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Overburden geochemistry of U.S. Bureau of Land Management ~~[illegible]~~ experimental coal mining reclamation site at Kimbeto, southeastern San Juan County, San Juan Basin, NM

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

OVERBURDEN GEOCHEMISTRY OF THE U.S. BUREAU OF LAND MANAGEMENT EXPERIMENTAL COAL-MINING RECLAMATION SITE AT KIMBETO, SOUTHEASTERN SAN JUAN COUNTY, SAN JUAN BASIN, NEW MEXICO

By

Todd K. Hinkley, James R. Herring

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

OVERBURDEN GEOCHEMISTRY OF U.S. BUREAU OF LAND MANAGEMENT EXPERIMENTAL COAL MINING RECLAMATION SITE AT KIMBETO, SOUTHEASTERN SAN JUAN 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 (BLM) experimental coal mine reclamation site at the Kimbeto, San Juan 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 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 without expensive analysis.

In order to assess the value of Kimbeto 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, and from both nearby and distant sites.

Sampling Scheme

Samples were taken from hole numbers 5 and 10, which are about 1 mi (0.6 km) apart. The holes were sampled to depths of 333 ft. (109 m) and 436 ft. (143 m), respectively. Choosing a random depth within the top 10 ft. (3 m) as a starting point, a 6 in. (0.16 m) segment of the "nx" core (about 2 in. or 5 cm in diameter) was taken every 10 ft. Every fifth sample, an extra sample was taken, separated by a 6 in. gap. This was 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 identified by quick, simple tests and by appearance in hand specimens, to determine whether the different rock types had distinctive chemistry. The theory being, it might be possible to predict the chemistry 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 approximately 0.2mm);

(2) Siltstone (grains visible by hand lens, 0.2mm or smaller); and

(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 as an appendix.

Chemical Distinctiveness of Rock Types

Overburden rocks at Kimbeto 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 Kimbeto site but also for the nearby experimental reclamation site 35 miles east southeast in northeastern McKinley County called Ojo Encino, 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 selected elements that are of the greatest geological and environmental interest. With few exceptions, the sandstones have the lowest, the siltstone (single sample) has intermediate and claystones have the highest concentrations of trace elements of potential environmental concern (boron, cobalt, chromium, copper, molybdenum, lead, vanadium, and zinc).

The rocks from the Kimbeto and Ojo Encino sites in the San Juan Basin have less chemical difference between rock type than 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 locations sandstones are much more purely quartz, and the clay minerals are concentrated to a greater extent in the claystones (shales). 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 Kimbeto (and Ojo Encino) Rocks

Compared to Other Overburden Rocks

of the Same and Different Ages

In order to assess the value of Kimbeto 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, where only average concentration values are given. For all chemical elements except SiO_2, the geometric mean rather than the arithmetic mean is shown because it tends to minimize the effect of the (very high) values which may appear in the data set, and 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 (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 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" (tables 1,2) 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--Kimbeto 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 rock) 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 Kimbeto and Ojo Encino 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 Kimbeto and Ojo Encino 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 Kimbeto and Ojo Encino than in other Cretaceous overburden. New Mexico concentrations are closer to those for corresponding rock types in overburden of Tertiary Fort Union Formation material but the New Mexico rocks are higher by as much as a factor of two.

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

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

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

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

Mo----Kimbeto and Ojo Encino 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 Kimbeto and Ojo Encino 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 Kimbeto and Ojo Encino rocks are similar to those in Cretaceous overburden rocks from other areas. They are similar to concentrations in Tertiary overburden rocks.

Zn----Zinc concentrtions in Kimbeto and Ojo Encino 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 Kimbeto Overburden Rocks to Natural San Juan Basin Soils

Kimbeto overburden rocks are similar in bulk composition to natural soils of the San Juan basin. The data are summarized in table 1. The rocks are very similar to the soils with respect to sodium, the element of most concern in reclamation considerations. There are, to varying but moderate degrees, higher concentrations of the following elements in the Kimbeto 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 very 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, Kimbeto overburden material is appropriate for use as replacement material for the soils of the area.

