	10	62	47	27	140	330	17	11	9	44	30
17021	80	550	1	4	32	10	64	48	25	130	300	22	7	10	40	30
17031	80	480	1	3	28	10	32	42	27	110	310	22	8	15	34	40
17041	80	1,100	1	3	39	11	77	68	27	97	370	31	9	12	57	60
17051	70	1,700	2	4	46	11	59	46	33	170	310	26	9	9	61	50
17061	90	680	1	4	38	11	63	47	29	150	330	25	9	26	41	40
17071	60	490	1	<2	29	12	46	55	30	110	330	26	8	6	47	50
17081	90	520	1	4	36	12	70	55	23	140	300	27	7	18	47	50
17091	100	1,700	1	4	36	11	33	41	22	130	280	25	<5	15	22	40
17101	80	570	1	3	30	8	59	40	27	140	300	18	8	11	33	30
17111	60	530	1	4	30	8	61	36	29	160	380	14	7	10	36	20
17121	60	370	2	5	61	5	41	21	37	57	64	6	14	24	23	50
17131	90	400	3	5	76	12	53	28	41	61	72	5	13	42	47	40
18011	60	380	1	3	43	4	22	15	28	47	250	<4	7	9	18	30
18021	70	440	1	3	39	7	34	21	32	46	420	5	9	18	20	20
18031	70	530	1	3	42	6	37	20	28	49	430	<4	8	18	21	20
18041	80	390	1	3	46	5	39	14	31	55	350	4	10	14	20	30
18042	70	500	1	2	35	6	36	20	29	56	450	5	9	10	16	20
18043	60	390	1	<2	34	3	31	14	24	52	320	<4	<5	6	20	20
18051	80	440	1	3	38	6	38	19	27	54	320	5	7	21	21	20
18061	70	420	1	2	38	4	23	16	29	59	290	<4	8	11	19	20
18071	80	430	1	3	38	4	40	18	27	49	300	<4	8	23	19	10
18081	<50	430	1	2	36	6	32	15	26	50	310	4	5	10	16	20
18082	80	500	1	3	47	7	39	23	27	54	350	5	6	22	26	20
Oil-shale Samples																
21001	<50	460	<1	<2	17	5	28	18	18	53	200	14	5	9	17	10
21002	<50	480	<1	3	14	5	26	18	16	55	210	14	<5	11	17	10
21011	<50	430	<1	<2	13	6	25	19	16	45	210	14	<5	14	17	10
21021	<50	370	<1	<2	13	7	33	24	17	44	190	20	<5	12	20	20
21022	<50	380	<1	2	17	6	30	25	20	44	210	21	<5	7	21	20

