CRITICAL MINERALS IN THE FOX HILLS (CRETACEOUS), HELL CREEK (CRETACEOUS) AND LUDLOW (PALEOCENE) FORMATIONS IN NORTH DAKOTA

by

Levi D. Moxness, Edward C. Murphy, and Ned W. Kruger

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Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources
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On the cover: Geological Survey drone photograph of a Ludlow channel sandstone cutting down through the variegated beds to the contact with the underlying Hell Creek Formation. Measured sections 253, 260, and 256. The photograph was taken looking to the southeast.

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Abstract

Fox Hills, Hell Creek, and Ludlow strata were sampled and analyzed for critical mineral content in southwestern and south-central North Dakota. Sampling occurred in three main areas in southwestern North Dakota: an eight square mile (21 km^2) area where the Marmarth ash is exposed in Slope County, a four-square mile (10 km^2) area around Mud Buttes in Bowman County, and the 32-acre (13 ha) area around Sunset Butte in Bowman County. The study area in south-central North Dakota covers 2,400 square miles (6,200 km^2) encompassing portions of Morton, Sioux, and Emmons Counties. Twenty-six geologic sections were measured in these study areas and 261 rock samples were collected, of which 242 were analyzed. Roughly 64% of the analyzed rock samples came from the Ludlow Formation (154 samples), 34% from the Hell Creek (82), and 2% from the Fox Hills (6). Rare earth element concentrations in Hell Creek lignites and carbonaceous mudstones averaged 173 ppm. The lignites and carbonaceous mudstones from the Ludlow Fm. averaged significantly higher at 229 ppm REE, possibly due to their proximity to upland weathering surfaces. Only four of the 53 carbonaceous samples in the Hell Creek Fm. were over 300 ppm REE, compared to 28 of 148 in the Ludlow Fm. All six samples from the Fox Hills Fm. were from the Linton volcanic ash, which was geochemically similar to the Breien ash (1 sample) and Marmarth ash (7 samples) from the Hell Creek Fm. These ashes did not contain high concentrations of the REE or most associated critical elements, but were relatively enriched in Mn, Rb, Ta, Th, and Sn. Bentonites (12 samples) also showed enrichment in these elements (sans Mn) and were, on average, the most enriched lithology in Co, Ga, Hf, Li, Mg, Ni, Sn, and Ti. Nodules from Hell Creek strata contained very high concentrations of As, Sb, and Mn, and also contained the highest concentrations of Sr and W. The most enriched samples of the REE, Ba, Be, Bi, Cs, Cr, Co, Ga, Ge, Hf, In, Li, Mg, Mo, Nb, Te, Ti, U, V, and Zr were from lignites and carbonaceous mudstones. Germanium, one of the most promising critical elements, was particularly high in samples from the Hell Creek Formation.

Acknowledgements

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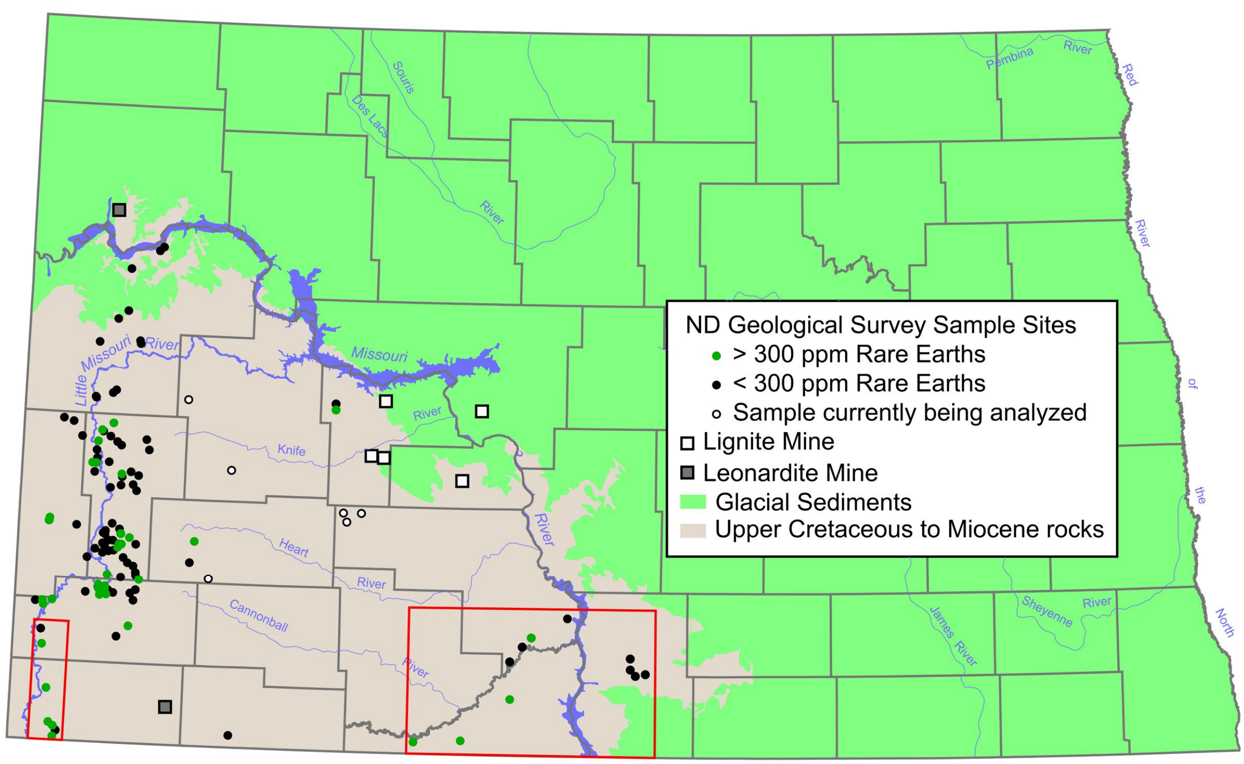
Introduction

