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BEAR LODGE RARE EARTHS

CROOK COUNTY, WYO.

By F. D. Everett 1/

SUMMARY

The Bureau of Mines investigated occurrences of rare earths in the Bear Lodge Mountains of the Black Hills, Crook County, Wyo., during the summer months of 1950. Topographic mapping, diamond core drilling, and sampling were performed in three separate areas. The work was conducted as a function of the Missouri Basin Development Program.

Rare earth occurrences were discovered during 1949 with the aid of a Geiger counter, and many claims were soon located. The Telmor Engineering Corp. of Chicago, Ill., obtained a lease on the Climax group of claims and began a bulldozer trenching campaign.

The deposits occur in igneous rocks of the Bear Lodge uplift. Rocks in the areas investigated consist principally of altered and brecciated syenite and trachyte porphyries.

Ten holes aggregating 844 feet were diamond drilled by the Bureau of Mines and core and sludge samples analyzed.

Microscopic studies of samples revealed that no rare earth minerals can be separated or identified and the rare earths are probably contained as absorbed salts in the clay or iron oxides.

Approximately 4,000 tons of material containing 3.2 percent rare earth oxides is indicated for Climax No. 8 claim and 40,000

1/ Mining engineer, Mining Division, Colorado Branch, Denver, Colorado.

tons of 1.46 percent material for Climax No. 10 claim. There are other occurrences of rare earths in the general vicinity, but the claim owners are waiting to see what degree of success the Telmor Engineering Corp. will experience with the Climax claims.

The deposits can be mined cheaply by open pit methods, however, it is not expected that the material can be economically concentrated.

No immediate production is anticipated from the low-grade Bear Lodge deposits, but increasing demand, current price trend, and uncertainty of foreign supply will stimulate a continued interest.

About 75 gallons of water per minute which probably could be developed in the vicinity of the deposits will be sufficient for a 100-ton a day mining and milling operation. A 100-ton per 24-hour day beneficiation plant would require electric facilities for approximately 150-kilowatt demand load.

INTRODUCTION

Rare earth oxide deposits were discovered in 1949 in the Bear Lodge Mountains near Sundance, Crook County, Wyo. The deposits, which are somewhat radioactive, were located with the aid of Geiger counters.

The rare earths comprise a group of 15 elements having the same valence properties and atomic numbers ranging between 57 and 71 on the chemical periodic table. Element No. 21, scandium, and No. 39, yttrium, also belong in this group. The element thorium is usually associated with the rare earth minerals.

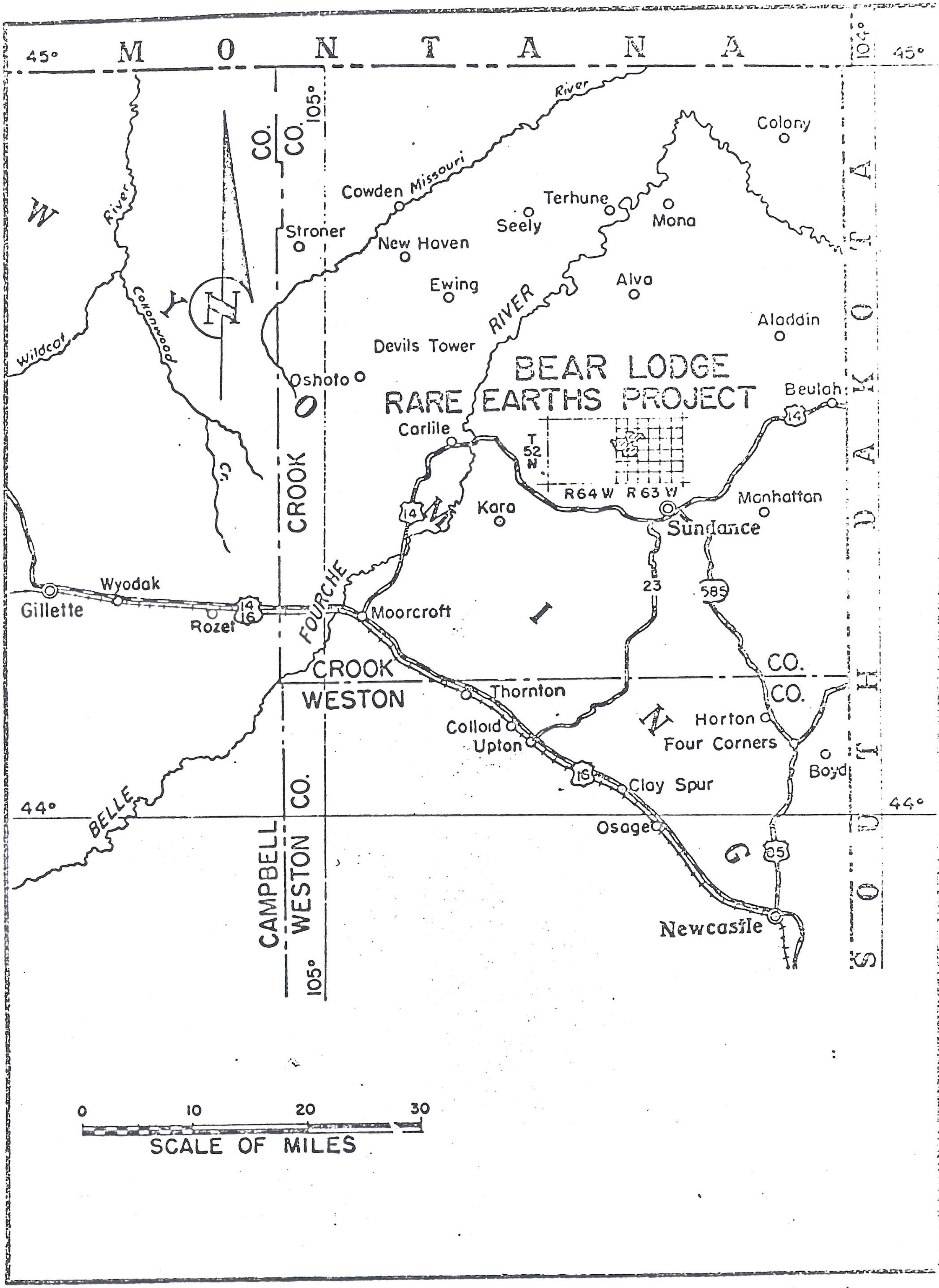

Figure 1.- Location map, Bear Lodge rare earth deposits, Crook County; Wyoming.

Table 1.--Rare Earth Elements

Element	Symbol	Atomic No.	Atomic Weight
Lanthanum	La	57	138.92
Cerium	Ce	58	140.13
Praseodymium	Pr	59	140.92
Neodymium	Nd	60	144.27
(Element 61)		61	?
Samarium	Sm	62	150.43
Europium	Eu	63	152.0
Gadolinium	Gd	64	157.3
Terbium	Tb	65	159.2
Dysprosium	Dy	66	162.46
Holmium	Ho	67	163.5
Erbium	Er	68	167.64
Thulium	Tm	69	169.4
Ytterbium	Yb	70	173.04
Lutecium	Lu	71	175.0

The term "rare earths" denotes the oxides but it is commonly used in referring to the elements themselves. These are among the least familiar of the 92 known elements. Cerium is the most abundant of the rare-earths and is the most important in commercial applications followed by praseodymium, neodymium, and lanthanum.

The rare earths are not as rare as the name implies; they form a larger percentage of the earth's crust than copper, lead, or zinc, but are not concentrated in large deposits. Some of the rare earth minerals are radioactive. Uranium and thorium minerals usually are associated with rare earths.