Relative Abundance of Rock Types

At Kimbeto the ratios of sandstone-to-siltstone-to-claystone in drill cores sampled were about 2 : $1/4$: 1 (46 samples); at Ojo Encino they were about 6 : $1/4$: 1 (31 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 fold more sand at Ojo Encino). Siltstone is not very abundant anywhere.

Conclusions

A. Summary of area characteristics in relation to reclamation potential--The various Kimbeto overburden rock types are congruous in their bulk chemical composition with the same rock types at other sites in the Western U.S. where Cretaceous age rocks overlie coal. The single major exception is higher sodium content in Kimbeto 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 BLM (livestock production and wildlife habitat)--There is no reason associated with bulk chemistry of the overburden rocks that the area should not be restored to a condition which would allow its designated post-mining use.

C. & D. Major reclamation problems and measures necessary to establish conditions suitable for anticipated post-mining use--It may be necessary to stockpile rocks 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, it would likely be desirable to place sandstone, with its potential loamy texture and comparatively low trace- and minor-element concentrations, near the top where it would have most contact with plant roots and would permit absorption of intense rain showers; it would likely be desirable to place claystone, with its higher elemental concentrations, either deep in the refill column where the reducing electrochemical potential would retard weathering and release of elements to ground water, or else 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.

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

[Values are geometric means except SiO_2 values are arithmetic means. Sand indicates sandstone; Silt indicates siltstone; and clay indicates shale and other very fine-grained rock, as used in the text. If the element was below the detection limit for some samples, Cohen's technique was used to estimate the probable average.]

	Kimbeto, New Mex.				Ojo Encino, New Mex.				Other sites with Cretaceous overburden [1]				San Juan Basin Soils & Mine Spoil[2]		San Juan Basin Soils [3]	
	Sand n=27	Silt n=4	Clay n=15	Total n=46	Sand n=26	Silt n=1	Clay n=4	Total n=31	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%	70	70	63	68	68	70	65	68	79.3	67.3	59.8	71.1	75	64	73	73
Al_2O_3%	13.2	15.0	16.4	14.3	13.4	15.8	16.3	13.8	6.1	10.4	13.7	8.7	4.9	11.5	8.3	8.3
CaO%	1.4	0.78	0.81	1.1	1.3	0.5	0.55	1.1	0.56	1.7	1.4	0.91	1.8	2.0	0.9	1.4
Na_2O%	1.8	1.8	1.3	1.5	1.5	1.6	1.3	1.5	0.13	0.27	0.20	0.16	1.4	2.0	1.3	1.3
K_2O%	2.1	2.6	2.7	2.3	2.3	2.1	2.6	2.3	1.5	2.0	2.1	1.7	1.8	1.2	2.5	2.5
B ppm	13	18	19	15	12	11	24	14	14	23	28	19	7	13	16	11
Co ppm	8	10	12	9	8	11	11	8	4	8	9.3	5.8	6	8.5	5	4
Cr ppm	19	30	30	22	12	22	35	14	16	36	43	25	22	14	20	13
Cu ppm	14	37	39	21	10	26	37	12	7	22	30	13	10	18	8.8	6.3
Mo ppm	2.3	3.4	2.8	2.5	2.2	1.7	3.7	2.3	1.8	2.1	2.3	2.0	1.8	2.7	1.0	2.9
Pb ppm	10	19	16	12	10	10	19	11	5.8	9	13	8	11	11	11	10
V ppm	60	80	92	71	51	73	93	56	37	79	91	56	45	56	28	28
Zn ppm	61	86	80	69	55	64	94	59	35	85	105	58	41	56	31	26

[1] Danforth Hills, northwest Colorado; Corral Canyon, southeast central Wyoming; Henry Mountains and Emery, Utah
[2] Unpublished data of Severson and Gough, Table 6
[3] Unpublished data of Severson and Gough, Table 4

Table 2.--Dispersion of data on bulk chemical composition of overburden rocks at Kimbeto and other sites where coal is overlain by Cretaceous 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). Sand indicates sandstone, Silt indicates siltstone, Clay indicates shale and other very fine grained rocks, as used in the text "n" indicates number of samples analyzed.]

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

* Unpublished data of Severson and Gough, Table 6
** Unpublished data of Severson and Gough, Table 4
† Danforth Hills, northwest Colorado; Corral Canyon, southeast central Wyoming; Henry Mountains and Emery, Utah

Appendix A

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

Analytical Methods

The first ten columns in the table 3 (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 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--K denotes Kimbeto

Second character--5 means sample was from hole 1, 9 means sample was from hole 10

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, and so forth.

