UNITED STATES DEPARTMENT OF THE INTERIOR

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OVERBURDEN GEOCHEMISTRY OF U.S. BUREAU OF LAND MANAGEMENT EXPERIMENTAL COAL-MINING RECLAMATION SITE AT OJO ENCINO, NORTHEAST McKINLEY COUNTY, SAN JUAN BASIN, NEW MEXICO

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Samples from the column of overburden rock at the U.S.Bureau of Land Management experimental coal-mining reclamation site at the Ojo Encino, McKinley County, San Juan Basin, New Mexico, were analyzed for bulk chemical composition. The purpose was to find out whether any of the rock material had unusually high contents of chemical elements of potential environmental concern, especially in comparison to rocks that overlie coal in other parts of the western energy regions.

A second goal was to find out whether benign rock material could be distinguished in some clear and simple way from potentially hazardous material (if any), without expensive analysis.

Sampling Scheme

Samples were taken from hole numbers 1a and 3, which are about a mile apart. The holes were sampled to depths of 131 ft, (43 m) and 147 ft (48 m), respectively. Choosing a random depth within the top 10 ft (3 m) as a starting point, a 6 ft (0.16 m) segment of the core (about 2 in. or 5 cm in diameter) was taken every 10 ft. Every fifth sample, an extra "companion" sample was taken from the adjacent 6-ft interval to aid in determining the relationship between chemical variability and spatial separation of samples.

Classification of Samples into Rock Types

Samples were classified by lithic type, as identifiable by quick, simple tests and by appearance in hand specimens. This classification was done to determine whether the different rock types had distinctive chemistry; if so, the chemistry might possibly be predicted from hand specimen observation in future work, thereby avoiding considerable delay and analytical expense.

The samples were classified into the following groups:

1. Sandstone (grain size greater than 0.2 mm, approximately)
2. Siltstone (grain size visible by hand lens, 0.2 mm or smaller)
3. Claystone (shale and other very fine grained rocks)

Analytical

The samples were analyzed for total concentrations of a suite of major, minor and trace elements, by spectrographic techniques (emission and X-ray fluorescence). Results of "availability" (chemical leach) determinations will be available later. A complete tabulation of determinations of all chemical elements detected, for all samples, is presented in appendix A.

Chemical Distinctiveness of Rock Types

Overburden rocks at Ojo Encino show a general relationship between chemistry and rock type. Coarse- and fine-grained rocks have characteristic chemical properties, but there is considerable overlap in chemical composition. The data are presented in Table 1, not only for the Ojo Encino site but also for the nearby Kimbeto experimental reclamation site 35 miles west- northwest in southeastern San Juan County, for a broader sampling of overburden rocks of similar age (Cretaceous) throughout the western energy regions, and for soils and mine spoils of the San Juan Basin.

Table 1 presents data for selected elements, a subset of all those analyzed, that are of the greatest geological and environmental interest. It shows that, with few exceptions, the sandstones have the lowest concentrations of trace elements of potential environmental concern (boron, cobalt, chromium, copper, molybdenum, lead, vanadium, and zinc), that the siltstone (single sample) has intermediate concentrations, and that the claystones have the highest concentrations.

The rocks from the Ojo Encino and Kimbeto sites in the San Juan Basin have less chemical difference between rock type than do rocks from other sites underlain by rocks of Cretaceous age. The chemical data suggest that this is so because the sandstones in the San Juan Basin are arkosic (contain grains of feldspar rather than of quartz) and because there is an appreciable amount of clay in rocks of all types. At some other localities sandstones are much more purely quartz, and clay minerals are concentrated in the claystones (shales) to a greater extent. Quartz is a mineral that is nearly barren of trace elements, feldspar contains modest amounts of many trace elements, and clay minerals contain larger amounts.

Chemistry of Ojo Encino (and Kimbeto) Rocks

Compared to Other Overburden Rocks

of the Same and Different Ages

In order to assess the value of Ojo Encino rocks for use in reclamation after mining, it is useful to know how their detailed chemistry compares with that of other overburden rocks that have been investigated, of both similar and different ages (Hinkley and others, 1980; Hinkley and others, 1978) and from both nearby and distant sites. In this respect, each of the chemical parameters in Table 1 is discussed below.

The basis of the discussion are the data in Table 1, in which only average concentration values are given. For all chemical elements except SiO_2, the type of average used is the geometric mean rather than the arithmetic mean. The geometric mean tends to minimize the effect of the (very high) values that may appear in the data set, and it tends to increase the likelihood that the average value will fall in the range of the more common central values that are really most typical of the set of data.