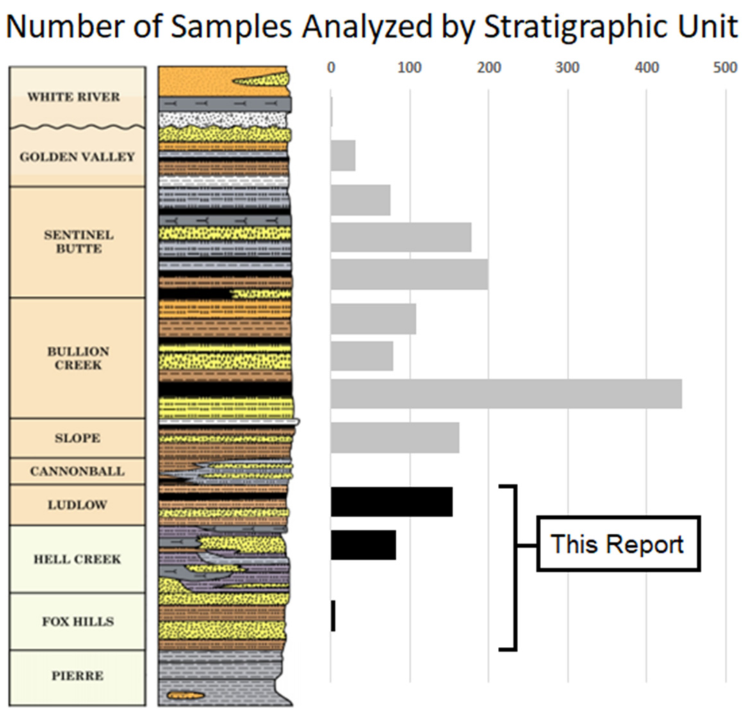
Since 2015, the Geological Survey has been engaged in a critical minerals project, systematically sampling nonmarine rocks from Cretaceous, Paleogene, and Miocene aged stratigraphic units exposed at the surface in western and central North Dakota (Figure 1). The results of the first two years of the study, 65 geologic sections and 352 total rare earth element (REE) concentrations, were reported in Kruger and others (2017). The report was the first documentation of rare earth enrichment in North Dakota and included sample analyses from the Hell Creek, Ludlow, Slope, Bullion Creek, and Sentinel Butte Formations. In 2018, as a result of 20 additional geologic sections and 113 more REE analyses, Murphy and others reported on high REE concentrations and their lateral variability within Bullion Creek lignites at Logging Camp Ranch in Slope County. In 2021, Moxness and others reported on the lateral persistence of high REE concentrations in thin, Sentinel Butte lignites and carbonaceous mudstones around the perimeter of Tracy Mountain in Billings County based upon 169 analyses and 15 measured sections. The Geological Survey recently published a ND Lignite Research Council White Paper (Moxness et.al., 2022) that included summary tables of the critical mineral concentrations of all 1,351 rock samples that had been analyzed during this project up until that time. The report also included a discussion of the critical minerals in North Dakota lignites that appear at this time to show promise.

The primary critical mineral study area encompasses a 30 x 150 mile (9 x 46 km) rectangle stretching from the southern border of Bowman County to Tobacco Garden Creek in McKenzie County. The study area was expanded in 2018 to include sites in central and south-central North Dakota (Figure 1).



▲ **Figure 1.** North Dakota Geological Survey critical element study sample sites. The study areas in this report are outlined in red; Marmarth ash, Sunset Butte, and Mud Buttes in the west and south-central ND to the east.

The rock samples for the overall project have been collected across an 1,800-foot (550 m)-long stratigraphic interval from the Fox Hills Formation (Cretaceous) through the Arikaree Formation (Miocene), involving 10 of the 12 bedrock formations that are exposed at the surface in western and south-central North Dakota (Figure 2). From the beginning, the focus of the study has been on the coal-bearing rocks of the Fort Union Group. The vast majority of analyzed samples have been organic-rich rocks (91%), either lignites (72%) or carbonaceous claystones and mudstones (19%). Additionally, volcanic ash (tuffs) or altered volcanic ashes (tonsteins and bentonites), clinker (scoria), natural coal ash, iron-manganese nodules, and sandstone concretions have also been analyzed (Table 1). The majority of samples have come from five study areas: west-central Billings County, Tracy Mountain, Logging Camp Ranch, the type section of the Slope Formation, and Mud Buttes (this report).