Chemical and Mineral Analyses--continued

Sample	Sc ppm	Sr ppm	Th ppm	V ppm	Y ppm	Zn ppm	Zr ppm	akerman	analcime	calcite	chlorite	diopside	dolomite	gypsum	illite
16101	6	870	9	89	12	23	50	12	5	36	--	18	15	--	1
16111	7	850	15	83	9	50	70	17	15	38	--	13	21	1	3
16112	6	890	6	87	9	49	50	16	16	38	--	12	21	--	3
16121	5	770	8	93	9	56	50	--	9	52	--	--	20	2	5
16131	5	680	6	85	9	53	60	--	12	44	--	--	25	3	6
16141	6	860	11	110	11	24	40	16	7	42	--	11	10	--	3
16151	5	890	14	93	9	46	40	14	8	54	--	10	--	--	2
16161	13	310	11	150	18	100	110	9	--	8	12	14	--	--	14
16171	13	300	11	150	19	100	170	--	--	9	16	--	--	--	18
16181	13	280	12	160	20	110	160	4	--	9	16	5	--	--	19
16191	7	400	12	81	13	20	80	--	9	29	4	--	39	--	8
16201	11	260	15	120	17	81	150	--	6	23	13	--	11	--	15
16211	7	260	13	74	13	57	100	--	3	32	8	--	21	--	9
16221	7	300	<4	77	13	21	90	--	6	25	9	--	25	--	9
17011	6	950	4	110	11	24	50	29	1	37	--	23	--	--	--
17021	5	930	7	120	11	32	50	27	3	34	--	16	--	--	--
17031	5	900	13	100	9	62	90	25	2	34	--	11	10	--	2
17041	5	910	6	130	12	43	50	24	--	24	--	17	11	5	--
17051	6	940	6	96	11	70	80	39	3	20	--	23	--	--	--
17061	7	910	16	110	12	29	50	26	6	30	--	15	--	--	--
17071	6	870	<4	120	11	71	70	39	3	18	--	17	--	--	--
17081	5	860	9	120	11	65	50	32	3	28	--	16	--	4	3
17091	5	830	9	88	11	28	50	7	13	50	--	9	19	--	4
17101	4	1,000	12	78	10	15	50	28	19	31	--	14	12	--	1
17111	5	990	7	73	10	51	50	35	8	29	--	14	--	--	--
17121	15	270	8	160	16	83	170	--	--	--	18	--	--	--	21
17131	15	230	19	170	29	140	120	--	--	--	15	--	--	--	20
18011	6	300	8	71	12	52	120	--	8	37	5	--	24	--	13
18021	7	310	13	74	13	52	100	--	7	40	4	--	32	--	10
18031	7	340	8	73	13	51	90	--	12	46	6	--	32	--	10
18041	6	370	8	74	13	51	90	--	10	41	4	--	43	--	10
18042	7	380	6	74	13	53	110	--	10	40	4	--	43	--	10
18043	5	390	<4	68	12	46	110	--	8	37	3	--	46	--	3
18051	6	360	9	70	12	19	80	--	10	46	4	--	39	--	9
18061	6	420	4	69	12	52	110	--	11	49	2	--	45	--	9
18071	5	380	<4	63	11	44	70	--	8	51	3	--	39	--	8
18081	6	350	6	73	12	59	120	--	9	38	4	--	33	--	9
18082	5	370	5	80	13	50	100	--	7	37	5	--	33	--	9
Oil-shale Samples															
21001	<4	1,100	7	50	5	29	20	--	3	61	--	--	63	--	--
21002	<4	1,100	<4	50	5	<4	30	--	--	60	--	--	65	--	2
21011	<4	1,000	9	50	5	27	<20	--	3	100	--	--	57	--	3
21021	<4	760	<4	68	5	33	30	--	5	54	--	--	72	--	--
21022	<4	780	6	69	6	37	30	--	4	56	--	--	73	--	2

Chemical and Mineral Analyses--continued

Sample	K-spar	mont-anh	Na-spar	quartz
16101	10	3	17	28
16111	12	--	20	36
16112	7	1	20	38
16121	11	--	28	42
16131	14	--	24	47
16141	12	--	22	27
16151	8	2	16	28
16161	17	5	22	120
16171	7	4	12	140
16181	7	5	10	150
16191	14	2	16	98
16201	10	4	20	140
16211	19	1	25	190
16221	12	3	24	140
17011	8	--	15	11
17021	7	--	16	21
17031	9	--	28	20
17041	9	--	22	13
17051	9	--	7	8
17061	7	--	13	14
17071	7	2	17	14
17081	9	4	18	17
17091	13	2	19	40
17101	5	--	12	16
17111	5	2	11	15
17121	10	12	8	150
17131	8	9	13	180
18011	18	--	24	130
18021	21	--	25	150
18031	15	--	21	130
18041	15	--	21	120
18042	10	--	32	130
18043	17	--	22	110
18051	17	--	19	110
18061	11	--	17	94
18071	24	--	21	120
18081	11	--	20	130
18082	38	--	28	170
				Oil-shale Samples
21001	9	--	27	37
21002	10	--	33	47
21011	8	--	30	35
21021	10	--	39	39
21022	9	--	37	40