The only commercial source of rare earths is the mineral monazite, which has been recovered from beach sand deposits in North Carolina, South Carolina, Florida, and in placer deposits of Idaho. The present commercial production is derived from beach deposits in Brazil and India. Additional information on rare earths and monazite can be obtained from Bureau of Mines Information Circulars 6847 and 7233.2/

ACKNOWLEDGMENTS

A. J. Katches was the first to investigate the possibilities of the Bear Lodge rare earth deposits. Much of the preliminary work for the project was facilitated by Mr. Katches' knowledge of the area. Bulldozer service for preparing drill sites and constructing roads and water reservoirs was furnished without cost to the Government.

H. E. Kremmers, chemical engineer for Lindsay Light & Chemical Co., supplied helpful economic and utilization information.

S. R. Wilson, chief, Utah-Wyoming Branch, Mining Division, Region IV, supervised the work.

The results of this investigation will be published as a Bureau of Mines Report of Investigations.

HISTORY AND PROPERTY OWNERSHIP

Charles A. Baker and Francis Michaud discovered that certain rocks in the Bear Lodge Mountains are radioactive. During the summer of 1949, A. J. Katches submitted radioactive samples to the Bureau of Mines, Intermountain Experiment Station, at Salt Lake City, Utah, where the presence of rare earth oxides was determined.

2/ Petar, Alice V., The Rare Earths: Bureau of Mines Information Circular 6847, 1935.
Honk, Lawrence G., Monazite Sand: Bureau of Mines Information Circular 7233, 1943.

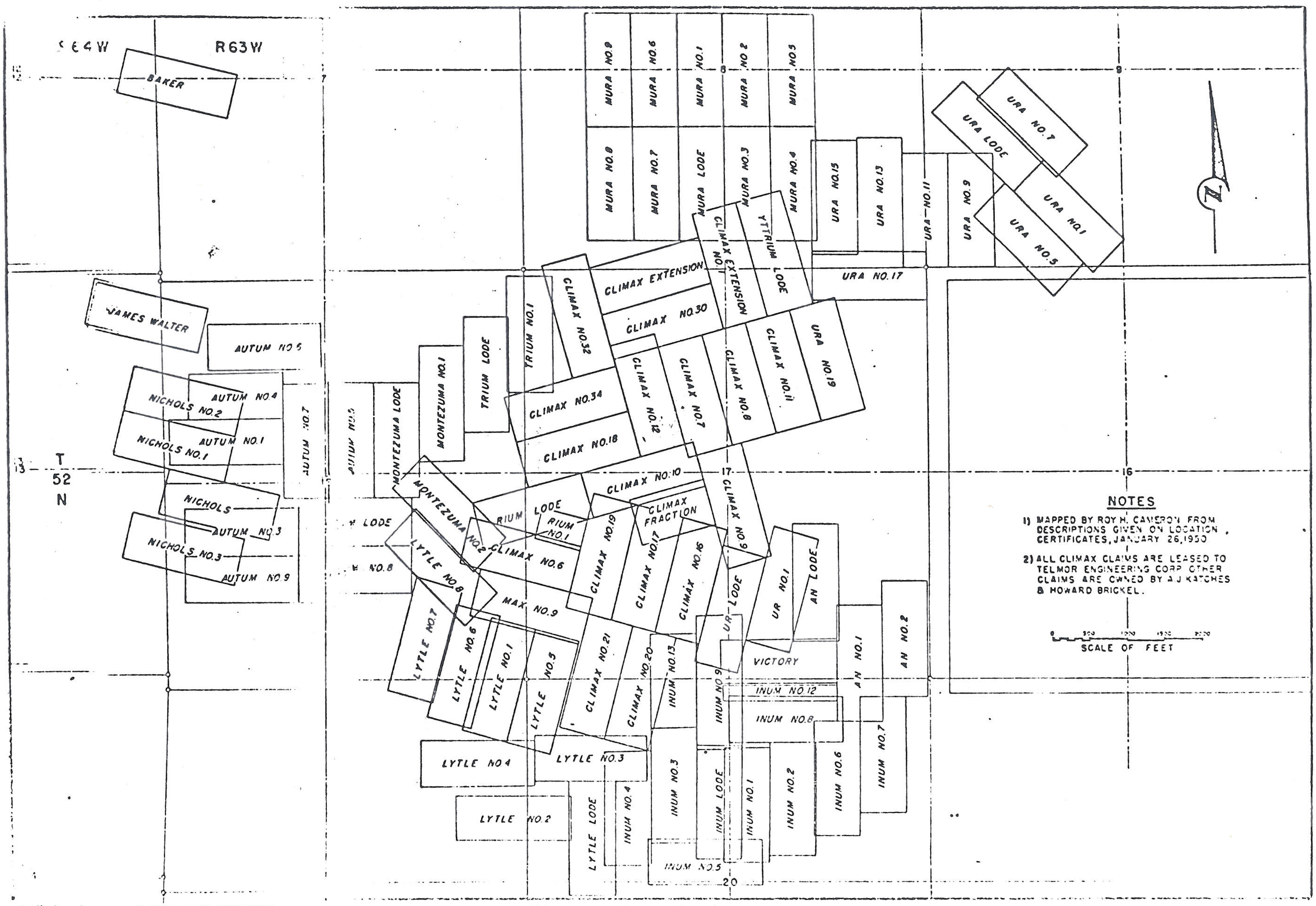

Figure 2. - Claim map.

Charles A. Baker, Andy Williamson, Howard Brickel, R. H. Nichols, Francis Michaud, and Tena E. Wright located the Climax group of claims which was subsequently leased to the Telmor Engineering Corp. of Chicago, Ill. Howard Brickel and A. J. Katches of Rapid City, South Dakota, located approximately 57 claims consisting of the Inum, Mura, Autum, Lytle, Rium, An, Montezuma, Trium, Ur, and Ura groups (figure 2) and leased school section (16) in T. 52 N., R. 63 W. Charles A. Baker and associates have located additional claims known as the Homefire group. Several local inhabitants also have located claims.

Development in the area consists of bulldozing trenches on some of the Climax and Inum claims by the Telmor Engineering Corp. and the Brickel-Katches partnership.

There has been no production from the deposits.

LOCATION AND PHYSICAL FEATURES

The rare earth deposits are in the Bear Lodge Mountains of the Black Hills, approximately 9 miles by dirt road north of Sundance, the county seat of Crook County, Wyo. Bureau of Mines investigation was conducted on Climax Nos. 8 and 10 claims, and Inum Nos. 1 and 2 claims in secs. 17 and 19, T. 52 N., R. 63 W., 6th P. M. These claims are northeast of Warren Peaks.

The Black Hills consist of a dome-shaped group of mountains in northeastern Wyoming and western South Dakota rising several hundred feet above the plains as a result of regional uplifting and subsequent erosion. The area is roughly 100 miles long and 50 miles wide.

Precipitation is abundant and most of the slopes are heavily covered with pinon trees and green vegetation. Numerous small streams flow during the spring months. Winters are cold and severe, while summers are warm and mild. Ranching, wheat farming, and lumbering are the main industries. Gold is mined from the famous Homestake mine at Lead, S. Dak. Rapid City, S. Dak., is the largest community in the Black Hills region.

Labor and common supplies can be obtained at Sundance. The nearest railroad shipping facilities are at Upton, on the Chicago, Burlington, & Quincy line, 28 miles south of Sundance.