◀ **Figure 2.** The number of samples analyzed for critical elements for the entire NDGS study by stratigraphic position. The Fort Union Group consists of the rocks from the Ludlow Formation through the Sentinel Butte Formation.

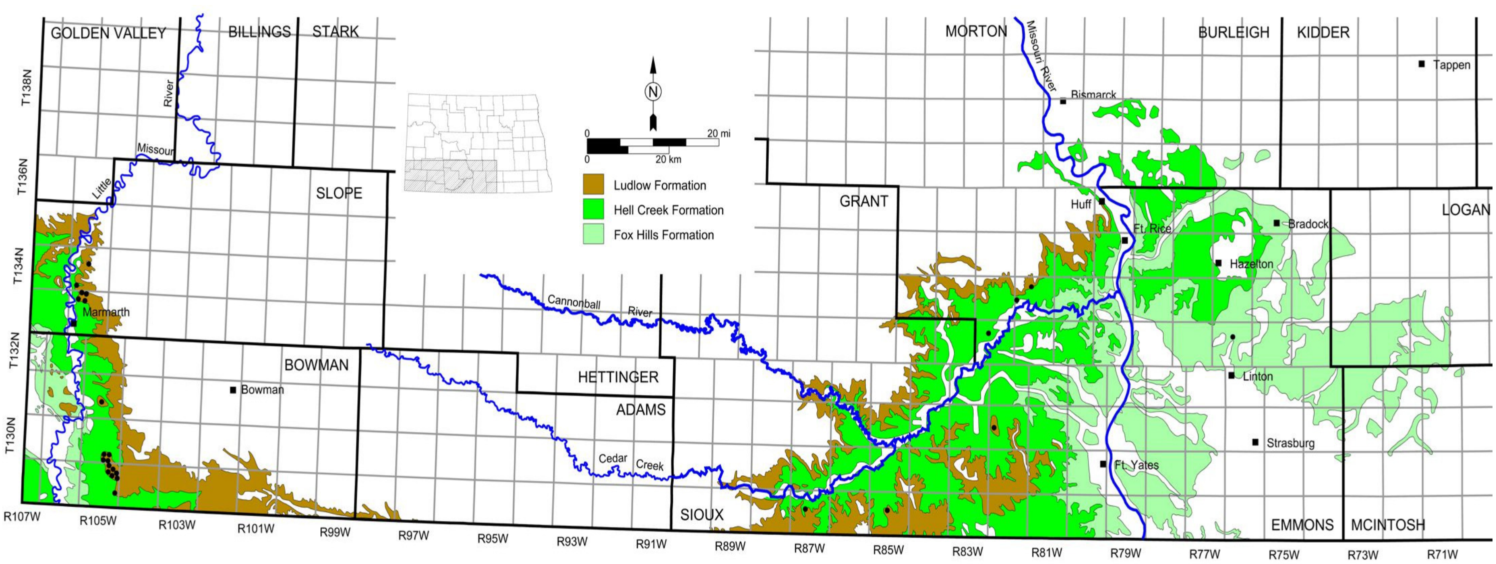
▼ **Table 1.** The number of samples in this report analyzed for REE and other critical elements by lithology.

Entire Project (2015-2022)	This Report	Lithology
1,089	112	Lignites
292	89	Carbonaceous clay/mudstones
25		Claystones and mudstones
25	12	Bentonites
22		Tonsteins
22	12	Nodules or concretions
20	14	Volcanic ashes
12		Natural coal ash
11		Sandstones and Siltstones
3	3	K/Pg ejecta
1,521	**242**	**Total**

Fieldwork

A field team of three geologists typically performed the fieldwork with one measuring section and the other two collecting the rock samples and reclaiming the site. Whenever possible, geologic sections were measured along steep, poorly vegetated slopes to minimize the amount of surface disturbance required to obtain a sample. A pick was used to excavate to fresh rock so that bed thickness and characteristics of the freshly exposed rock could be recorded in a field notebook. Rock samples were collected in three-inch-thick (8 cm) stratigraphic intervals after a minimum of six inches (15 cm) of weathered rock was removed from the outcrop. A typical sample weighed 3.3 pounds (1,500 g) and was stored in a gallon-size Ziploc bag. Samples were generally taken from the top three inches (8 cm) of a bed or from wherever the most carbonaceous horizon was within a bed.