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. Seven 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 which further characterizes the basic rock type, as follows:

A--pure

S--sandy

T--silty

C--clayey

Example--the seventeenth sample listed in the table, K5010XSC, is from hole 5, is the uppermost 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 K50100SC, listed immediately above in the table), and was called a "clayey sandstone" during description and classification.

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

Sample	Latitude	Longitude	SiO_2%	Al_2O_3%	T-Fe_2O_3%	MgO%	CaO%	Na_2O%	K_2O%	TiO_2%	P_2O_5%
Sandstones											
K50200SA	36 9 17	107 54 4	61.0	17.5	5.0	.89	4.8	3.0	1.8	.58	.3
K50410SA	36 9 17	107 54 4	64.8	17.0	4.1	.87	.7	1.5	1.5	.68	<.1
K50500SA	36 9 17	107 54 4	72.8	14.3	2.7	.83	1.2	2.5	2.2	.50	<.1
K50600SA	36 9 17	107 54 4	75.9	13.3	1.5	.50	1.3	2.9	2.1	.50	<.1
K51300SA	36 9 17	107 54 4	70.4	14.7	3.5	.85	1.1	2.5	2.7	.58	.2
K51400SA	36 9 17	107 54 4	69.7	14.2	2.7	.66	2.8	2.3	2.6	.80	.2
K5140XSA	36 9 17	107 54 4	69.2	14.1	2.7	.64	2.9	2.3	2.5	.77	.2
K51800SA	36 9 17	107 54 4	92.4	3.2	.4	<.10	<.02	<.2	.9	.13	<.1
K51810SA	36 9 17	107 54 4	68.8	12.9	3.3	.80	3.4	2.0	2.7	.55	.1
K51900SA	36 9 17	107 54 4	66.7	13.6	1.9	.73	5.2	1.8	2.2	.62	.1
K5190XSA	36 9 17	107 54 4	66.9	13.0	1.9	.73	5.1	1.9	2.2	.60	.1
K52200SA	36 9 17	107 54 4	65.8	15.8	2.3	.62	2.6	1.2	2.3	.72	.2
K5220XSA	36 9 17	107 54 4	67.1	16.1	2.3	.70	2.5	1.3	2.4	.73	.2
K92800SA	36 7 22	107 49 46	83.5	7.9	.9	.30	.1	1.2	1.8	.22	<.1
K93200SA	36 7 22	107 49 46	75.2	11.8	2.7	1.00	.7	2.1	2.3	.43	<.1
K50100SC	36 9 17	107 54 4	70.2	15.0	3.4	.92	1.8	2.5	1.7	.74	.2
K5010XSC	36 9 17	107 54 4	70.1	15.1	3.4	.90	1.8	2.5	1.7	.74	.2
K50800SC	36 9 17	107 54 4	65.1	15.9	4.5	1.30	1.1	2.0	3.3	.65	.2
K51700SC	36 9 17	107 54 4	66.4	14.4	3.0	.84	3.5	2.0	2.4	.56	.1
K52100SC	36 9 17	107 54 4	56.1	13.8	2.7	.93	9.0	1.1	2.1	.57	.1
K52900SC	36 9 17	107 54 4	71.3	16.1	2.6	.68	.1	1.3	2.0	.62	<.1
K92100SC	36 7 22	107 49 46	75.5	12.9	2.3	.75	1.0	2.6	2.2	.40	<.1
K92500SC	36 7 22	107 49 46	75.7	11.6	1.9	.73	1.3	1.7	2.2	.34	<.1
K93600SC	36 7 22	107 49 46	76.1	10.1	1.9	.77	3.2	2.2	2.1	.37	<.1
K94100SC	36 7 22	107 49 46	66.7	14.7	3.8	2.20	1.5	1.9	2.1	.46	<.1
K50300ST	36 9 17	107 54 4	72.1	14.1	2.8	.74	1.5	2.5	1.6	.56	<.1
K50700ST	36 9 17	107 54 4	67.8	16.0	3.5	1.10	1.4	2.1	2.3	.65	.1
Siltstones											
K51600TA	36 9 17	107 54 4	77.4	13.2	1.1	.40	.3	1.7	2.5	.27	<.1
K50310TC	36 9 17	107 54 4	68.5	15.9	3.8	.96	1.2	2.4	1.5	.71	<.1
K51100TC	36 9 17	107 54 4	66.4	16.1	4.9	1.40	.7	1.5	3.5	.66	<.1
K51110TC	36 9 17	107 54 4	67.0	14.9	4.5	1.20	1.7	1.6	3.6	.66	.1
Claystones											
K52300CA	36 9 17	107 54 4	64.8	18.0	3.6	.97	.4	1.1	2.3	.72	<.1
K52310CA	36 9 17	107 54 4	63.2	16.4	3.3	1.20	2.2	1.0	2.4	.65	.1
K50000CT	36 9 17	107 54 4	48.8	15.9	3.5	.65	1.6	1.2	1.7	.56	<.1
K50900CT	36 9 17	107 54 4	66.0	15.7	5.0	1.10	.8	1.3	4.6	.69	.2
K51000CT	36 9 17	107 54 4	59.3	16.1	4.3	1.50	4.1	1.2	3.6	.65	.1