DESCRIPTION OF THE DEPOSITS

The deposits occur in the igneous rocks of the Bear Lodge uplift. A series of gradual to steeply dipping sedimentary rocks ranging from Middle Cambrian to Quaternary can be observed in outcrops approaching the igneous intrusion. According to Darton[3/] the original uplift was caused by a pre-Cambrian granitic intrusion. Several varieties of igneous rocks have intruded the sedimentary rocks at different horizons probably during the Tertiary period. The principal laccolithic uplift and most of the associated smaller masses about the flanks of the uplift consist of syenite porphyry. However, a considerable variation can be found in the Bear Lodge porphyries and monzonitic and trachytic types. The rocks are usually altered and are colored in various shades of red, yellow, or gray.

The rocks observed in the areas investigated consist of: (1) highly altered syenite porphyry with irregular amounts of

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3/ Darton, N. H., Sundance Folio, U. S. Geological Survey Geologic Atlas, 1905.

yellow, soft, earthy clay with some black manganese oxide on the Climax No. 8 claim; (2) red-stained syenite porphyry with orthoclase phenocrysts varying in size from very small to over one-quarter of an inch on the Climax No. 10 claim; and (3) fine-grained, white to gray altered trachyte porphyry on the Inum Nos. 1 and 2 claims.

The rocks are covered by heavy overburden except at occasional exposures on the well rounded ridges, and in newly bulldozed trenches or old prospect holes. Cores from the diamond drill holes on the Climax claims show considerable fracturing and brecciation with some soft seams of manganese and iron oxide. Cores from the drill hole on the Inum No. 2 claim display alteration and leaching near the surface with an occasional veinlet of limonite. A deep bulldozer trench on the Inum No. 1 claim shows the igneous rocks to be jointed, dipping 30°, and a 6-inch seam in the center of the cut is filled with iron oxide.

In the areas investigated, radioactivity increased in the iron and manganese mineralized zones. However, some of the old gold and copper prospect dumps within the general area did not affect the field Geiger counter.

WORK DONE BY THE BUREAU OF MINES

The investigation by the Bureau of Mines included topographic mapping,[4] diamond core drilling and sampling.

Ten holes totaling 844 feet were diamond drilled. Dry drive samples were taken in zones containing rocks too soft for coring. Cores were logged and sections displaying radio-

4/ Young, W. E., and Thurber, H. K., mining engineers, Bureau of Mines, Salt Lake City, Utah.

activity evenly split into two portions; one used for analytical purposes and the other placed in the core library at Salt Lake City. A survey of the radioactivity in the drilling areas was made with a Geiger counter using a 25-foot grid system laid out with Brunton compass and cloth tape. The survey is illustrated by sensitivity contours on the topographic maps (figures 3, 4, and 5).

Four holes were drilled in the center of zones having a relatively high Geiger counter reaction. The remaining six shallow holes were drilled near the limits of the surface radioactive zones. Hole No. 4 was drilled to intersect at depth a 6-inch seam of iron oxide which gave a relatively strong reaction by the Geiger counter.

The results of the investigation are included in tables 1, 2, and 3 in the appendix.

ORE RESERVES

The rare earth values appear to be higher in the soft and altered earthy material. Some of the highly brecciated zones with fractures and cracks filled with iron and manganese oxides contain varying amounts of rare earths. Hole 2 contained a soft zone of brown earthy material between 126 and 150 feet, averaging 3.95 percent rare earth oxides. A similar zone in hole 1 assayed very low in rare earths. Generally, the higher grades appear to be near the surface and the deposits are probably the result of erosion and subsequent mechanical and chemical deposition in fractures and other channelways.

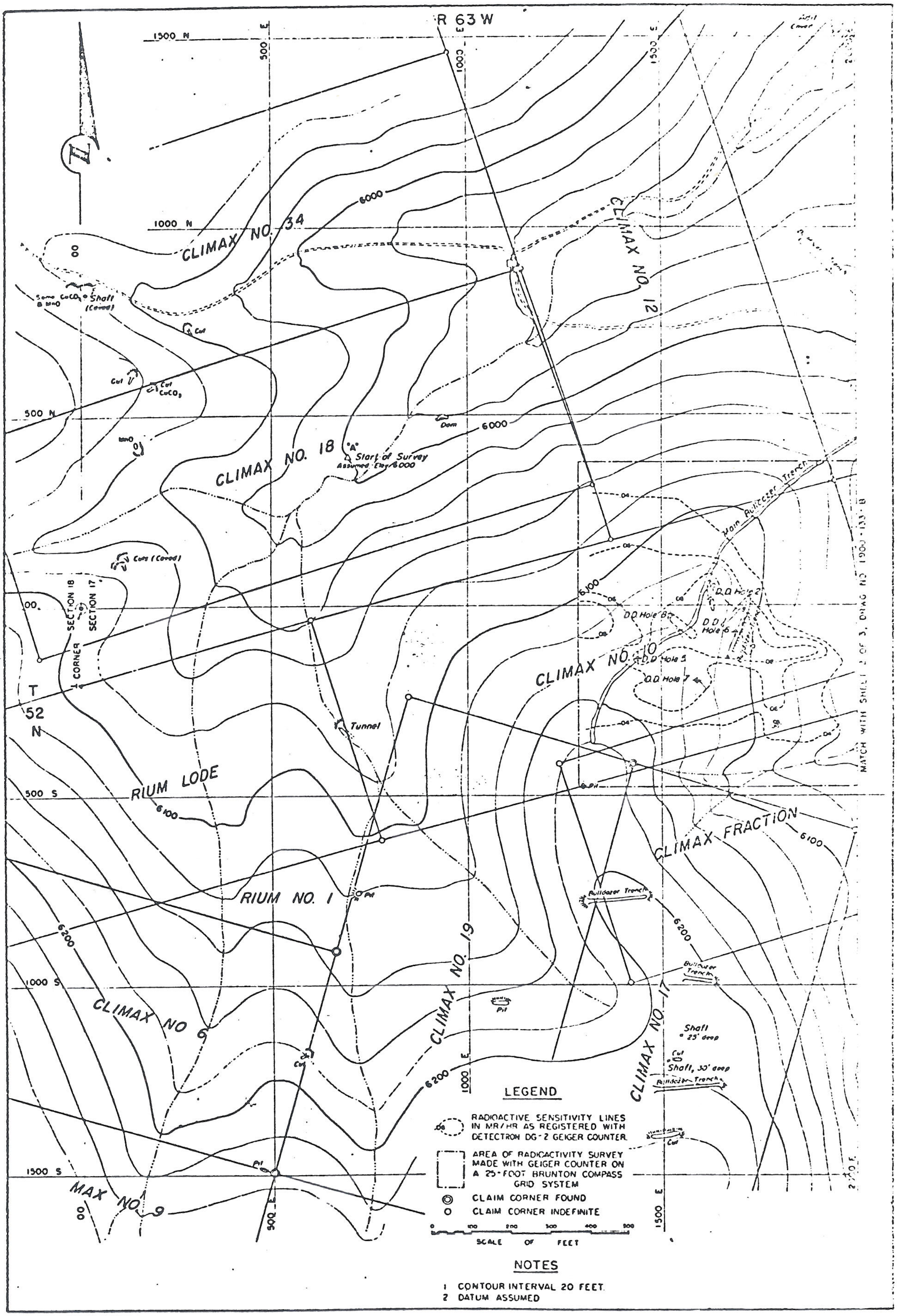

Figure 3.— Topographic map showing locations of diamond drill holes. Sheet 1 of 3.