For this project, 26 geologic sections were measured through Fox Hills, Hell Creek and Ludlow strata in southwestern and south-central North Dakota (Figure 3). Eighteen sections were measured in Bowman and Slope counties, eight were measured in Morton and Sioux counties, and one in Emmons County. A total of 261 rock samples were collected, of which 242 were analyzed (Table 1). Roughly 64% of the analyzed rock samples came from the Ludlow Formation (154), 34% from the Hell Creek (82), and 2% from the Fox Hills (6). Organic-rich claystone and mudstone beds or lenses were the Hell Creek lithology most often analyzed (42 of the 82 samples) for this project. Lignite samples made up only 21% of the total organic-rich samples (11 of 53 samples) in the Hell Creek Fm., and all of those thin lignite beds were lenticular. In contrast, lignite samples comprised 68% of the organic-rich samples in the Ludlow Formation (101 of 148). All six of the Fox Hills samples were volcanic ashes. Fieldwork at Mud Buttes took place in 2017 and 2021. Fieldwork took place at the Marmarth Ash site, Sunset Butte, and south-central North Dakota in 2021.



▲ **Figure 3.** The Fox Hills, Hell Creek, and Ludlow sample locations (black dots) comprising the Marmarth ash site in Slope County, the Mud Buttes and Sunset Butte study sites in Bowman County, and the South-Central ND study site in Morton, Sioux, and Emmons Counties. The base map was modified from Clayton (1980).

Laboratory Analysis

Upon return to the office, rock samples were split into a 2.2 pound (1,000 g) sample that was shipped to Standard Laboratories in Casper, Wyoming and a 1.1 pound (500 g) sample that was archived in the Geological Survey warehouse. Most rock samples from the Hell Creek and Ludlow Formations were submitted to the laboratory for analysis in 2017 and 2021. In total, 242 of the 261 samples collected were submitted to the laboratory for analysis.

The initial focus of the Geological Survey's critical elements project was on rare earth elements. In 2018, the U.S. Department of Interior finalized a list of 35 critical minerals. In response, the rock analysis was expanded to all on that list that potentially could be found in coal, with the exception of the platinum group. After approximately 50 analyses, the expanded list was trimmed of those critical elements that had not shown any promise. A year or so later, the list of analyses was further reduced to a dozen (beyond the rare earth elements) elements that showed potential for economic development. Throughout the project the focus has remained on the critical elements. Major ions, including sodium, calcium, potassium, and sulfate were not analyzed to enable funding to be focused on determining the extent of high critical element concentrations. The total REE concentrations of 168 of 242 samples in this report were modeled using concentrations of the major seven of the 16 rare earth elements using methodologies outlined by Kruger (2020).

Fox Hills Formation

The Fox Hills Formation consists of alternating beds of sandstone, siltstone, and mudstone deposited in a marine setting, primarily shore and nearshore environments. The lower contact with the Pierre Formation is gradational, going from gray shale in the Pierre Formation to light gray mudstone in the Fox Hills. The upper contact is generally placed at the base of the first persistent carbonaceous bed. The Fox Hills Formation contains organic laminae in some of the mudstones. The Fox Hills Formation is a clastic wedge that thins to the north in North Dakota. It is approximately 150-350 feet (46-107 m) thick throughout most of western North Dakota and approximately 300 feet (91 m) thick in Sioux County (Carlson, 1979, 1982).

A 25-30 foot (8-9 m) thick ash/tuff is present in a couple of outcrops near the town of Breien in Sioux County, in outcrops northwest and southwest of the town of Cannonball in eastern Sioux County, in localized outcrops near Coal Butte in northwestern Emmons County, and in a series of outcrops within a five mile (8 km) radius of the town of Linton in Emmons County (Murphy, 2005). Near Breien, the ash layer is located within the uppermost part of the Fox Hills Formation, while in the Linton area, the ash layer is in the lower part of the Fox Hills, only 45 feet (14 m) above the basal contact (Figure 4). Artzner (1974) determined the Linton ash is 80% volcanic glass, 10% quartz, 7% feldspar, 1% hornblende, and 2% minor constituents. Feldman (1972) noted that the similarity of ash chemistries between the Breien, Cannon Ball, and Linton sites, as well as the fining of the ash from west to east (assuming a western source), suggested they were all deposits of the same ash fall event. The stratigraphic position of the ash bed at Coal Butte, in the uppermost Fox Hills Formation, may be reflective of an irregular coastline for the Western Interior Seaway or an argument for multiple ash falls (Murphy, 2005).

▲ **Figure 4.** The Linton ash outcrops along Spring Creek, 3.5 miles (5.6 km) north of the town of Linton. At this locality, the ash is located in the lower Fox Hills Formation.

Hell Creek Formation

The Hell Creek Formation primarily consists of alternating, nonmarine beds of sandstone, siltstone, mudstone, and claystone. However, it does contain two, thin, brackish water tongues in portions of south-central North Dakota. The first brackish tongue, the Breien Member, occurs in the lower part of the Hell Creek Formation and the second, the Cantapeta Tongue, occurs in the upper half of the formation (Murphy et al., 2002). Hell Creek strata are generally somber in color, typically shades of gray and purple. Lignite beds are rare in the Hell Creek Formation, with an occasional, thin lignite occurring below the Breien Member in Burleigh, Morton, and Sioux counties (Hoganson and Murphy, 2002). Although rare, thin, very localized lenses of lignite occur throughout the Hell Creek in North Dakota (Figure 5). Due to lignite scarcity, carbonaceous mudstones and claystones were the primary sample target in the Hell Creek Formation. Lenticular, organic-rich foresets are often present in Hell Creek channel sandstones (Figure 6). It is very difficult to separate the organic-rich laminae from the surrounding sandstone, but four samples were obtained from this type of setting. Volcanic activity is assumed to have been relatively high during Hell Creek deposition based upon the numerous beds of swelling claystones (Figure 7), assumed to be altered volcanic glass (bentonites). A 20-foot-thick (6 m) ash layer (the Marmarth ash) is present within the uppermost Hell Creek Formation in several localities north-northeast of the town of Marmarth in southwestern North Dakota (Figure 8). Where exposed, the ash is typically overlain by a bentonite of variable thickness. Forsman (1992) determined the Marmarth ash was 86% glass grains, 8% phenocrysts and admixed detrital grains, and 6% secondary montmorillonite. He further determined the glass was rhyolitic in composition and ranges in grain size from silt to fine sand.