To give an idea of the dispersion (variance) of the data, a table of geometric deviations is presented in Table 2. The geometric deviations in Table 2 provide information about how closely the whole body of data is grouped about the average, or how broadly dispersed it is, with extreme values far from the average. The geometric means (GM) and geometric deviations (GD) are used in the following way to assess the spread of the data: about two-thirds of the values fall between a lower limit of GM/GD and an upper limit of GM·GD; about 95 percent of the values fall in the broader range defined by $GM/(GD)^2$ and $GM \cdot (GD)^2$. For example, zinc in claystone from "Other sites with Cretaceous overburden" has a geometric mean of 105 ppm and a geometric deviation of 1.4; 95 percent of samples of such material should have values between $105/(1.4)^2 = 54$ ppm and $105 \times (1.4)^2 = 206$ ppm.

SiO_2--Ojo Encino rocks fall into the middle part of the total range in SiO_2 concentration seen in the the larger group of sites that have the same age rock (Cretaceous) overlying coal. This indicates that the New Mexico rocks are less pure as lithic types--there is more clay and feldspar in the sandstones, and more sand in the claystones than is common elsewhere.

Al_2O_3-There is more aluminum in the Ojo Encino and Kimbeto rocks than in other Cretaceous overburden, indicating, in complement to the SiO_2 data, that there are larger amounts of clay and feldspar in the sandstone and siltstone.

CaO---Sandstone and siltstone at Ojo Encino and Kimbeto are high in calcium relative to other Cretaceous overburden, whereas the claystones are low in calcium relative to the other rocks. This is probably because of the presence of Ca-rich feldspars in the sandstone and siltstone.

Na_2O--All three rock types are several times higher in sodium at Ojo Encino and Kimbeto than in other Cretaceous overburden. New Mexico rock concentrations are closer to those for corresponding rock types in overburden of the Tertiary Fort Union Formation material in North Dakota, Montana and Wyoming (Hinkley and others, 1980), but still higher by up to a factor of two.

K_2O---Ojo Encino and Kimbeto rocks are slightly higher in potassium than other Cretaceous overburden.

B-----Ojo Encino and Kimbeto rocks are similar to other Cretaceous overburden rocks in boron concentration. However, some suites of Tertiary overburden samples have boron concentrations 2 to 5 times higher in both sandstone and claystone.

Co----Ojo Encino and Kimbeto rocks, especially sandstones, are higher in cobalt concentration than other Cretaceous overburden rocks, but are about comparable to Tertiary rocks.

Cr----Ojo Encino and Kimbeto rocks are comparable in chromium content to other Cretaceous overburden sites; New Mexico sandstones slightly higher, siltstone and claystones are slightly lower. Tertiary overburden rocks may be 2 to 5 times higher.

Cu----Ojo Encino and Kimbeto rocks are higher in copper than other Cretaceous overburden rocks, but are comparable to Tertiary overburden rocks.

Mo----Ojo Encino and Kimbeto rocks are comparable to or slightly higher than other Cretaceous rocks in molybdenum concentration, but they apparently have only about half (or less) as much as Tertiary overburden rocks. In areas of Tertiary overburden, molybdenum toxicity is widely regarded as a potential problem in mine spoil reclamation (Erdman and others, 1978).

Pb----Lead concentrations are slightly higher in Ojo Encino and Kimbeto rocks than in other Cretaceous overburden. They are comparable to lead values in Tertiary rocks, but in Tertiary rocks there is much greater difference between sandstone (high) and claystone (low) than in Cretaceous rocks.

V-----Vanadium concentrations in Ojo Encino and Kimbeto rocks are similar to those in Cretaceous overburden rocks from other areas, and they are similar to concentrations in Tertiary overburden rocks.

Zn----Zinc concentrations in Ojo Encino and Kimbeto rocks are similar to those in Cretaceous rocks from other areas, but in the other areas there is a greater contrast in concentrations between sandstone (low) and claystone (high) than is seen at the New Mexico sites. Concentrations are similar to those in Tertiary overburden rocks.

Similarity of Ojo Encino Overburden Rocks to Natural San Juan Basin Soils

Ojo Encino overburden rocks are similar in bulk composition to natural soils of the San Juan basin. The data are summarized in Table 1. With respect to sodium, the element of most concern in reclamation considerations, the rocks are similar to the soils. There are, to varying but moderate degrees, higher concentrations of the following elements in the Ojo Encino overburden than in the soils: aluminum, cobalt, copper, lead, vanadium and zinc. The higher concentrations of copper and zinc in the rocks might be favorable should they ever be used as soil-replacement material. Except for unusual geochemical and climatic settings, the elements cobalt, lead and vanadium are seldom present in sufficiently high concentrations to be toxic hazards.

Based on bulk chemical composition, Ojo Encino overburden material is appropriate for use as replacement material for the soils of the area.