Chemical and Mineral Analyses--continued

Sample	hole no.	depth(m)	Al_2O_3 pct	CaO pct	Fe_2O_3 pct	K_2O pct	MgO pct	MnO pct	Na_2O pct	P_2O_5 pct	SiO_2 pct	TiO_2 pct	LOI pct	As ppm
21023	--	.61	5.17	19.1	2.12	1.35	5.31	<.02	1.80	.13	22.4	.17	40.6	20
21031	--	.91	5.17	15.6	2.30	1.35	6.24	<.02	2.02	.17	23.5	.18	41.0	20
21041	--	1.22	5.28	14.4	2.35	1.09	6.41	<.02	2.37	.11	25.3	.19	39.9	30
21051	--	1.52	5.44	16.9	1.99	1.56	8.57	.02	2.16	.06	28.1	.21	34.1	<10
21061	--	1.83	5.37	22.6	2.06	1.55	6.53	.02	2.07	.05	24.9	.20	33.2	20
21071	--	2.13	6.74	18.4	2.78	1.09	5.06	.02	3.33	.10	30.3	.22	30.5	30
22001	--	4.13	4.63	22.8	1.60	.97	6.21	.03	2.14	.24	24.0	.15	36.0	50
22061	--	5.96	6.34	19.3	2.76	1.30	4.28	.02	3.58	.36	25.4	.23	33.9	60
							Standards							
31001	--	--	7.70	16.9	3.27	1.79	5.59	.03	2.15	.41	33.2	.28	26.0	70
31002	--	--	7.74	16.8	3.27	1.79	5.60	.03	2.23	.41	33.1	.27	25.9	70
32001	--	--	6.83	19.1	2.91	1.55	6.05	.02	2.14	.43	30.0	.24	26.4	50
32002	--	--	6.92	19.0	2.92	1.53	6.00	.03	2.15	.43	30.1	.25	26.3	60
33001	--	--	6.20	13.6	2.67	1.47	4.52	.03	1.73	.33	27.1	.23	38.8	50
33002	--	--	6.15	13.6	2.66	1.47	4.55	.02	1.73	.32	26.8	.22	39.0	60

Chemical and Mineral Analyses--continued

Sample	B ppm	Ba ppm	Be ppm	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cu ppm	La ppm	Li ppm	Mn ppm	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm
21023	<50	330	<1	<2	15	5	27	20	18	41	190	20	<5	<5	18	20
21031	<50	360	<1	2	15	7	33	35	19	79	180	22	6	14	22	20
21041	70	320	<1	3	13	7	29	35	14	120	170	24	<5	8	21	20
21051	<50	370	1	2	27	6	40	21	20	190	210	11	6	8	23	10
21061	<50	580	<1	3	24	3	37	18	21	100	240	8	6	14	20	20
21071	<50	240	<1	<2	22	5	24	35	21	55	210	10	<5	7	22	30
22001	<50	380	<1	<2	15	4	28	13	16	46	280	10	<5	13	17	10
22061	<50	390	1	3	34	11	37	44	25	34	220	18	8	19	30	30
Standards																
31001	90	1,400	1	4	36	12	31	66	26	59	270	32	7	13	27	40
31002	80	810	1	4	28	11	29	62	20	58	250	31	<5	13	26	40
32001	80	770	1	3	23	9	23	42	21	68	260	27	6	16	21	20
32002	80	710	1	3	26	10	31	52	34	76	400	29	10	6	27	30
33001	70	450	<1	3	25	10	26	52	23	47	300	26	5	9	24	30
33002	70	470	<1	3	22	9	25	51	19	49	210	25	<5	12	24	30