▲ **Figure 5.** A thin, lenticular lignite in the Hell Creek Formation. Sample no. 269 Q2 was taken from this bed.

▲ **Figure 6.** A carbonaceous lens within a channel sandstone in the Hell Creek Fm. in south-central North Dakota.

▲ **Figure 7.** A greenish-gray bentonite at the top of the Hell Creek Formation drapes the small knobs and ridges in the foreground at Mud Buttes.

▲ **Figure 8.** An outcrop of the 20-foot (6 m) thick Marmarth ash in southwestern North Dakota. As a result of weathering, the ash is capped with a bed of bentonite of variable thickness.

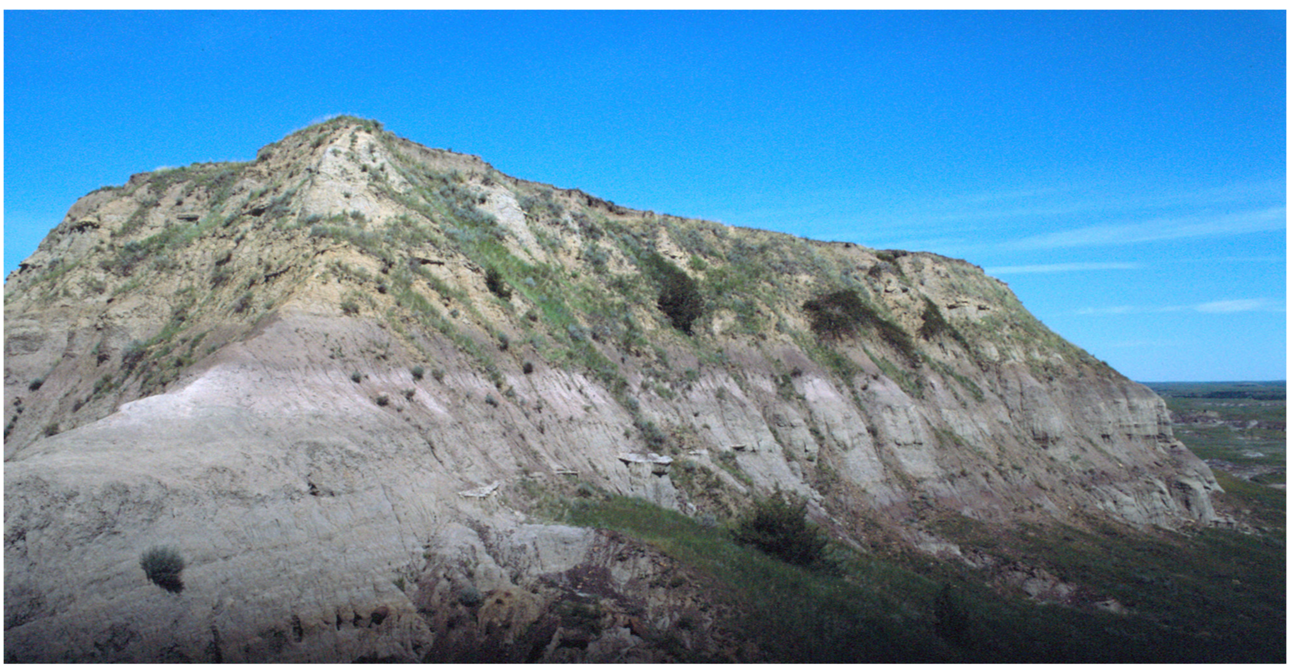
▲ **Figure 9.** Iron-manganese nodules (black rocks) litter the slopes of a Hell Creek outcrop south of the town of Breien in Sioux County.

▲ **Figure 10.** Iron-manganese nodules have a distinctive polygonal ridge surface pattern. Note the thin, brown remnants of the limonite covering (rind) that originally incased the nodule. The siderite core is visible in the nodules to the left and right of the central nodule. The level is eight inches (20 cm) long.