Relative Abundance of Rock Types

At Ojo Encino the ratios of sandstone:siltstone:claystone in drill cores sampled were about 6: 1/4 :1 (31 samples). At Kimbeto they were about 2: 1/4 :1 (46 samples), and at the other four Cretaceous sites from other states, they were about 1 1/3 : 1/2 :1 (112 samples). In New Mexico, sandstone was more dominant over claystone (shale) than at other Cretaceous sites, although there is a big difference between the two San Juan Basin sites (3 times more sand at Kimbeto). Siltstone is not abundant at any of the sampling sites.

Conclusions

A. Summary of area characteristics in relation to reclamation potential--The various Ojo Encino overburden rock types are congruous, in their bulk chemical composition, with the same rock types at other sites in the Western United States where Cretaceous age rocks overlie coal. The single major exception is higher sodium content in Ojo Encino overburden. The rocks are also generally similar to the native soils of the San Juan Basin. On the basis of their bulk chemistry, the overburden rocks could be used as acceptable soil-replacement material and should not be expected to have long-term unfavorable effects on element concentration in ground water.

B. Reclamation potential of the area based on anticipated post-mining use as designated by USBLM (livestock production and wildlife habitat)--There is no reason associable with bulk chemistry of the overburden rocks that the area should not be restorable to a condition that would allow its designated post-mining use.

C. Major reclamation problems and measures necessary to establish conditions suitable for anticipated post-mining use--Rocks may have to be stockpiled in a segregated manner, by distinct lithic types, in order to allow replacement of rocks in the refill column in positions best suited to their particular chemical character. For example, sandstone, with its potential loamy texture and comparatively low trace- and minor-element concentrations, should be placed near the top where it would have most contact with plant roots and would permit absorption of intense rain showers. Claystone, with its higher elemental concentrations, should be placed either deep in the refill column where the reducing electrochemical potential would retard weathering and release of elements to ground water, or in the middle of the refill column where it would be physically distant from either roots or ground water and could form an impermeable barrier to downward movement of elements from the surface and to downward loss of soil moisture.

Appendix A

COMPLETE TABULATION OF BULK CHEMICAL DATA FOR OJO ENCINO OVERBURDEN ROCK DRILL CORE SAMPLES

Analytical Methods

The first ten columns in the table (SiO_2% through MnO%) are determinations by X-ray fluorescence spectrography, a precise technique good for many such major and minor (not trace) elements. "LOI%" (11th column) means "loss on ignition"; this is the water and other volatile components driven off when the sample was fused into a ceramic disc. The remaining columns "B ppm-s" through "Zr ppm-s" are determinations by emission spectrography, a less-accurate and less-precise but more sensitive method good for many trace elements ("-s" means "spectrographic"). Where elements are reported by both methods, the X-ray results are generally to be preferred.

Explanation of the coded eight-character sample identifier:

First character--O denotes Ojo Encino

Second character--1 means sample was from hole 1, 3 means sample was from hole 3

Third and fourth characters--these identify the position of the sample in the sequence of 10-ft intervals down the hole: 01 would denote the sample nearest the surface, 02 the next one down, etc.

Fifth character--0, denotes that sample is on the usual 10-ft spacing; 1, denotes that sample is a "companion" sample to another at the regular 10-ft spacing, separated by a 6-in. gap.

Sixth character--x indicates that sample is split from another sample (otherwise coded the same) and analyzed separately to test for reliability of analytical methods. Eight samples were split in this manner.

Seventh and eighth characters--the seventh character is the basic rock type into which the sample was classified, by hand-specimen inspection and by simple tests, as follows:

S--sandstone

T--siltstone

C--claystone (shale and very fine grained rocks)

the eighth character is a "modifier" or adjective that further characterizes the basic rock type, as follows:

A--pure

S--sandy

T--silty

C--clayey

Example--the ninth sample listed in the table, 01070XSC, is from hole 1, is the seventh sample from the top taken in the sequence of 10-ft spacings, is exactly on the 10-ft pattern (not a companion sample with a 6-in. gap), is an "analytical split" (made by dividing, after grinding and mixing, sample 010700SC, listed immediately above in the table), and was described and classified as a "clayey sandstone".

REFERENCES CITED

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Hinkley, Todd K., Ebens, R. J., and Boerngen, Josephine G., 1978, Overburden chemistry and mineralogy at Hanging Woman Creek, Big Horn County, Montana and recommendations for sampling at similar sites: U.S. Geological Survey Open-File Report 78-393, 58 p.