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

Sample	MnO%	LOI%	Al%-S	B ppm-S	Ba ppm-S	Be ppm-S	Ca%-S	Ce ppm-S	Co ppm-S	Cr ppm-S	Cu ppm-S
					Sandstones						
K50200SA	.22	5.3	5.8	12	610	1.6	1.5	110	12	9	13
K50410SA	<.02	8.0	7.4	13	390	2.9	.6	71	6	27	22
K50500SA	<.02	3.3	6.2	17	580	2.0	.7	72	15	13	12
K50[illegible]00SA	<.02	2.1	6.0	10	700	1.1	1.0	68	5	10	6
K51300SA	<.02	2.9	6.6	16	750	1.8	.9	81	7	23	14
K51400SA	.07	4.3	7.2	11	730	1.9	1.3	74	13	21	14
K5140XSA	.08	4.4	7.3	16	810	1.8	1.5	73	12	21	15
K51800SA	<.02	1.1	.3	6	210	4.1	<.1	<46	2	4	2
K51410SA	.07	5.1	6.9	18	560	1.5	1.5	75	8	20	20
K51900SA	.07	6.5	6.9	17	1,000	1.2	1.5	69	7	17	16
K5170XSA	.08	6.6	5.1	10	710	1.8	1.7	56	6	24	13
K52200SA	.04	6.6	7.1	22	480	2.2	1.2	72	9	24	32
K5220XSA	.04	6.5	2.8	6	320	1.4	.9	75	8	17	26
K92800SA	<.02	1.5	3.2	6	400	2.0	.1	<46	4	8	3
K93200SA	<.02	3.2	5.4	18	540	1.7	.5	<46	6	14	6
K50100SC	<.02	3.6	7.9	11	760	2.1	1.3	100	13	22	24
K5010XSC	<.02	3.5	7.2	17	480	2.3	1.1	88	12	25	20
K50800SC	<.02	5.0	8.8	20	800	3.2	.8	78	8	24	38
K51700SC	.04	6.5	7.7	11	810	2.0	1.7	77	7	51	26
K52100SC	.10	11.8	6.2	13	450	1.5	4.8	89	10	25	27
K52900SC	<.02	5.2	7.4	13	360	1.3	.2	74	12	29	14
K92100SC	<.02	2.4	8.7	11	640	1.6	1.1	73	7	27	16
K92500SC	<.02	3.4	7.7	21	640	1.2	1.1	76	8	19	13
K93600SC	<.02	4.0	4.8	13	470	1.3	1.2	66	5	22	5
K94100SC	<.02	6.1	6.7	14	370	2.6	.9	100	9	24	16
K50300ST	<.02	3.5	7.5	17	670	2.2	1.0	100	7	17	17
K50700ST	<.02	4.5	8.2	16	660	2.3	1.1	110	13	26	26
					Siltstones						
K51600TA	<.02	3.0	7.2	16	610	2.9	1.6	140	9	34	38
K50310TC	<.02	5.2	10.0	18	490	3.9	1.1	110	14	20	34
K51100TC	<.02	5.0	8.9	22	530	3.3	.7	100	8	40	46
K51110TC	.04	4.7	6.0	16	550	2.2	.9	85	9	31	33
					Claystones						
K52300CA	<.02	7.0	8.9	25	440	3.3	.5	98	25	41	38
K52310CA	<.02	8.4	6.3	14	370	2.2	1.0	110	10	27	36
K50000CT	<.02	24.3	2.6	13	150	1.8	.5	79	5	8	23
K50900CT	<.02	4.2	6.2	13	580	2.2	.6	130	8	31	38
K51000CT	.03	7.7	6.4	20	450	2.5	1.5	<46	9	33	35