The Hell Creek Formation contains abundant concretions and nodules. Concretions in sandstone are variable in size and shape and are typically calcite cemented. Iron-manganese nodules are abundant throughout Hell Creek strata. According to Groenewold (1971), these nodules typically contain an outer layer of brown limonite, followed by a thin purplish black manganese layer, with a gray to dark gray siderite core (Figures 9 and 10). The Hell Creek Formation is a clastic wedge that thins from west to east across the western half of North Dakota. Carlson (1979) noted a complete section of the Hell Creek Formation is not exposed at any one locality in southwestern North Dakota, but estimated Hell Creek thickness at 450-475 feet (137-145 m) in western Bowman County. Carlson (1982) estimated the maximum thickness of the Hell Creek around the town of Selfridge (Sioux County) in south-central North Dakota at 300-350 feet (91-107 m).

Ludlow Formation

The Ludlow Formation consists of alternating beds of sandstone, siltstone, mudstone, claystone, lignite, and clinker. Ludlow strata are typically shades of gray and brown in contrast to the more somber colored beds of the underlying Hell Creek Formation and the darker brown beds of the overlying Slope Formation. The color change at the contact between the Hell Creek and Ludlow Formations ranges from stark to subtle. The contact between Hell Creek and Ludlow strata is typically placed at the top of the highest, persistent bentonite and the stratigraphically lowest, persistent lignite. Often, these two criteria coincide, but at other surface localities additional criteria are needed to identify the contact including at: a change in slope, an increase in vegetation on the outcrop surface, and where the beds become more laterally persistent (Figure 11). Channel sandstones at or near the Hell Creek\Ludlow contact can make it more difficult to identify the contact. Although Ludlow channel sandstones tend to be cleaner (fewer mud



▲ **Figure 11.** Although there are channel sandstones in the lower Ludlow Fm. and in the upper Hell Creek Fm. at this locality, the roughly 10 feet (3 m) of mudstone on either side of the contact makes it easier to identify the color change from the grays and dark grays of the Hell Creek Formation to the yellows, browns and grays of the overlying Ludlow Formation. In addition, there is a change of slope at the contact and an increase in vegetative cover. The site is in Grant County.

▲ **Figure 12.** The Hell Creek\Ludlow contact is at the base of the 2.5 foot (0.8 m)-thick lignite in the left, foreground. The locality is in eastern Grant County.

drapes and organic lenses). The lignites in the Ludlow Formation range from less than one foot (0.3 m) thick to more than 30 feet (9 m) in the case of the TCross lignite at the top of the formation (Figure 12).

Visually, carbonaceous claystones and mudstones in the Ludlow Formation appear to have a higher organic content than the typical carbonaceous mudstone in the Hell Creek Formation. The Ludlow Formation contains bentonites, but they are not as numerous and generally not as thick as those in the underlying Hell Creek Formation. The Ludlow Formation is a clastic wedge that thins from west to east in the western half of North Dakota. Carlson (1983) estimated the maximum thickness of the Ludlow Formation in southwestern North Dakota at about 280 feet (85 m). In contrast, the Ludlow Formation averaged 45 feet (14 m) thick in five measured sections in south-central North Dakota (Murphy et.al., 1995).

Results

Table 2 contains a complete summary of ICP-MS results of 242 samples from the Ludlow, Hell Creek, and Fox Hills Formations, including 23 samples with REE analyses previously reported in Kruger and others (2017; Samples 64A through 65B). The table includes results from non-carbonaceous lithologies such as volcanic ashes (14 samples), bentonites (12), concretions (12), and the K/Pg ejecta layer (3).

▼ **Table 2.** Summarized analytical results. Abbreviations: A is the atomic number of the element; n is the number of samples analyzed.