Table 1.--Bulk chemical composition of overburden rocks at Ojo Encino and other sites where coal is overlain by Cretaceous age rocks; also soils and mine spoil material from the San Juan Basin

[Values are geometric means* (except for SiO_2). "Sand" indicates sandstone, "Silt" indicates siltstone,"Clay" indicates shale and and other very fine-grained rocks, as used in the text. "n" indicates number of samples analyzed.]

	Ojo Encino, NM				Kimbeto, NM				Other sites with Cretaceous overburden †				San Juan Basin Soils & Mine Spoil**		San Juan Basin Soils **	
	Sand n=26	Silt n=1	Clay n=4	Total n=31	Sand n=27	Silt n=4	Clay n=15	Total n=46	Sand n=110	Silt n=25	Clay n=77	Total n=212	Topsoil n=12	Spoil n=12	A horiz. n=30	C horiz. n=30
SiO_2%	68	70	65	68	70	70	63	68	79.6	67.4	59.8	71.1	75	64	73	73
Al_2O_3%	13.4	15.8	16.3	13.8	13.2	15.0	16.4	14.3	6.1	10.4	13.7	8.7	4.9	11.5	8.3	8.3
CaO%	1.3	0.5	0.55	1.1	1.4	0.78	0.81	1.1	0.56	1.7	1.4	0.90	1.8	2.0	0.9	1.4
Na_2O%	1.5	1.6	1.3	1.5	1.8	1.8	1.3	1.5	0.13	0.27	0.20	0.16	1.4	2.0	1.3	1.3
K_2O%	2.3	2.1	2.6	2.3	2.1	2.6	2.7	2.3	1.5	2.0	2.1	1.7	1.8	1.2	2.5	2.5
B ppm	12	11	24	14	13	18	19	15	14	23	28	19	7	13	16	11
Co ppm	8	11	11	8	8	10	12	9	4	8	9.3	5.8	6	8.5	5	4
Cr ppm	12	22	35	14	19	30	30	22	16	36	43	25	22	14	20	13
Cu ppm	10	26	37	12	14	37	39	21	7	22	30	13	10	18	8.8	6.3
Mo ppm	2.2	1.7	3.7	2.3	2.3	3.4	2.8	2.5	1.8	2.1	2.3	2.0	1.8	2.7	1.0	2.9
Pb ppm	10	10	19	11	10	19	16	12	5.8	9	13	8	11	11	11	10
V ppm	51	73	93	56	60	80	92	71	37	79	91	56	45	56	28	28
Zn ppm	55	64	94	59	61	86	80	69	35	85	105	58	41	56	31	26

*SiO_2 values are arithmetic means. If the element was below the detection limit for some samples, Cohen's technique was used to estimate the probable average.

**Unpublished data of Severson & Gough.

†Danforth Hills, N.W. Colorado; Corral Canyon, S.E. Central Wyoming; Henry Mountains and Emery, Utah

Table 2.--Dispersion of data on bulk chemical composition of overburden rocks at Ojo Encino and other sites where coal is overlain by Cretaceous age rocks; also soils and mine spoil material from the San Juan Basin

[Values are Geometric Deviations (except for SiO_2 for which the values are Standard Deviations). Leaders are used in place of any statistics for siltstone at Ojo Encino because only a single sample was analyzed. "Sand" indicates sandstone, "Silt" indicates siltstone, "Clay" indicates shale and other very fine grained rock, as used in the text. "n" indicates number of samples analyzed]

	Ojo Encino, NM				Kimbeto, NM				Other sites with Cretaceous overburden †				San Juan Basin Soils & Mine Spoil*		San Juan Basin Soils *	
	Sand n=26	Silt n=1	Clay n=4	Total n=31	Sand n=27	Silt n=4	Clay n=15	Total n=46	Sand n=77	Silt n=25	Clay n=77	Total n=212	Topsoil n=12	Spoil n=12	A horiz. n=30	C horiz. n=30
SiO_2%	8.3	--	2.5	7.7	7.0	5.1	4.6	7.0	12.1	11.5	10.4	14.8	1.1	1.1	1.1	1.0
Al_2O_3%	1.2	--	1.0	1.2	1.4	1.1	1.0	1.3	1.6	1.3	1.3	1.8	1.1	1.1	1.1	1.2
CaO%	5.9	--	1.2	5.2	3.8	2.2	1.9	3.1	8.6	3.9	3.8	6.3	1.3	1.2	1.3	1.7
Na_2O%	2.0	--	1.1	1.9	1.7	1.2	1.2	1.5	2.8	2.5	3.0	2.9	1.0	1.2	1.2	1.3
K_2O%	1.3	--	1.0	1.3	1.3	1.5	1.3	1.3	1.5	1.2	1.5	1.5	1.1	1.1	1.1	1.2
B ppm	1.6	--	1.2	1.6	1.4	1.2	1.4	1.5	1.6	1.4	1.6	1.7	1.8	1.5	1.4	1.8
Co ppm	1.4	--	1.6	1.6	1.5	1.6	1.3	1.9	2.1	1.4	1.7	2.1	1.1	1.2	1.3	1.4
Cr ppm	2.0	--	1.1	2.1	1.6	1.3	1.5	1.6	2.0	1.3	1.7	2.1	1.4	1.3	1.5	1.5
Cu ppm	2.1	--	1.0	2.3	2.1	1.2	1.2	2.2	2.8	1.6	1.6	2.9	1.5	1.6	1.4	1.7
Mo ppm	1.5	--	1.2	1.5	1.4	1.3	1.3	1.4	1.5	1.4	1.6	1.5	1.3	1.1	1.2	1.8
Pb ppm	1.4	--	1.3	1.5	1.5	1.7	1.6	1.7	1.7	1.5	6	1.9	1.2	1.2	1.2	1.3
V ppm	1.5	--	1.2	1.5	1.8	1.2	1.3	1.7	2.1	1.2	1.4	2.1	1.1	1.3	1.2	1.4
Zn ppm	1.4	--	1.3	1.5	2.2	1.1	1.4	1.7	2.2	1.3	1.4	2.3	1.1	1.5	1.2	1.4