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

Sample	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	Mg%-S
					Sandstones						
K50200SA	<10	<4.6	<1.0	2.1	13	<10	<1.0	1.3	38	<100	.46
K50410SA	<10	<4.6	<1.0	2.1	14	11	<1.0	1.3	31	<100	.46
K50500SA	<10	<4.6	<1.0	1.8	14	13	<1.0	1.4	39	<100	.36
K50600SA	<10	<4.6	<1.0	.9	12	<10	<1.0	1.6	37	<100	.21
K51300SA	<10	<4.6	<1.0	1.7	14	<10	<1.0	2.6	37	<100	.40
K51400SA	<10	<4.6	<1.0	1.5	13	<10	<1.0	1.9	41	110	.38
K5140XSA	<10	<4.6	<1.0	1.8	15	<10	2.6	1.7	40	<100	.30
K51800SA	<10	<4.6	<1.0	.4	2	<10	2.9	.4	15	<100	<.06
K51810SA	<10	<4.6	<1.0	2.3	18	16	1.8	2.2	37	<100	.52
K51900SA	<10	<4.6	<1.0	1.5	14	<10	1.5	1.3	47	<100	.34
K5190XSA	<10	<4.6	<1.0	1.0	8	<10	<1.0	1.3	32	<100	.32
K52200SA	<10	<4.6	<1.0	1.4	13	17	1.8	1.4	42	<100	.30
K5220XSA	<10	<4.6	<1.0	.8	7	<10	<1.0	1.5	37	<100	.29
K92800SA	<10	<4.6	<1.0	.4	4	12	<1.0	1.2	29	<100	.11
K93200SA	<10	<4.6	<1.0	.9	8	<10	1.6	1.6	26	<100	.44
K50100SC	14	<4.6	<1.0	2.4	19	22	1.6	1.5	48	<100	.54
K5010XSC	<10	<4.6	1.1	2.1	16	<10	1.3	1.6	45	<100	.46
K50800SC	<10	<4.6	<1.0	3.5	18	<10	1.4	2.6	48	<100	.69
K51700SC	<10	<4.6	<1.0	2.4	14	<10	1.7	1.8	43	<100	.43
K52100SC	<10	<4.6	<1.0	1.7	12	<10	1.1	1.6	42	<100	.46
K52900SC	<10	<4.6	<1.0	1.4	14	<10	1.2	1.5	38	<100	.33
K92100SC	<10	<4.6	1.2	2.2	17	<10	2.0	2.1	42	<100	.42
K92500SC	<10	<4.6	<1.0	2.2	15	<10	1.8	1.9	45	<100	.36
K93600SC	<10	<4.6	<1.0	.7	7	13	<1.0	1.2	36	<100	.39
K94100SC	<10	<4.6	1.1	1.9	13	15	1.3	1.8	48	<100	.97
K50300ST	<10	<4.6	1.0	1.7	13	<10	1.6	1.5	42	<100	.37
K50700ST	<10	<4.6	1.2	2.5	19	22	2.1	2.3	49	<100	.64
					Siltstones						
K51600TA	<10	<4.6	<1.0	3.7	16	<10	<1.0	3.2	48	<100	.82
K50310TC	15	<4.6	<1.0	2.8	21	23	1.5	1.5	56	<100	.64
K51100TC	<10	<4.6	<1.0	3.0	20	24	1.6	3.3	47	<100	.76
K51110TC	<10	<4.6	1.1	2.6	12	17	<1.0	3.0	48	<100	.52
					Claystones						
K52300CA	<10	<4.6	<1.0	2.7	23	25	<1.0	1.8	41	<100	.56
K52310CA	<10	<4.6	<1.0	1.6	15	<10	1.2	1.6	45	<100	.52
K50000CT	<10	<4.6	<1.0	.7	7	<10	6.1	1.0	39	<100	.22
K50900CT	<10	<4.6	1.4	2.4	13	14	<1.0	3.5	54	<100	.54
K51000CT	<10	<4.6	<1.0	2.2	19	<10	<1.0	2.9	48	<100	.69