Chemical Group	Element	Symbol	A	n	Analyses (All lithologies, concentrations in ppm) – Dry Coal/Rock Basis MAX	MIN	MEAN	Dry Ash Basis MAX	MIN	MEAN
Alkali Metals	Lithium	Li	3	90	90.5	3.1	27.9	103	3.7	40
	Rubidium	Rb	37	39	119	1	51	126	1	60
	Cesium	Cs	55	80	12.0	0.04	3.9	13.6	0.05	5.1
Alkaline Earth Metals	Beryllium	Be	4	118	12.3	0.6	3.6	46.0	0.8	7.4
	Magnesium	Mg	12	206	28400	525	7990	70400	621	12700
	Strontium	Sr	38	52	676	59	221	2130	82	350
	Barium	Ba	56	71	21600	105	1620	35100	295	2400
Rare Earth Elements – Lanthanides	Lanthanum	La	57	242	128	1.9	31	448	2.2	53
	Cerium	Ce	58	242	273	2.9	61	955	3.4	109
	Praseodymium	Pr	59	74	31.9	0.7	10.3	112	0.8	21.9
	Neodymium	Nd	60	242	129	1.1	29	451	1.3	52
	Samarium	Sm	62	74	27.8	0.6	9.0	97.2	0.7	19.6
	Europium	Eu	63	74	6.83	0.19	2.20	23.9	0.22	4.8
	Gadolinium	Gd	64	242	30.3	0.4	6.0	106	0.5	11.6
	Terbium	Tb	65	74	4.66	0.15	1.38	16.3	0.17	3.09
	Dysprosium	Dy	66	74	26.7	1.1	8.2	93.4	1.3	18.5
	Holmium	Ho	67	74	5.2	0.26	1.7	18.2	0.30	3.8
	Erbium	Er	68	242	14.6	0.73	3.5	51.1	0.86	7.0
	Thulium	Tm	69	74	1.92	0.11	0.69	6.72	0.16	1.55
	Ytterbium	Yb	70	74	12	0.78	4.5	42.0	1.15	10.1
	Lutetium	Lu	71	74	1.83	0.12	0.68	6.40	0.19	1.54
Rare Earth Elements; Transition Metals	Scandium	Sc	21	242	35.7	0.8	13.6	81	0.9	24
	Yttrium	Y	39	242	129	6	32	451	7	63
Transition Metals	Titanium	Ti	22	190	8880	68	2590	10500	80	3790
	Vanadium	V	23	204	407	14	117	718	18	192
	Chromium	Cr	24	131	157	7	55	298	9	88
	Manganese	Mn	25	38	22000	24	2800	23700	39	3400
	Cobalt	Co	27	47	34.8	1.0	10.6	78.3	1.2	17.2
	Zirconium	Zr	40	204	794	15.1	180	2030	18.0	326
	Niobium	Ni	41	204	51.7	1.9	12.8	72.0	2.4	21.1
	Molybdenum	Mo	42	210	85.8	<0.2	10.2	164	<0.2	22.2
	Hafnium	Hf	72	168	11.0	0.2	3.4	23.3	0.2	5.7
	Tantalum	Ta	73	77	1.63	0.04	0.82	2.01	0.05	1.08
	Tungsten	W	74	77	46.1	0.1	3.4	100	0.1	6.4
Post-Transition Metals	Gallium	Ga	31	206	37.0	<1	17.5	119	<1	27.9
	Indium	In	49	37	0.09	<0.02	N/A	0.16	<0.02	N/A
	Tin	Sn	50	37	2.2	0.3	1.4	3.4	0.4	1.7
	Bismuth	Bi	83	37	0.56	<0.1	N/A	1.32	<0.1	N/A
Metalloids	Germanium	Ge	32	212	724	1	18	4990	1	52
	Arsenic	As	33	37	657	1.4	34	910	1.8	49
	Antimony	Sb	51	77	63.5	0.25	4.0	88.0	0.28	7.4
	Tellerium	Te	52	37	0.11	<0.1	N/A	0.37	<0.1	N/A
Actinides	Thorium	Th	90	39	28.8	0.6	11.7	38.4	0.7	14.1
	Uranium	U	92	206	53.9	0.9	8.6	111	1.2	16.0

Rare Earth Element Concentrations

Rare earth element concentrations from 11 coals and 42 carbonaceous mudstones in the Hell Creek Fm. averaged 173 ppm. The 101 coals and 47 carbonaceous mudstones from the Ludlow Fm. averaged significantly higher at 229 ppm REE. The Ludlow Fm. contains more abundant higher-grade coals than the Hell Creek Fm., which could explain some of the difference in overall REE concentrations, but even Ludlow carbonaceous mudstones (207 ppm REE; Table 3) averaged higher than Hell Creek coals (189 ppm). The average ash yield of all 53 carbonaceous Hell Creek samples was 78.7%, but the four samples over 300 ppm REE averaged 61.6%. The 148 carbonaceous Ludlow samples averaged 57.5% with the 28 most enriched samples averaging 50.6%. The average REE concentrations in carbonaceous beds in the Hell Creek and Ludlow Formations are both higher than comparable lithologies from the Bullion Creek and Sentinel Butte Formations, as reported in Kruger and others (2017). Roughly half of these earliest samples did not include scandium, which is difficult to model from other elements, but using averages from other coal tops and carbonaceous mudstones from the same formation, samples from the Bullion Creek Fm. would average about 161 ppm REE and the Sentinel Butte Fm. would average around 148 ppm. None of the non-carbonaceous samples in this report were over 300 ppm total REE, including six samples of volcanic ash from the Fox Hills Formation.