*Unpublished data of Severson & Gough.
†Danforth Hills, N.W. Colorado; Corral Canyon, S.E. Central Wyoming; Henry Mountains and Emery, Utah

Complete tabulation of bulk chemical data, Ojo Encino overburden rock, dry weight basis

Sample	Latitude	Longitude	SiO2%	Al2O3%	T-Fe2O3%	MgO%	CaO%	Na2O%	K2O%	TiO2%	P2O5%
					Sandstones						
010110SA	35 53 49	107 24 42	53	11	1.8	.4	14.9	2.10	2.3	.3	<.1
01011XSA	35 53 49	107 24 42	54	11	1.8	.3	14.3	2.10	2.2	.2	<.1
031100SA	35 54 49	107 21 29	78	13	1.0	.4	.3	1.80	2.5	.3	<.1
031300SA	35 54 49	107 21 29	82	11	.9	.3	.1	1.40	1.9	.3	<.1
010000SC	35 53 49	107 24 42	66	14	1.7	.4	5.8	2.50	2.5	.4	<.1
01000XSC	35 53 49	107 24 42	66	14	1.6	.4	5.9	2.40	2.5	.3	<.1
010610SC	35 53 49	107 24 42	76	13	1.0	.5	.8	2.30	2.1	.3	<.1
010700SC	35 53 49	107 24 42	71	13	1.0	.5	4.1	2.00	1.9	.3	<.1
01070XSC	35 53 49	107 24 42	71	13	1.1	.5	4.1	2.00	1.9	.3	<.1
010800SC	35 53 49	107 24 42	77	14	1.2	.6	.8	2.10	2.0	.5	.1
011000SC	35 53 49	107 24 42	79	12	.7	.2	.1	1.10	2.0	.5	<.1
011310SC	35 53 49	107 24 42	78	9	1.5	.4	.7	1.20	1.9	.3	<.1
030000SC	35 54 49	107 21 29	71	14	2.2	.5	2.6	2.90	2.4	.4	<.1
030100SC	35 54 49	107 21 29	69	15	3.6	1.0	.4	1.70	3.7	.7	.2
030200SC	35 54 49	107 21 29	55	13	2.7	.9	11.0	1.30	3.0	.5	.2
030600SC	35 54 49	107 21 29	64	15	2.7	1.0	4.3	1.50	2.5	.6	.1
030700SC	35 54 49	107 21 29	62	14	2.5	.8	6.8	1.60	2.4	.5	.1
03070XSC	35 54 49	107 21 29	62	14	2.4	.8	6.7	1.70	2.4	.5	.1
031000SC	35 54 49	107 21 29	78	13	.7	.2	.0	<.20	1.9	.3	<.1
03100XSC	35 54 49	107 21 29	80	14	.7	.2	.0	<.20	2.0	.3	<.1
031200SC	35 54 49	107 21 29	63	18	3.6	1.0	.7	2.30	1.6	.4	<.1
03120XSC	35 54 49	107 21 29	63	18	3.6	1.0	.7	2.30	1.6	.4	<.1
031210SC	35 54 49	107 21 29	72	15	2.7	.9	.5	2.20	1.9	.4	<.1
03121XSC	35 54 49	107 21 29	72	14	2.7	.9	.5	2.20	1.9	.4	<.1
030300ST	35 54 49	107 21 29	64	16	3.0	1.0	3.0	1.50	4.2	.7	.2
030310ST	35 54 49	107 21 29	65	16	2.4	.8	3.3	1.70	4.3	.7	.2
					Siltstones						
010500TC	35 53 49	107 24 42	70	16	3.2	1.5	.5	1.60	2.1	.7	<.1
					Claystones						
030400CA	35 54 49	107 21 29	66	18	4.7	1.1	.4	1.20	2.7	.7	<.1
030500CA	35 54 49	107 21 29	61	15	4.5	1.4	.6	1.40	2.5	.6	<.1
010200CT	35 53 49	107 24 42	66	16	5.2	1.3	.6	1.40	2.6	.7	.1
01020XCT	35 53 49	107 24 42	66	16	5.1	1.3	.6	1.40	2.5	.7	.1