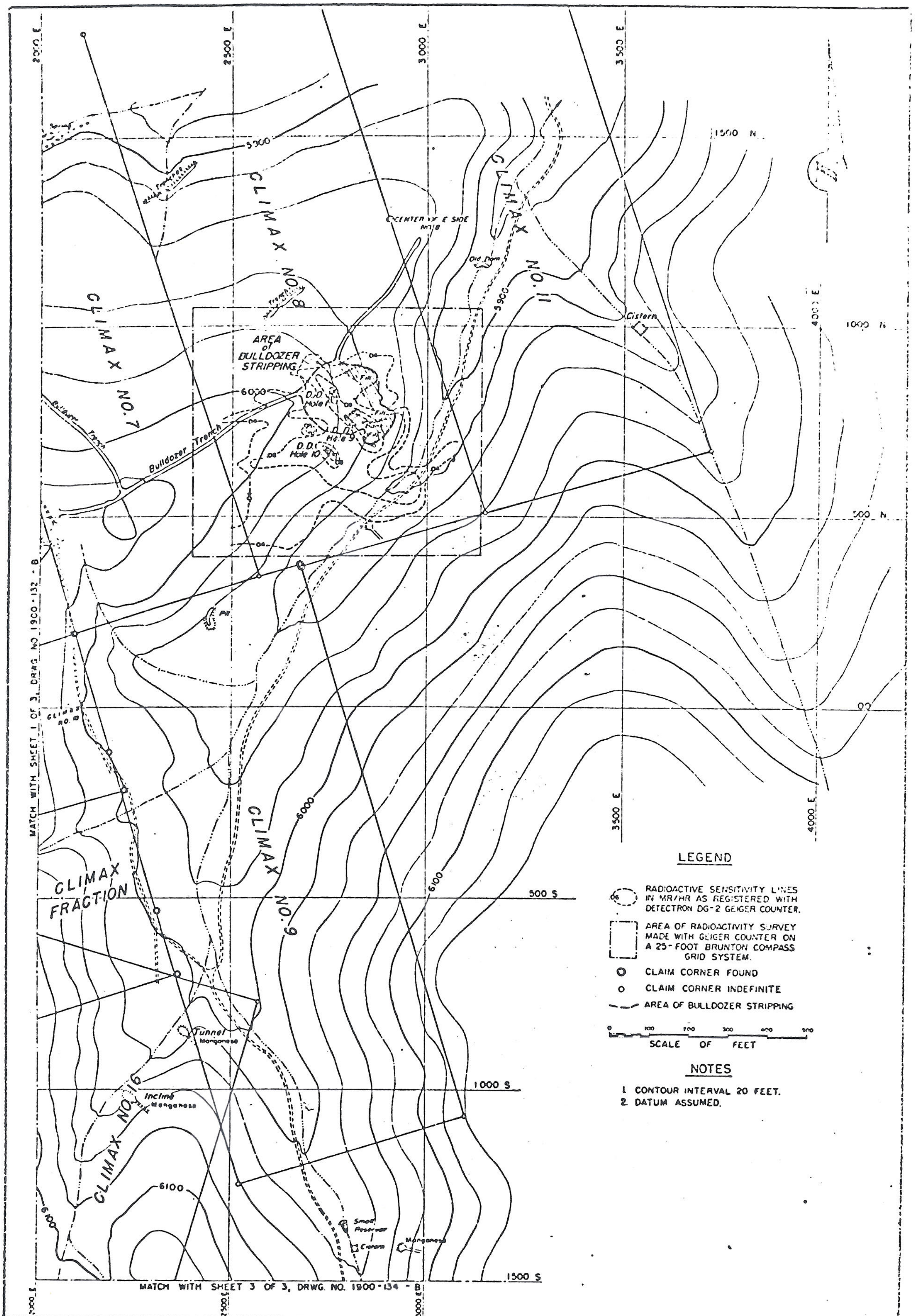

Figure 4.—Topographic map showing locations of diamond drill holes. Sheet 2 of 3.

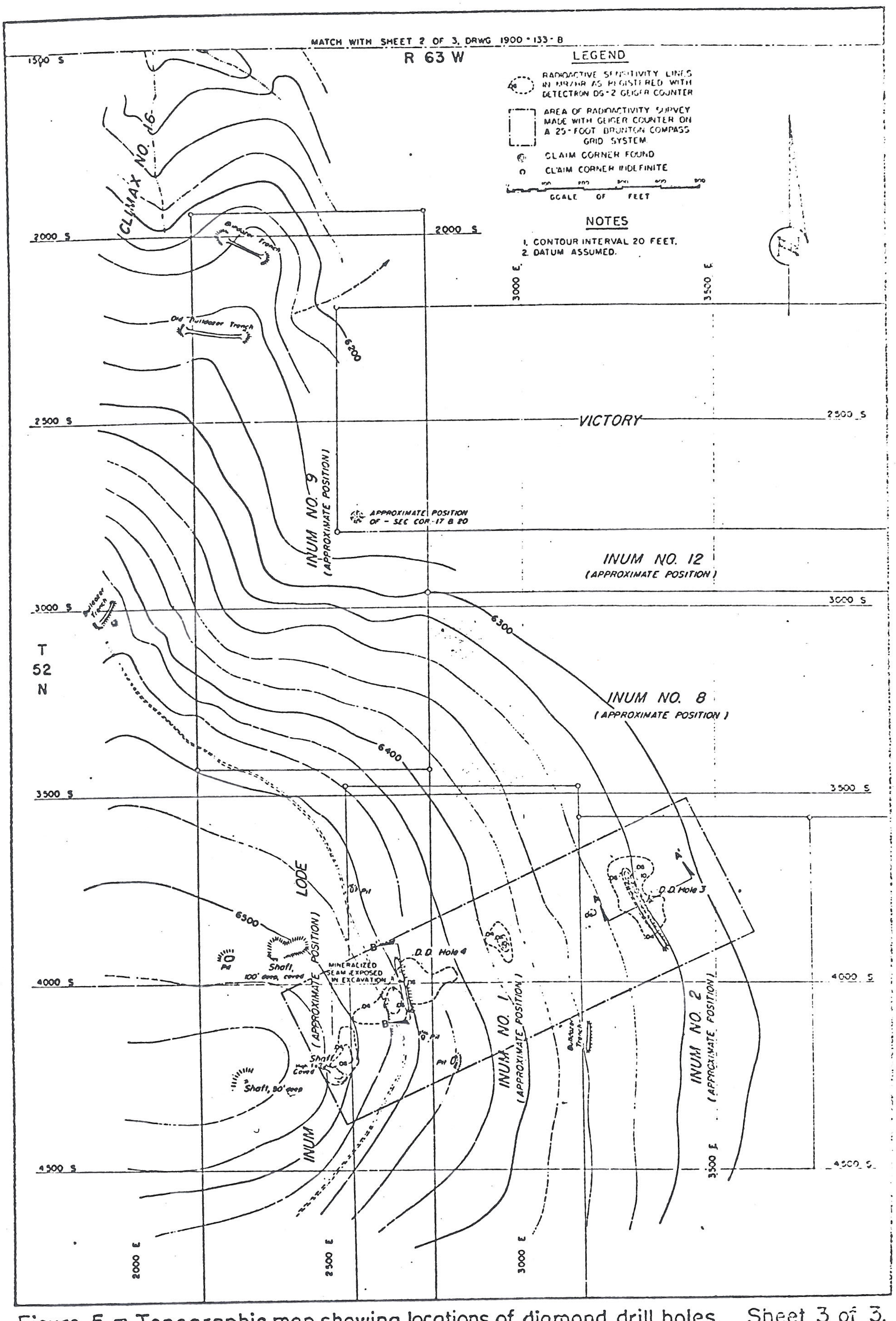

Figure 5.– Topographic map showing locations of diamond drill holes. Sheet 3 of 3.