Chemical and Mineral Analyses--continued

Sample	Sc ppm	Sr ppm	Th ppm	V ppm	Y ppm	Zn ppm	Zr ppm	akerman	analcime	calcite	chlorite	diopside	dolomite	gypsum	illite
21023	<4	740	6	64	5	38	30	--	3	58	--	--	74	--	2
21031	<4	710	<4	77	5	40	30	--	--	30	--	--	98	--	2
21041	<4	620	6	77	6	4	20	--	--	18	--	--	100	--	2
21051	<4	810	6	56	6	30	30	--	--	11	--	--	120	--	3
21061	4	890	6	60	8	<4	20	--	--	62	--	--	82	--	--
21071	4	650	8	62	6	49	20	--	--	55	--	--	75	--	--
22001	<4	840	10	38	5	26	20	--	--	70	--	--	88	--	--
22061	5	850	13	73	9	59	30	--	--	34	--	--	63	--	--
								Standards							
31001	5	690	9	110	9	68	50	--	5	27	--	--	65	--	3
31002	5	680	8	110	9	36	40	--	5	26	--	--	63	--	4
32001	<4	850	6	91	8	23	40	--	4	27	--	--	64	--	3
32002	9	950	6	100	9	66	50	--	5	27	--	--	62	--	3
33001	5	540	12	90	7	56	50	--	15	16	--	--	62	--	3
33002	<4	560	11	93	7	20	40	--	9	15	--	--	58	--	3

Chemical and Mineral Analyses--continued

Sample	K-spar	mont-anh	Na-spar	quartz
21023	8	--	43	48
21031	10	--	60	47
21041	10	--	68	58
21051	10	--	47	60
21061	10	--	33	38
21071	7	--	60	45
22001	6	--	38	47
22061	9	--	59	23
			Standards	
31001	10	--	31	67
31002	10	--	31	70
32001	9	--	39	56
32002	9	--	36	58
33001	10	--	27	70
33002	9	--	25	58

Table 4.--Comparison of averages from the literature for oil-shale and retorted oil-shale standard samples with those values obtained during this study

[FASS, Fisher assay spent shale; SS-1, spent shale; OS-1, oil shale; pct, percent; ppm, parts per million]

Element	FASS		SS-1		OS-1	
	Study average	Literature average[1]	Study average	Literature average[1]	Study average	Literature average[1]
Major elements (pct)						
SiO_2	33.5	33.6	30.1	31.0	27.0	28.0
Al_2O_3	7.72	7.78	6.88	6.80	6.18	6.48
Fe_2O_3	3.27	3.3	2.92	3.0	2.67	2.67
MgO	5.60	5.0	6.03	6.1	4.54	4.31
CaO	16.9	15.9	19.1	20.0	13.6	13.4
Na_2O	2.19	2.39	2.15	2.35	1.73	1.83
K_2O	1.79	1.84	1.54	1.57	1.47	1.48
TiO	0.28	0.23	0.25	0.23	0.23	0.18
P_2O_5	0.41	--	0.43	--	0.33	--
MnO	0.03	0.04	0.03	0.04	0.03	0.04
Trace elements (ppm)						
As	70	85	60	69	60	71
B	90	110	80	119	70	80.8
Ba	1100	1859	740	6555	460	1295
Cd	4	1.28	3	0.41	3	1.05
Ce	32	42	25	38	24	35
Co	11	13.3	10	17.5	10	12.7
Cr	30	43	27	35	26	36
Cu	64	60	47	48	52	46
La	24	22.0	28	19.5	21	18.5
Mo	32	35	28	31	26	28
Nb	7	5.6	8	30	5	4.5
Nd	13	18	11	15	24	29
Ni	27	35	24	30	30	29
Pb	40	38	30	29	5	4.9
Sc	5	6.0	9	5.3	5	4.9
Sm	11	3.3	6	2.9	5	2.6
Sr	690	800	900	1007	550	620
Th	9	6.2	6	5.3	12	4.9
V	110	161	96	108	92	127
Y	9	12	9	11	7	8.1
Zn	52	94	45	82	38	80
Zr	50	81	50	62	50	55

[1]Wildeman, 1979.