Complete tabulation of bulk chemical data, Ojo Encino overburden rock, dry weight basis

Sample	MnO%	LOI%	Ag ppm-S	Al%-S	B ppm-S	Ba ppm-S	Be ppm-S	Ca%-S	Cd ppm-S	Ce ppm-S	Co ppm-S	Cr ppm-S
						Sandstones						
010110SA	.23	12.4	<.46	5.1	15.0	1,100	1	9.2	<10.0	110	6	7
01011XSA	.23	12.2	<.46	5.3	16.0	800	1	9.6	<10.0	110	7	9
031100SA	<.02	2.9	<.46	5.8	11.0	630	1	.3	<10.0	78	5	8
031300SA	<.02	2.3	<.46	5.4	9.6	450	3	.2	<10.0	<46	6	10
010000SC	.12	6.3	<.46	4.5	<5.0	520	2	1.8	<10.0	87	5	8
01000XSC	.12	6.7	<.46	5.8	6.2	640	1	1.6	<10.0	100	5	8
010610SC	<.02	2.8	<.46	6.6	8.6	570	3	.8	<10.0	77	9	11
010700SC	<.02	5.2	<.46	6.6	8.4	1,800	2	1.6	<10.0	76	8	14
01070XSC	<.02	5.2	<.46	5.7	6.0	1,700	2	1.7	<10.0	56	7	12
010800SC	<.02	2.6	<.46	6.6	6.8	1,800	2	.6	<10.0	81	12	14
011000SC	<.02	3.8	<.46	4.6	12.0	410	3	.1	<10.0	74	6	12
011310SC	<.02	6.3	<.46	4.3	10.0	890	1	.5	<10.0	<46	7	10
030000SC	.03	3.7	<.46	6.3	14.0	1,200	1	1.4	<10.0	97	9	15
030100SC	<.02	4.1	<.46	9.0	19.0	750	2	.5	<10.0	91	12	36
030200SC	.32	11.6	<.46	4.4	14.0	450	1	1.9	<10.0	95	6	19
030600SC	.06	7.6	<.46	7.2	23.0	530	1	1.9	<10.0	89	13	25
030700SC	.15	8.3	<.46	6.3	17.0	430	2	1.8	<10.0	84	11	14
03070XSC	.15	8.4	<.46	8.3	21.0	790	3	6.3	<10.0	130	14	18
031000SC	<.02	4.3	<.46	5.5	12.0	320	2	<.1	<10.0	<46	5	6
03100XSC	<.02	4.1	<.46	3.8	12.0	270	2	<.1	<10.0	<46	5	<1
031200SC	<.02	9.8	<.46	6.4	21.0	350	2	.5	<10.0	81	6	14
03120XSC	<.02	9.6	<.46	5.5	15.0	370	1	.5	<10.0	98	6	13
031210SC	<.02	4.3	<.46	8.7	15.0	550	2	.6	<10.0	56	8	22
03121XSC	<.02	4.4	<.46	7.0	22.0	560	2	.6	<10.0	94	8	15
030300ST	.03	6.2	<.46	6.6	20.0	680	2	1.3	<10.0	110	17	22
030310ST	.05	5.3	<.46	9.1	12.0	850	2	1.6	<10.0	99	9	37
						Siltstones						
010500TC	<.02	6.2	<.46	5.6	11.0	220	2	.4	<10.0	90	11	22
						Claystones						
030400CA	<.02	5.8	<.46	7.3	20.0	300	3	.4	<10.0	80	7	35
030500CA	<.02	11.7	<.46	8.3	29.0	320	4	.6	<10.0	100	9	36
010200CT	<.02	5.6	<.46	9.6	29.0	500	3	.6	<10.0	120	18	30
01020XCT	<.02	6.0	<.46	8.5	21.0	420	3	.6	<10.0	98	15	38

Complete tabulation of bulk chemical data, Ojo Encino overburden rock, dry weight basis