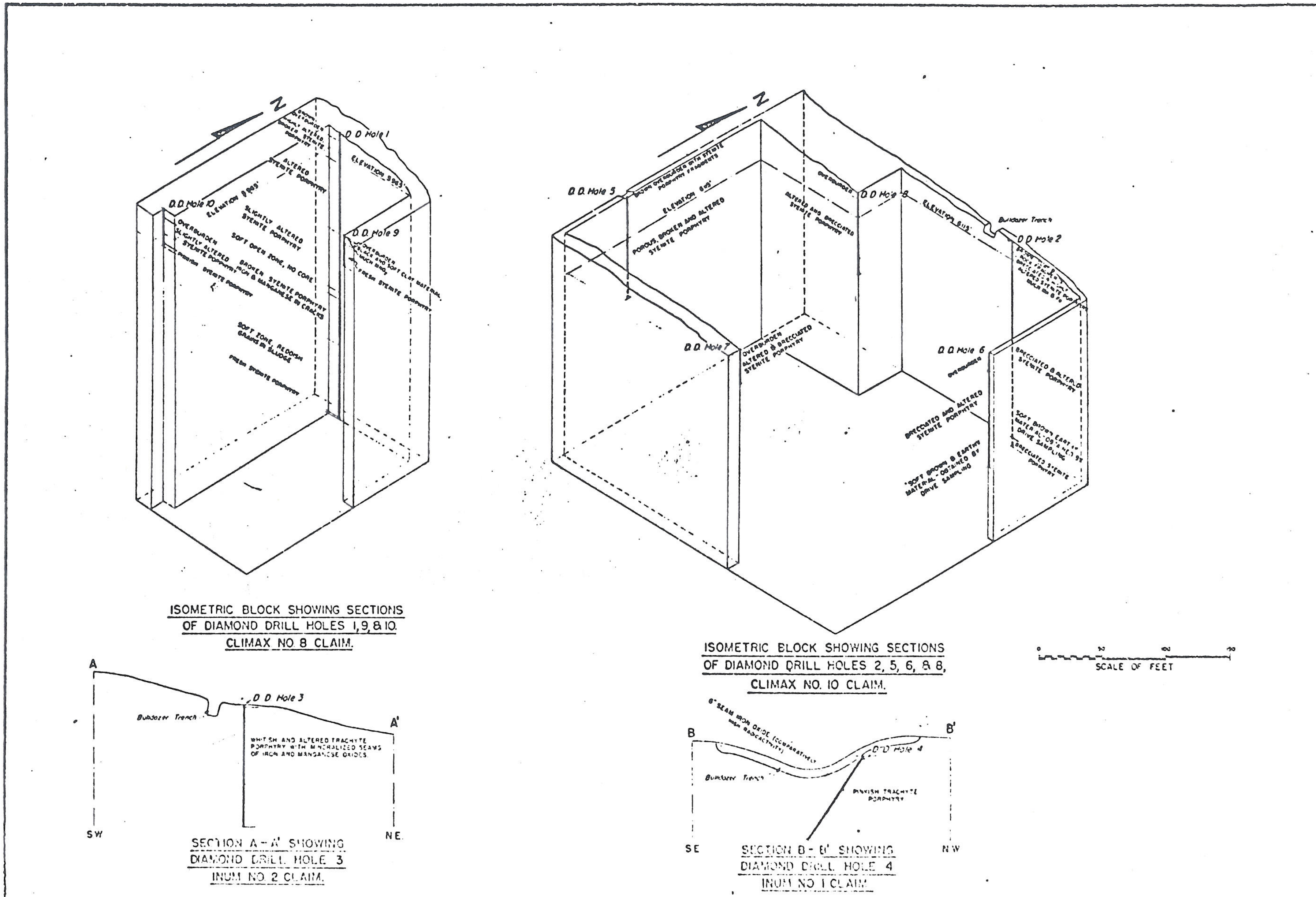

Figure 6. - Diamond drill hole sections.

Core and sludge sample results from holes 1, 9, and 10, on the Climax No. 8 claim indicate 4,000 tons of material containing 3.2 percent rare earth oxides extending to an average depth of 10.6 feet. Sample analyses from holes 2, 6, and 8, on Climax No. 10 claim indicate 40,000 tons of material containing 1.46 percent rare earth oxides for depths ranging from 56 to 139 feet.5/

Other occurrences of rare earths in the general vicinity are known but the various claim owners, before doing any extensive development work, are awaiting the success of the Telmor Engineering Corp. with the Climax claims.

The deposits can be mined economically by open pit methods. Bulldozers can be used for stripping overburden and maintaining roads and a small loading shovel can dig and load the material into trucks. Near the surface no blasting will be necessary as the material is fractured and broken but with increased depth wagon drills or a small churn drill can be utilized for blasting. It is estimated that the mining costs for a 200 to 300 tons a day operation will range between $2.00 and $3.00 per ton.

METALLURGICAL TESTS

The Telmor Engineering Corp. has submitted samples to commercial ore testing laboratories which have not as yet succeeded in making an economical concentrate. The company has indicated that these tests will be continued.

Microscopic tests on samples submitted to the Bureau of Mines laboratory are summarized in the following statement.6/

5/ A factor of 13 cubic feet per ton was used in the calculations.

6/ Gibbs, Harold L., microscopist, Bureau of Mines, Salt Lake City, Utah.

"Feldspar and clay with varying amounts of dark brown staining make up most of these samples. Some of the most radioactive material is a white bentonitic clay of the montmorillonite group having an index of refraction of $\gamma = 1.51$. Other than this clay it has not been possible to separate or identify any rare earth minerals. Because of the highly altered condition or those portions of the rocks which contain a concentration of the rare earths, the rare earths are probably present as absorbed salts on the clays and as mixtures of oxides with iron and other impurities."

The inability to separate or identify the rare earth minerals microscopically indicates that the beneficiation of the rare earths from the Bear Lodge deposits will be difficult to accomplish.

USES FOR RARE EARTHS

Prior to 1920 the principal value of monazite was for its thorium content which in the form of thorium nitrate was used in making incandescent gas mantles. Since this type of lighting has been replaced by electric lights most of the monazite is valued for its cerium and other rare earth content. The Federal Atomic Energy Commission placed production and consumption controls over monazite in 1947 because of the contained thorium and other radioactive compounds. Yost, Russel, and Garner7/ have reported on the radioactive and other properties of the rare earths.

7/ Yost, Russel, and Garner, The Rare Earth Elements and Their Compounds: John Wiley & Sons, 1947.

About one-fourth of the rare earths are used to make misch metal or mixed metal which, when combined with iron and aluminum, is a pyrophoric alloy that when rasped with steel will produce a spark hot enough to ignite vapors of light gas. Flints in cigarette lighters, carbide lamps and welding torch lighters are made with this alloy. Much of the rare earth consumption is utilized in cored carbon electrodes for arc lights, search lights, and movie projectors. Rare earth chlorides and acetates are used in textiles as waterproofing agents and mildew preventatives.

Cerium is the most abundant and widely used of all the rare earth elements,8/ and it accounts for about 50 percent of the total rare earth content of monazite.

Cerium, in combination with sodium nitrate and other physical decolorizers, is used as a chemical decolorizer for glass. Cerium acts as an oxygen carrier to oxidize iron so that the resulting glass is stable toward colorization and reheating.

A specially prepared ceric oxide has proved to be a superior substitute for rouge in polishing optical glass and spectacle lenses.