Sample	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					
K50200SA	1,300	4.2	1.1	13	<46	10	9	<68	14	19
K50410SA	65	2.6	.5	22	<46	14	13	<68	10	23
K50500SA	59	3.4	1.7	15	<46	18	9	<68	6	27
K50600SA	68	2.2	1.1	11	<46	8	6	<68	5	30
K51300SA	270	2.6	1.3	12	<46	14	12	<68	9	24
K51400SA	660	2.1	1.0	21	<46	19	11	<68	11	26
K5140XSA	600	1.9	.8	18	<46	17	11	<68	10	32
K51800SA	18	2.4	.1	10	<46	2	5	<68	<1	>37
K51810SA	560	2.6	1.7	17	<46	15	12	<68	10	27
K51900SA	550	1.6	.6	15	<46	11	7	<68	8	30
K5190XSA	540	1.6	.5	21	<46	10	6	<68	8	21
K52200SA	310	2.0	.4	20	<46	16	9	<68	9	27
K5220XSA	260	2.3	.5	13	<46	11	6	<68	9	16
K92800SA	21	1.0	.4	10	<46	3	3	<68	4	28
K93200SA	55	1.9	1.2	16	<46	10	8	<68	6	27
K50100SC	93	3.4	.9	17	<46	19	10	<68	13	32
K5010XSC	78	2.6	1.0	17	<46	16	10	<68	12	29
K50800SC	230	3.4	.8	11	<46	19	14	<68	10	30
K51700SC	410	2.2	.8	14	<46	14	10	<68	9	32
K52100SC	780	2.3	.5	18	<46	19	9	<68	12	25
K52900SC	30	1.7	.5	17	<46	19	15	<68	12	28
K92100SC	190	2.9	1.2	17	<46	12	15	<68	8	>37
K92500SC	220	2.4	.7	18	<46	15	14	<68	9	>37
K93600SC	230	1.4	.5	17	<46	9	8	69	7	25
K94100SC	90	2.4	.9	25	<46	18	15	<68	11	23
K50300ST	270	1.8	1.1	20	<46	10	14	<68	7	31
K50700ST	300	2.7	1.0	19	<46	20	19	<68	13	33
					Siltstones					
K51600TA	350	5.0	.7	22	<46	21	17	<68	14	23
K50310TC	180	3.0	1.1	23	<46	19	37	<68	10	35
K51100TC	190	2.9	.8	19	<46	22	20	<68	14	30
K51110TC	330	3.0	1.2	20	<46	17	11	<68	14	23
					Claystones					
K52300CA	56	2.7	.5	24	<46	54	25	<68	16	33
K52310CA	180	2.3	.3	19	<46	21	11	<68	13	22
K50000CT	23	1.7	.3	12	<46	6	4	<68	6	12
K50900CT	180	3.0	.6	16	<46	20	11	<68	12	23
K51000CT	280	2.5	.5	17	<46	21	15	<68	14	24