Sample	Cu ppm-S	Dy ppm-S	Er ppm-S	Eu ppm-S	Fe%-S	Ga ppm-S	Gd ppm-S	Ge ppm-S	K%-S	La ppm-S	Li ppm-S
					Sandstones						
010110SA	9	<10	<4.6	1.9	1.4	14	<10	2.0	2.2	64	<100
01011XSA	10	<10	<4.6	1.2	1.1	12	<10	<1.0	2.2	57	<100
031100SA	4	<10	<4.6	<1.0	.6	9	<10	1.5	1.7	42	<100
031300SA	4	<10	<4.6	<1.0	.4	7	13	<1.0	1.2	23	<100
010000SC	5	<10	<4.6	1.2	.7	9	10	<1.0	1.7	44	<100
C1000XSC	6	<10	<4.6	1.1	.9	11	<10	<1.0	1.6	49	<100
010610SC	6	<10	<4.6	1.8	.9	14	<10	1.9	1.6	30	<100
010700SC	10	<10	<4.6	<1.0	.7	12	<10	<1.0	1.5	31	<100
01070XSC	6	<10	<4.6	1.1	.7	11	<10	<1.0	1.3	26	<100
010800SC	6	<10	<4.6	1.3	.8	10	17	<1.0	1.3	33	<100
011000SC	6	<10	<4.6	<1.0	.4	8	10	2.1	1.3	30	<100
011310SC	5	<10	<4.6	<1.0	.8	6	18	4.3	1.2	21	<100
030000SC	23	<10	<4.6	1.4	1.3	15	<10	1.5	1.9	41	<100
030100SC	34	12	<4.6	<1.0	2.8	18	26	1.8	3.1	48	<100
030200SC	23	<10	<4.6	<1.0	1.2	9	<10	<1.0	2.1	46	<100
030600SC	25	<10	<4.6	<1.0	1.6	15	16	1.6	2.0	47	<100
030700SC	22	<10	<4.6	<1.0	1.4	15	11	1.6	2.0	35	<100
03070XSC	27	<10	<4.6	1.5	1.9	20	16	2.3	2.7	51	<100
031000SC	4	<10	<4.6	<1.0	.4	8	15	<1.0	1.1	18	<100
03100XSC	4	<10	<4.6	<1.0	.3	7	<10	1.6	1.0	22	<100
031200SC	7	<10	<4.6	<1.0	2.4	12	<10	1.5	1.4	40	<100
03120XSC	6	<10	<4.6	1.1	1.5	11	<10	1.2	1.2	42	<100
031210SC	10	<10	<4.6	<1.0	2.5	15	18	1.5	1.4	40	<100
03121XSC	11	<10	<4.6	1.4	1.6	17	11	1.3	1.9	41	<100
030300ST	29	<10	<4.6	1.1	1.6	15	17	<1.0	2.8	51	<100
030310ST	27	<10	<4.6	1.0	2.0	22	19	1.6	3.1	49	<100
					Siltstones						
010500TC	26	<10	<4.6	<1.0	1.5	11	<10	1.2	1.7	42	<100
					Claystones						
030400CA	35	<10	<4.6	<1.0	2.8	15	19	<1.0	2.4	40	<100
030500CA	36	<10	<4.6	<1.0	3.3	17	<10	3.1	2.2	51	<100
010200CT	37	<10	<4.6	<1.0	4.4	19	22	2.2	2.9	55	<100
01020XCT	38	<10	<4.6	<1.0	3.8	15	21	1.2	2.3	51	<100

Complete tabulation of bulk chemical data, Ojo Encino overburden rock, dry weight basis