A potential use for ceric oxide is an opacifier in vitreous enamels.

INDUSTRIAL POSSIBILITIES

The utilization of the Bear Lodge rare earth deposits is dependent on finding an amenable concentrating method. The Telmor Engineering Corp. is having mineral dressing tests

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8/ Kremmer, H. E., Cerium: Kirk and Othmer Encyclopedia of Chemical Technology, vol. 3, p. 634.

conducted by specialists on samples from the deposits. The Lindsay Light & Chemical Co., one of the importers of Brazilian monazite, is cooperating by analyzing samples and providing technical assistance.

According to Dr. H. E. Kremmers,[9] the present demand for rare earths is considerably greater than the production. Many possible rare earth consumers have been discouraged and research has been retarded because of the insufficient supply. However, a search for domestic resources has been stimulated and these least familiar of the known elements, which have been regarded by many as only a laboratory curiosity, are becoming more widely known by mineral investigators as well as consumers.

There were 3,686 and 2,397 tons of monazite concentrates imported to the United States in 1946 and 1947, respectively. This supply came principally from Brazil. Monazite concentrate prices since 1946 are listed in table 2.

Table 2.--Prices for monazite concentrates containing 65 percent rare earth oxides, c.i.f. Atlantic ports[1]

Period	Dollars per ton	Cents per pound
January-November 1946	60	
December 1946	65	
January 1947	100	
February-April 1947	120	
May 1947	80-120	
June 1947	100-125	
July-August 1947	135-145	
September 1947-March 1948	140-150	
April-October 1948	175-185	
November 1948	170	
December 1948-February 1949	200	

9/ Dr. H. E. Kremmers, chief chemist, Lindsay Light & Chemical Co.

Table 2.--Prices for monazite concentrates containing 65 percent rare earth oxides, c.i.f. Atlantic ports[1]--(Cont'd)

Period	Dollars per ton	Cents per pound
March-May 1949	230	
June-December 1949	245	
January-March 1950		13-15
April-May 1950		15-16
June-August 1950		16
September-December 1950		16-1/2

1/ Engineering & Mining Journal Metal and Mineral Markets, 1946-1950.

No immediate production is expected from the low-grade Bear Lodge deposits, but increasing demand, current price trend, and uncertainty of foreign supply will encourage investigations of all domestic prospects. The deposits might be a source for atomic fissionable ore. It is very probable that the deposits investigated and other rare earth occurrences in the Bear Lodge area will be utilized.

WATER AND POWER REQUIREMENTS

The water for a mining operation could easily be developed near the deposits. Any mining operation probably will require less than 500 gallons for a 100- to 150-ton a day production.

A milling operation for a 100-ton per 24-hour plant, which consists of grinding and leaching or flotation, would require about 75 gallons of water per minute. This amount of water probably could be developed in the proximity of the deposits.

The mining operation would probably utilize gasoline or Diesel energy. The milling operation for 100 tons per 3-shift day would require about 200 horse power or 150 kilowatts of demand load. Power facilities are available at the town of Sundance, but if a mill were placed near the deposits a 4- to 5-mile power line must be constructed.

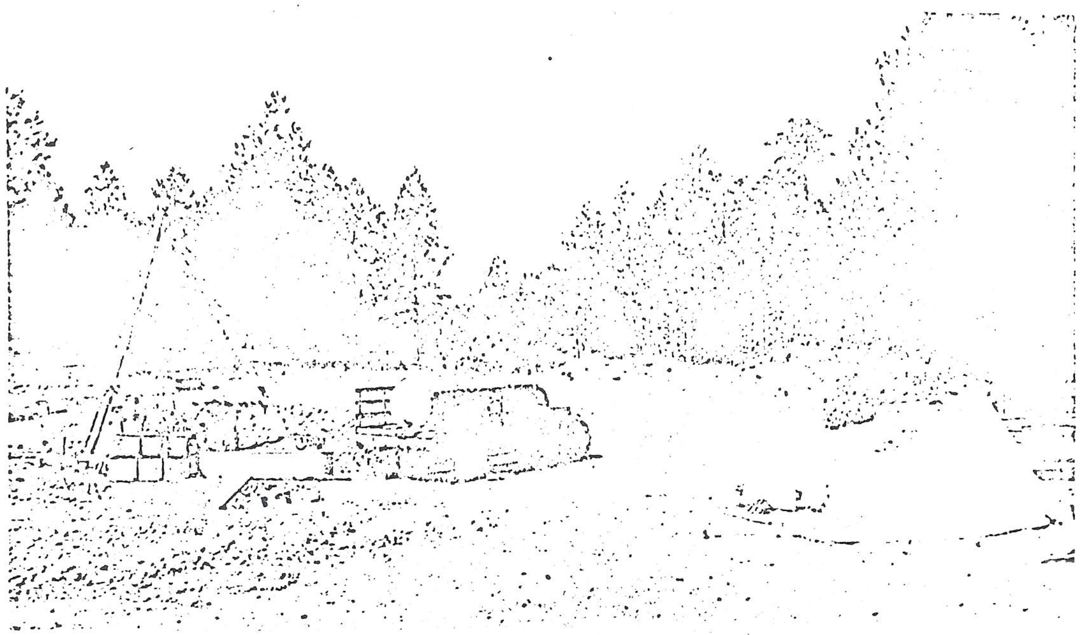

Figure 7. - Bulldozed area, Climax No. 8 claim.

Figure 8. - Diamond drilling setup, hole 4.

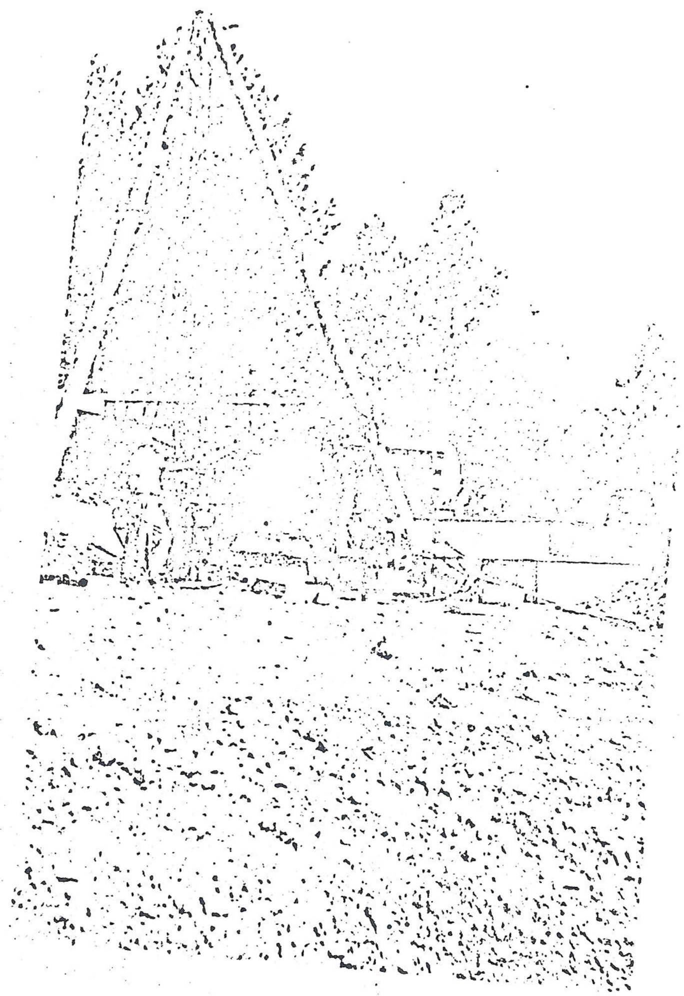

Figure 9. - Diamond drilling setup, hole 1.