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

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

Sample	Sn ppm-S	Sr ppm-S	Ti%-S	V ppm-S	Y ppm-S	Yb ppm-S	Zn ppm-S	Zr ppm-S	Lab. No.
				Sandstones					
K50200SA	<4.6	520	.21	88	31	3.1	86	180	215,104
K50410SA	<4.6	240	.30	66	21	2.4	63	350	215,225
K50500SA	<4.6	280	.17	46	24	2.2	46	190	215,332
K50600SA	<4.6	330	.24	35	18	1.8	32	120	215,243
K51300SA	<4.6	270	.27	75	22	2.6	61	150	215,227
K51400SA	<4.6	230	.33	67	25	2.7	80	210	215,071
K5140XSA	<4.6	210	.44	94	27	3.4	110	180	215,251
K51800SA	5.0	76	.07	6	8	.7	<5	71	215,288
K51810SA	<4.6	240	.27	80	24	2.3	120	290	215,308
K51900SA	<4.6	200	.31	75	26	2.3	71	290	215,198
K5190XSA	<4.6	200	.22	72	21	1.9	70	180	215,235
K52200SA	<4.6	130	.27	64	29	2.4	92	330	215,297
K5220XSA	<4.6	110	.14	52	28	2.7	64	280	215,097
K92800SA	<4.6	53	.08	25	13	1.4	18	100	215,113
K93200SA	<4.6	150	.14	47	20	2.2	63	140	215,340
K50100SC	<4.6	420	.42	110	48	4.8	87	700	215,087
K5010XSC	<4.6	360	.33	88	35	4.5	93	460	215,121
K50800SC	<4.6	300	.33	95	31	3.7	100	260	215,208
K51700SC	<4.6	230	.30	98	27	2.6	81	220	215,199
K52100SC	<4.6	180	.28	92	37	3.1	85	400	215,248
K52900SC	<4.6	120	.28	64	31	3.7	57	330	215,055
K92100SC	<4.6	290	.40	61	29	3.3	51	340	215,165
K92500SC	<4.6	210	.36	72	36	3.3	47	220	215,167
K93600SC	<4.6	170	.18	56	23	2.4	64	260	215,108
K94100SC	<4.6	250	.23	58	37	3.6	110	200	215,068
K50300ST	<4.6	370	.28	45	28	3.0	53	300	215,238
K50700ST	<4.6	320	.48	89	43	4.3	85	590	215,274
				Siltstones					
K51600TA	<4.6	280	.37	75	40	3.7	94	270	215,060
K50310TC	<4.6	370	.46	75	36	4.3	86	540	215,245
K51100TC	<4.6	230	.46	100	34	3.1	88	240	215,182
K51110TC	<4.6	200	.25	76	36	3.4	77	230	215,335
				Claystones					
K52300CA	<4.6	170	.39	110	29	2.6	76	320	215,268
K52310CA	<4.6	160	.23	77	31	3.1	76	230	215,229
K50000CT	<4.6	260	.08	49	31	3.1	34	160	215,111
K50900CT	<4.6	200	.29	86	39	3.7	110	210	215,218
K51000CT	<4.6	220	.27	99	33	3.6	82	210	215,123

Sample	Latitude	Longitude	SiO2%	Al2O3%	T-Fe2O3%	MgO%	CaO%	Na2O%	K2O%	TiO2%	P2O5%
					Claystones--continued						
K51500CT	36 9 17	107 54 4	65.1	15.8	6.4	1.40	.7	1.5	3.0	.69	<.1
K52000CT	36 9 17	107 54 4	60.8	15.8	5.0	1.20	.7	1.4	2.3	.63	<.1
K5200XCT	36 9 17	107 54 4	61.5	15.9	5.1	1.20	.6	1.4	2.3	.64	<.1
K90000CT	36 7 22	107 49 46	62.4	17.3	4.9	1.40	.9	1.3	3.3	.72	.2
K90400CT	36 7 22	107 49 46	65.3	15.5	5.5	1.30	.8	1.6	2.9	.65	<.1
K9040XCT	36 7 22	107 49 46	64.8	15.4	5.5	1.30	.8	1.5	2.9	.64	<.1
K90800CT	36 7 22	107 49 46	60.1	20.4	5.1	1.40	.6	1.9	2.0	.65	<.1
K91210CT	36 7 22	107 49 46	64.5	16.6	5.2	1.40	.5	1.7	3.4	.67	<.1
K91600CT	36 7 22	107 49 46	67.1	16.0	4.1	1.30	.4	1.2	2.4	.63	<.1
K9160XCT	36 7 22	107 49 46	67.1	15.9	4.1	1.40	.4	1.2	2.3	.63	<.1

Complete tabulation of bulk chemical data, Kimbeto overburden rock, dry weight basis--continued