Sample	Mg%-S	Mn ppm-S	Mo ppm-S	Na%-S	Nb ppm-S	Nd ppm-S	Ni ppm-S	Pb ppm-S	Pr ppm-S	Sc ppm-S	Si%-S
Sandstones											
010110SA	.16	1,800	2.4	1.1	16	<46	6	9	<68	6	32
01011XSA	.17	1,700	2.9	1.1	11	<46	7	10	<68	5	28
031100SA	.16	19	1.5	.8	13	<46	7	8	<68	6	27
031300SA	.16	20	2.6	.5	11	<46	9	8	<68	4	32
010000SC	.20	710	1.4	.9	8	<46	7	8	<68	6	21
01000XSC	.18	820	1.5	.9	10	<46	7	9	<68	6	25
010610SC	.25	77	1.2	1.0	13	<46	10	11	<68	8	>37
010700SC	.32	290	2.0	1.8	13	<46	12	7	<68	10	28
01070XSC	.23	230	1.5	.9	13	<46	9	8	<68	8	29
010800SC	.31	33	1.7	.9	14	<46	12	9	<68	9	30
011000SC	.07	24	1.2	.4	11	<46	8	9	<68	5	>37
011310SC	.15	68	1.2	.4	14	<46	15	18	<68	3	31
030000SC	.27	330	2.2	1.2	14	<46	11	10	<68	7	29
030100SC	.59	200	3.7	1.0	22	<46	27	17	<68	12	>37
030200SC	.42	1,800	2.7	.6	15	<46	10	6	<68	9	19
030600SC	.51	520	3.2	.7	21	<46	23	12	<68	12	27
030700SC	.43	1,100	3.6	1.4	18	<46	17	14	<68	8	25
03070XSC	.44	1,300	4.2	1.2	18	<46	22	20	<68	10	34
031000SC	.07	12	2.7	.1	11	<46	6	7	<68	3	30
03100XSC	.07	10	1.6	.1	11	<46	4	5	<68	2	24
031200SC	.46	93	2.2	.9	16	<46	9	12	<68	8	23
03120XSC	.44	98	2.4	.9	12	<46	9	11	<68	8	20
031210SC	.45	240	3.8	1.7	16	<46	16	13	<68	9	35
03121XSC	.46	230	3.0	1.0	19	<46	14	11	<68	9	29
030300ST	.47	290	2.6	.7	17	<46	23	11	<68	12	24
030310ST	.49	540	2.1	.9	18	<46	17	17	<68	12	36
Siltstones											
010500TC	.64	46	1.7	.6	19	<46	18	10	<68	12	25
Claystones											
030400CA	.56	50	3.3	.5	18	<46	19	16	<68	13	25
030500CA	.74	85	3.3	.6	21	<46	23	16	<68	16	29
010200CT	.76	190	4.9	.7	23	<46	29	26	<68	14	36
01020XCT	.68	88	3.6	.5	18	<46	25	19	<68	12	29

Complete tabulation of [illegible]

Sample	Sn ppm-S	Sr ppm-S	Ti%-S	Tm ppm-S	V ppm-S	Y ppm-S	Yb ppm-S	Zn ppm-S	Zr ppm-S	Lab. No.
					Sandstones					
010110SA	<4.6	290	.16	<5	35	54.0	3	81	160	215,162
01011XSA	<4.6	310	.13	<5	32	44.0	4	90	100	215,252
031100SA	<4.6	120	.13	<5	36	23.0	2	29	110	215,059
031300SA	<4.6	95	.12	<5	37	13.0	1	52	190	215,341
010000SC	<4.6	200	.13	<5	44	31.0	3	56	110	215,115
01000XSC	<4.6	240	.15	<5	37	32.0	3	66	160	215,190
010610SC	<4.6	200	.26	<5	66	28.0	3	34	110	215,155
010700SC	<4.6	220	.19	<5	63	28.0	2	63	120	215,302
01070XSC	<4.6	220	.14	<5	55	22.0	2	49	99	215,215
010800SC	<4.6	190	.22	<5	48	19.0	2	49	110	215,078
011000SC	<4.6	110	.22	<5	40	15.0	2	37	260	215,259
011310SC	<4.6	120	.13	<5	33	18.0	2	46	100	215,175
030000SC	<4.6	510	.24	<5	63	25.0	3	42	170	215,125
030100SC	<4.6	190	.49	<5	97	35.0	3	72	430	215,283
030200SC	<4.6	140	.15	<5	66	33.0	3	73	220	215,101
030600SC	<4.6	230	.35	<5	92	34.0	3	89	290	215,195
030700SC	<4.6	180	.23	<5	61	27.0	2	76	220	215,295
03070XSC	<4.6	280	.39	<5	65	38.0	3	99	320	215,156
031000SC	<4.6	27	.10	<5	28	12.0	1	30	130	215,052
03100XSC	<4.6	25	.06	<5	25	9.8	1	31	99	215,096
031200SC	<4.6	200	.15	<5	47	28.0	3	35	180	215,057
03120XSC	<4.6	230	.15	<5	51	30.0	3	54	170	215,116
031210SC	<4.6	200	.27	<5	66	28.0	3	54	200	215,322
03121XSC	<4.6	220	.22	<5	53	29.0	3	50	220	215,213
030300ST	<4.6	210	.28	<5	92	32.0	3	82	290	215,226
030310ST	<4.6	200	.47	<5	100	35.0	5	72	390	215,284
					Siltstones					
010500TC	<4.6	220	.22	<5	73	36.0	4	64	270	215,118
					Claystones					
030400CA	<4.6	200	.24	<5	77	27.0	3	83	200	215,338
030500CA	<4.6	230	.35	<5	110	33.0	3	71	270	215,318
010200CT	<4.6	250	.42	<5	100	38.0	5	130	320	215,254
01020XCT	<4.6	220	.34	<5	90	33.0	3	100	200	215,306