APPENDIX

Table 1.--Diamond drill hole data

Hole	Coordinates	Elevation	Dip	Depth	Claim No.
1	N. 810, E. 2765	5980	Vertical	220.1	Climax 8
2	N. 15, E. 1625	6125	do.	152.0	Climax 10
3	S.3785, E. 3330	6315	do.	93.5	Inum 2
4	S.3965, E. 2680	6450	55°	73.0	Inum 1
5	S. 145, E. 1435	6145	Vertical	76.0	Climax 10
6	S. 65, E. 1685	6115	do.	87.2	do.
7	S. 200, E. 1590	6135	do.	26.0	do.
8	S. 25, E. 1525	6135	do.	63.0	do.
9	N. 750, E. 2830	5965	do.	23.5	Climax 8
10	N. 670, E. 2745	5985	do.	29.0	do.

Table 2.--Diamond drill hole logs

Hole	Footage From	Footage To	Geiger counter reaction, *Mr/hr.	Description
1	0	5.7	.05	Brown, earthy, and claylike overburden mixed with altered syenite porphyry.
	5.7	15	.05	Brown, altered, and broken syenite porphyry; numerous cracks filled with iron and manganese oxides.
	15	72.5	.04	Altered syenite porphyry; cracks show rusty stains.
	72.5	114	.03	Slightly altered, greenish-white syenite porphyry with iron and manganese oxides in narrow fractures.
	114	162.5	.04	Slightly altered, bluish syenite porphyry; numerous oxide-filled fractures.
	162.5	220	.03	Soft and sandy red grains in sludge; very few rock fragments.
	220	220.1	.02	Hard, greenish syenite porphyry.
2	0	2	.05	Black earth
	2	9	.08	Brown clay and syenite porphyry fragments.
	9	116	.05	Highly altered and brecciated syenite porphyry; iron and manganese oxide stains in pores and fractures.

Hole	Footage From	To	Geiger counter reaction, *Mr/hr.	Description
2	116	131.5	.04	Altered syenite porphyry.
	131.5	152	.10	(Drive sample) Soft, brown, earthy material.
	152	152.8	.04	Solid, altered syenite porphyry.
3	0	1	.05	Black earth.
	1	2	.05	Brown overburden.
	2	6.5	.05	Whitish trachyte porphyry.
	6.5	93.5	.02	do.
4	0	2	.03	Brown overburden.
	2	28	.03	Whitish, altered trachyte porphyry.
	28	28.5	.04	Slightly more alteration.
	28.5	46	.03	Whitish, trachyte porphyry.
	46	47	.03	Little manganese mineralization.
	47	73	.03	Whitish trachyte porphyry.
5	0	4	.05	Brown overburden.
	4	7.5	.05	Broken and altered syenite porphyry fragments.
	7.5	76	.04	Slightly altered syenite porphyry.
6	0	7	.05	Brown overburden.
	7	63	.04	Slightly altered syenite porphyry.
	63	87	.10	Dark brownish material, soft and earthy; obtained by drive sampling.
7	0	6	.06	Black and brown overburden.
	6	9	.06	Fragments of altered syenite porphyry.
	9	26	.03	Slightly altered syenite porphyry.
8	0	4	.06	Black earth.
	4	6	.06	Brown overburden and syenite porphyry fragments.
	6	13	.04	Slightly altered syenite porphyry.
	13	18	.05	Highly altered syenite porphyry.
	18	20	.10	Black, grainy manganese oxide.
	20	56	.05	Altered syenite porphyry.
	56	63	.05	Soft, earthy material obtained by drive sampling.
9	0	4	.10	Brown overburden.
	4	5.5	.15	Black manganese oxide, very soft.
	5.5	7.5	.10	Black and brown, soft earthy material.
	7.5	23.5	.03	Fresh syenite porphyry.

Hole	Footage From	To	Geiger counter reaction,*Mr/hr.	Description
10	0	6	.08	Brown overburden and fragments of syenite porphyry.
	6	29	.03	Slightly altered syenite porphyry.

*Detectron, Model DG-2, Geiger counter.

Table 3.--Analyses of diamond drill hole samples

Hole	Footage From	To	Percent Feet	U_3O_8	ThO_2	Ce	Rare earth oxides	Sample description
1	0	3.5	3.5	0.008	-	0.21	0.24	Core
	3.5	5.7	2.2	.01	-	.26	.47	do.
	5.7	10	4.3	.012	<0.05	.55	1.46	do.
	10	15	5	.032	.12	3.24	4.82	do.
	21.5	23	1.5	.006	-	.16	.19	do.
	40	45	5	.014	-	.29	.91	do.
	51	56.9	5.9	.005	-	.01	.02	do.
	137	142	5	.005	-	<.01	.01	do.
	169	177	8	.005	-	<.01	<.01	Sludge
	185	195	10	.005	-	<.01	<.01	do.
2	0	5	5	.009	<.01	.35	.86	Core
	5	10	5	.017	<.01	.69	1.23	do.
	10	16	6	.018	<.01	1.03	3.47	do.
	16	19.5	3.5	.019	<.01	1.3	4.31	do.
	19.5	24	4.5	.018	<.01	1.39	4.68	do.
	24	27.5	3.5	.018	<.01	.79	2.77	do.
	27.5	32	4.5	.015	-	-	.09	do.
	27.5	32	4.5	.02	-	.44	1.50	Sludge
	32	37	5	.015	<.01	.26	.74	Core
	37	43	6	.015	-	.64	2.15	do.
	43	47.5	4.5	.009	<.01	.16	.43	do.
	47.5	52	4.5	.01	-	-	.35	do.
	52	53	1	.009	<.01	.04	.06	do.
	52	55	4.5	.03	-	.64	2.2	Sludge
	55	61	6	.02	-	.28	1.2	Core
	55	61	6	.025	-	.37	1.4	Sludge
	61	67	6	.025	<.01	.23	.85	Core
	61	67	6	.03	-	.4	1.45	Sludge
	67	76	9	.01	-	-	.4	Core
	76	79	3	.008	<.01	.05	.16	do.
	76	82	6	.015	-	-	.85	Sludge