Sample	MnO%	LOI%	Al%-S	B ppm-S	Ba ppm-S	Be ppm-S	Ca%-S	Ce ppm-S	Co ppm-S	Cr ppm-S	Cu ppm-S
					Claystones--continued						
K51500CT	<.02	5.4	11.0	31	490	3.8	.8	110	9	36	39
K52000CT	<.02	11.2	7.7	22	460	2.6	.7	80	6	31	40
K5200XCT	<.02	10.5	9.0	32	500	3.7	.7	95	7	38	48
K90000CT	<.02	7.1	8.3	16	540	2.7	.8	110	17	29	46
K90400CT	<.02	5.8	6.8	14	450	2.9	.6	130	37	32	34
K9040XCT	<.02	5.8	12.0	30	580	4.2	1.0	140	68	39	50
K90800CT	<.02	7.5	8.4	14	470	2.9	.6	110	12	23	27
K91210CT	<.02	5.2	9.0	26	510	2.5	.6	140	42	31	39
K91600CT	<.02	6.6	8.0	23	480	2.2	.5	81	4	37	49
K9160XCT	<.02	6.7	6.0	13	400	1.9	.4	67	4	30	47

Complete tabulation of bulk chemical data, Kimbeto overburden rock, dry weight basis--continued

Sample	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	Mg%-S
					Claystones--continued						
K51500CT	<10	5.6	1.3	4.7	24	14	1.6	3.2	49	<100	.85
K52000CT	<10	<4.6	<1.0	2.7	21	<10	2.7	2.6	34	<100	.62
K5200XCT	<10	<4.6	<1.0	3.6	17	<10	2.5	1.9	44	<100	.72
K90000CT	<10	<4.6	<1.0	2.9	18	<10	1.4	3.1	53	<100	.83
K90400CT	<10	<4.6	<1.0	2.9	14	<10	1.4	2.9	50	<100	.66
K9040XCT	<10	<4.6	1.5	5.1	26	13	2.2	3.4	62	<100	.89
K90800CT	<10	<4.6	<1.0	2.3	17	17	1.4	1.5	45	110	.63
K91210CT	<10	<4.6	1.2	4.0	26	12	1.4	3.3	65	<100	.78
K91600CT	<10	<4.6	<1.0	2.7	20	18	1.7	2.6	34	<100	.76
K9160XCT	<10	<4.6	<1.0	1.9	13	<10	<1.0	2.2	27	<100	.66

Complete tabulation of bulk chemical data, Kimbeto overburden rock, dry weight basis--continued

Complete tabulation of bulk chemical data, Kimbeto overburden rock, dry weight basis--continued

Sample	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
					Claystones--continued					
K51500CT	220	4.6	.8	21	<46	25	22	<68	15	36
K52000CT	110	2.7	.7	18	<46	14	16	<68	13	29
K5200XCT	82	3.6	.7	18	<46	19	15	<68	15	33
K90000CT	220	3.2	.7	23	<46	29	22	<68	12	25
K90400CT	62	3.6	.7	18	53	43	18	<68	15	25
K9040XCT	200	1.7	.8	24	47	62	31	<68	18	>37
K90800CT	59	3.0	.8	18	<46	21	18	<68	13	21
K91210CT	170	3.3	.9	23	<46	57	25	<68	16	33
K91600CT	81	3.5	.5	21	<46	14	20	<68	14	31
K9160XCT	42	2.1	.5	22	<46	12	11	<68	14	23

Sample	Sn ppm-S	Sr ppm-S	Ti%-S	V ppm-S	Y ppm-S	Yb ppm-S	Zn ppm-S	Zr ppm-S	Lab. No.
				Claystones--continued					
K51500CT	<4.6	280	.59	120	37	4.3	100	380	215,159
K52000CT	<4.6	240	.32	82	24	3.2	99	270	215,147
K5200XCT	<4.6	250	.40	98	27	2.7	110	260	215,276
K90000CT	<4.6	240	.36	98	44	4.6	94	380	215,214
K90400CT	<4.6	280	.32	94	35	3.5	67	230	215,069
K9040XCT	<4.6	280	.76	130	52	4.9	89	410	215,154
K90800CT	<4.6	260	.27	65	26	2.8	110	280	215,062
K91210CT	<4.6	200	.48	120	53	5.1	84	360	215,136
K91600CT	<4.6	230	.39	100	25	3.1	59	320	215,246
K9160XCT	<4.6	220	.23	96	27	3.1	62	340	215,095

program publst terminated normally

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