Hole	Footage			Percent				Sample description
	From	To	Feet	U_3O_8	ThO_2	Ce	Rare earth oxides	
2	79	85	6	.01	-	-	.4	Core
	85	88	3	.016	< .01	.25	.88	do.
	88	92	9	.01	-	-	.65	do.
	88	92	9	.015	-	.33	.95	Sludge
	92	97	5	.009	< .01	.09	.13	Core
	97	101	5	.015	-	-	.55	do.
	97	101	5	.01	-	-	.65	Sludge
	101	106	5	.008	< .01	.14	.49	Core
	110	116	6	.011	< .01	.28	.68	do.
	116	121	5	.015	-	-	.95	do.
	116	121	5	.02	-	.47	1.75	Sludge
	121.5	126.5	5	.008	< .01	.12	.42	Core
	126.5	131.5	5	.025	-	.77	2.55	Sludge
	131.5	136.5	5	.035	< .01	1.36	3.76	Core
	139.5	142	2.5	.049	< .01	2.78	7.24	do.
	146	149.5	3.5	.021	< .01	1.31	3.88	do.
3	0	5.5	5.5	0.005	<0.01	0.01	0.01	Core
	5.5	8.6	3.1	.002	< .01	< .01	< .01	do.
	8.6	12	3.4	.005	< .01	< .01	< .01	do.
	12	16	4	.025	< .01	.77	2.12	do.
	16	22.5	6.5	.01	-	.4	1.3	do.
	22.5	23.5	1	.015	-	.39	1.25	Sludge
	66	72	6	.005	-	-	< .05	Core
	66	72	6	.005	-	-	< .05	Sludge
4	0	4	4	.007	< .01	.08	.09	Core
	4	8.5	4.5	.004	< .01	< .01	< .01	do.
	8.5	13	4.5	.003	< .01	< .01	.03	do.
	13	18	5	.005	-	-	< .05	do.
	18	21	3	.005	-	-	.03	do.
	21	28	7	.005	-	-	< .05	do.
	28	32	4	.005	-	-	< .05	do.
	32	35	3	.005	-	-	< .05	do.
	35	43	8	.005	-	-	.05	do.
	43	45	2	.006	-	-	.9	do.
	45	49	4	.008	-	-	.5	do.
	49	52	3	.005	-	-	.15	do.
	52	56	4	.005	-	-	.05	do.
	56	61.5	5.5	.005	-	-	.4	do.
	61.5	64.8	3.3	.005	-	-	.05	do.
	64.8	73	8.2	.005	-	-	.05	do.
5	0	5	5	.018	< .01	.3	.81	do.
	5	7.5	2.5	.008	< .01	.14	.48	do.
	7.5	11	3.5	.012	< .01	.18	.6	do.
	11	16	5	.012	< .01	.06	.96	do.
	11	16	5	.013	< .01	.47	1.21	Sludge
	16	22.5	6.5	.027	< .01	.29	1.45	Core

Hole	Footage From	Footage To	Feet	U3O8 (Percent)	ThO2 (Percent)	Ce (Percent)	Rare earth oxides (Percent)	Sample description
5	16	22.5	6.5	.025	<.01	.46	1.43	Sludge
	22.5	26	3.5	.024	<.01	.67	2.34	Core
	26	30	4	.018	<.01	.4	.98	do.
	30	34	4	.018	<.01	.21	.75	do.
	34	36	2	.018	<.01	.5	1.0	do.
	36	41	5	.014	<.01	.17	.5	do.
	34	41	7	.021	<.01	.8	1.97	Sludge
	41	48.5	7.5	.016	<.01	.06	.28	Core
	48.5	51	2.5	.02	<.01	.07	.61	do.
	51	56	5	.018	<.01	.3	1.85	do.
	56	61	5	.008	<.01	<.01	<.01	do.
	56	61	5	.022	<.01	.13	.72	Sludge
	61	66	5	.025	<.01	.24	1.5	Core
	66	71	5	.013	<.01	.23	1.83	Sludge
	71	76	5	.014	<.01	.44	1.11	do.
6	0	2	2	.014	<.01	.03	.25	Core
	2	5	3	.027	<.01	.41	1.83	do.
	5	8.5	3.5	.015	<.01	.22	1.04	do.
	8.5	13	4.5	.01	<.01	.1	.48	do.
	13	19.5	6.5	.013	<.01	.12	.42	do.
	19.5	31	11.5	.011	<.01	.03	.09	do.
	23	28	5	.032	<.01	.48	1.59	Sludge
	31	36	5	.008	<.01	.11	.3	Core
	33.5	41.5	8	.008	<.01	.4	1.0	Sludge
	41.5	47	5.5	.013	<.01	.33	.76	do.
	47	52	5	.017	<.01	.46	1.73	do.
	52	54	2	.014	<.01	.35	.95	do.
	55	57	2	.015	<.01	.26	.7	do.
	59	63	4	.014	<.01	.34	1.28	do.
	63	67	4	.014	<.01	.24	.66	do.
	67	72.5	5.5	.016	<.01	.37	1.06	Core
	72.5	74	1.5	.019	<.01	.2	.42	do.
	74	78.5	4.5	.015	<.01	.35	1.01	do.
	78.5	80	1.5	.015	<.01	.55	1.62	do.
	80	86	6	.016	<.01	.53	1.42	do.
	86	87.2	1.2	.037	<.01	.51	1.73	do.
7	0	1	1	.008	<.01	.03	.11	do.
	1	3	2	.026	<.01	.17	.51	do.
	3	6	3	.014	<.01	.34	1.01	do.
	6	9	3	.019	<.01	.16	.52	do.
	9	13	4	.008	<.01	.13	.38	do.
	9	13	4	.013	<.01	.18	.67	Sludge
	13	18	5	.011	<.01	.15	.42	Core
	13	18	5	.009	<.01	.1	.24	Sludge
	18	23	5	.013	<.01	.32	.96	Core
	18	20	2	.025	<.01	<.01	<.01	Sludge

Hole	Footage From	Footage To	Feet	Percent U_3O_8	Percent ThO_2	Percent Ce	Percent Rare earth oxides	Sample description
7	23	26	3	0.012	<0.01	.16	.54	Core
	23	26	3	.017	< .01	.18	.57	Sludge
8	0	2	2	.036	< .01	1.06	3.56	Core
	2	4	2	.031	< .01	1.18	3.47	do.
	4	6.5	2.5	.012	< .01	.09	.28	do.
	5	7.8	2.8	.017	< .01	.35	1.07	Sludge
	6.5	8	1.5	.006	< .01	<.01	.03	Core
	8	10	2	.01	< .01	.04	.16	do.
	10	13	3	.021	< .01	.06	.11	do.
	10	12	2	.01	<.01	< .01	< .01	Sludge
	13	16	3	.013	< .01	.09	.32	Core
	16	24	8	.019	<.01	.36	.96	do.
	16	22	6	.02	<.01	.37	1.29	Sludge
	24	26	2	.024	< .01	1.24	5.64	Core
	26	30	4	.03	<.01	.36	1.59	Core
	26	30	4	.038	<.01	1.0	3.91	Core
	30	36	6	.018	<.01	.22	.79	Core
	30	36	6	.021	<.01	.7	1.87	Sludge
	36	41	5	.012	<.01	.09	.42	Core
	36	41	5	.02	<.01	.82	2.0	Sludge
	41	46	5	.012	<.01	.11	.31	Core
	41	46	5	.017	<.01	.42	1.22	Sludge
	46	50	4	.013	<.01	.11	.37	Core
	46	50	4	.02	<.01	.47	1.37	Sludge
	50	56	6	.015	<.01	.09	.33	Core
	50	56	6	.018	<.01	.55	1.46	Sludge
	56	60.5	4.5	.013	<.01	.19	.52	Core
	60.5	61.5	1	.01	<.01	.11	.44	do.
	61.5	63	1.5	.011	<.01	.1	.3	do.
	61.5	63	1.5	.011	<.01	.01	.1	Sludge
9	0	2	2	.026	<.01	.36	.42	Core
	2	4	2	.028	<.01	1.73	7.95	do.
	4	5.5	1.5	.028	<.01	2.55	10.95	do.
	5.5	7.5	2	.027	<.01	1.49	5.63	do.
	7.5	13	5.5	.018	<.01	.59	2.06	do.
	13	17.5	4.5	.007	<.01	.08	.37	do.
	17.5	20.5	3	.006	<.01	<.01	.03	do.
10	0	2	2	.021	<.01	1.61	2.65	do.
	2	4	2	.019	<.01	.92	1.92	do.
	4	6	2	.022	<.01	.85	3.24	do.
	6	12	6	.01	<.01	.5	1.67	do.
	12	18	6	.013	<.01	.11	.29	do.
	18	20	2	.007	<.01	.08	.25	do.
	20	26	6	.011	<.01	.08	.18	do.
	26	29	3	.011	<.01	.03	.05	do.