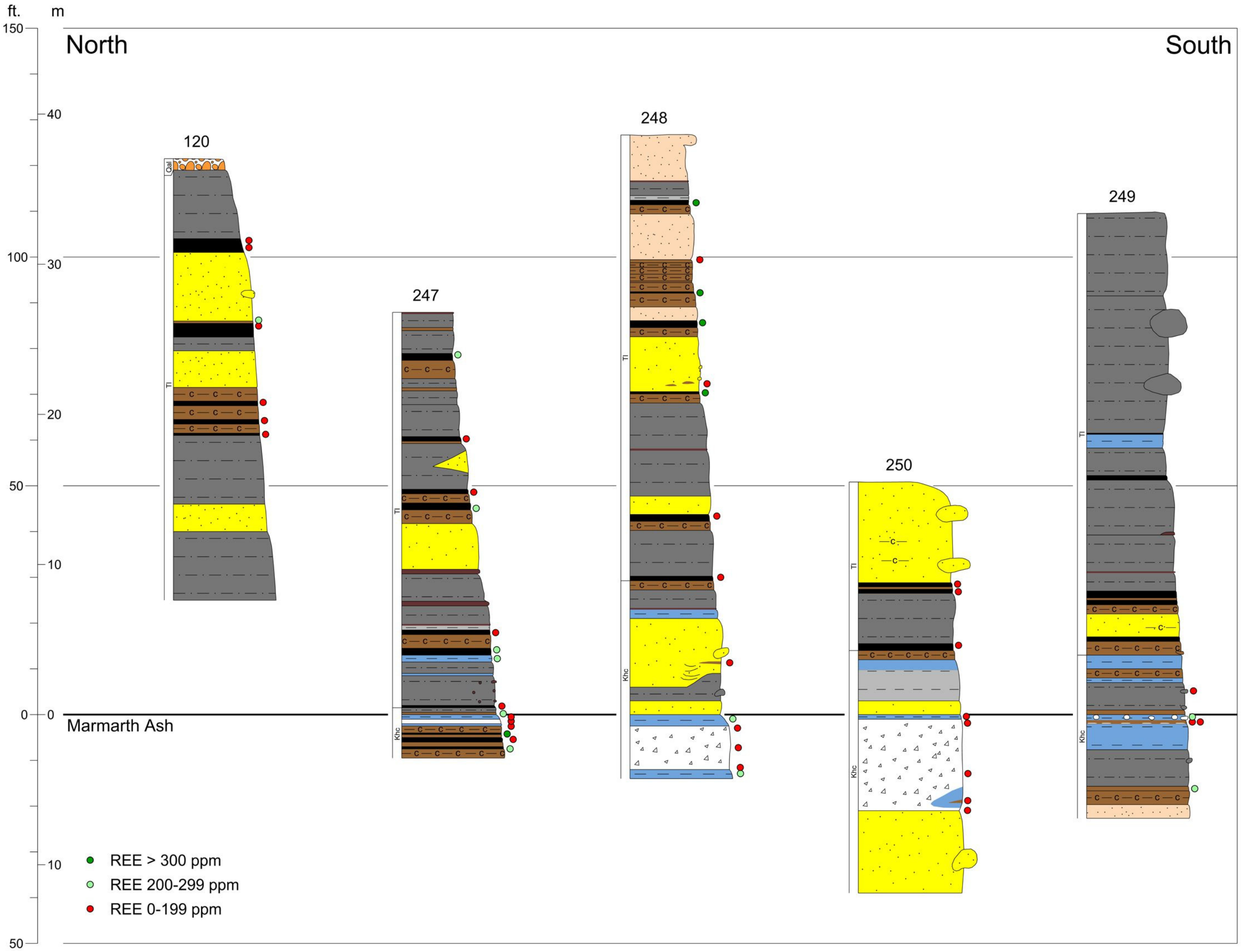
▼ **Table 3.** Sample lithology and total rare earth element concentrations (ΣREE) by formation.

		Number of Samples	Mean ΣREE	Max ΣREE	Mean ash yield	Number of samples >300 ppm ΣREE	Percent of samples >300 ppm ΣREE
Tl	Bentonites	1	-	282	94.3%	0	0%
Tl	Carbonaceous Mudstones	47	207	661	81.5%	3	6%
Tl	Coals	101	239	846	47.0%	25	25%
Tl	Nodules	2	69	73	77.7%	0	0%
Tl	K/Pg Ejecta	3	131	261	85.5%	0	0%
	Ludlow Fm. Total	**154**	**225**	**846**	**59.0%**	**28**	**18%**
Khc	Marmarth Ash	7	166	195	92.0%	0	0%
Khc	Breien Ash	1	-	134	94.9%	0	0%
Khc	Bentonites	11	177	212	92.1%	0	0%
Khc	Carbonaceous Mudstones	42	170	438	85.6%	2	5%
Khc	Coals	11	189	369	50.4%	2	18%
Khc	Nodules & Concretions	10	101	190	85.2%	0	0%
	Hell Creek Fm. Total	**82**	**164**	**438**	**82.4%**	**4**	**5%**
Kfh	Linton Ash	6	128	134	94.2%	0	0%
	Fox Hills Fm. Total	**6**	**128**	**134**	**94.2%**	**0**	**0%**

Marmarth Ash Study Site

The Marmarth ash site covers roughly eight square miles (21 km^2) and is four miles (6.4 km) northeast of the town of Marmarth in Slope County (Figures 1 and 3). The Marmarth ash is positioned in the uppermost Hell Creek Formation and typically consists of 10-20 feet (3-6 m) of volcanic ash overlain by 2-3 feet (0.6-1 m) of gray bentonite (Figure 8). The site was chosen to determine if critical minerals were present within the 66-million-year-old volcanic ash and associated tuffs and whether critical minerals had leached out of the ash and attached to underlying strata, especially to organic-rich strata.

Four geologic sections were measured in the Marmarth ash area (247-250) and another section (120) was measured through Ludlow strata three miles (5 km) to the north (Figure 13). A total of 49 rock samples from the Marmarth ash site were submitted for critical mineral analysis, 23 samples were from Hell Creek strata and 26 samples were from the Ludlow Formation (Figure 13).



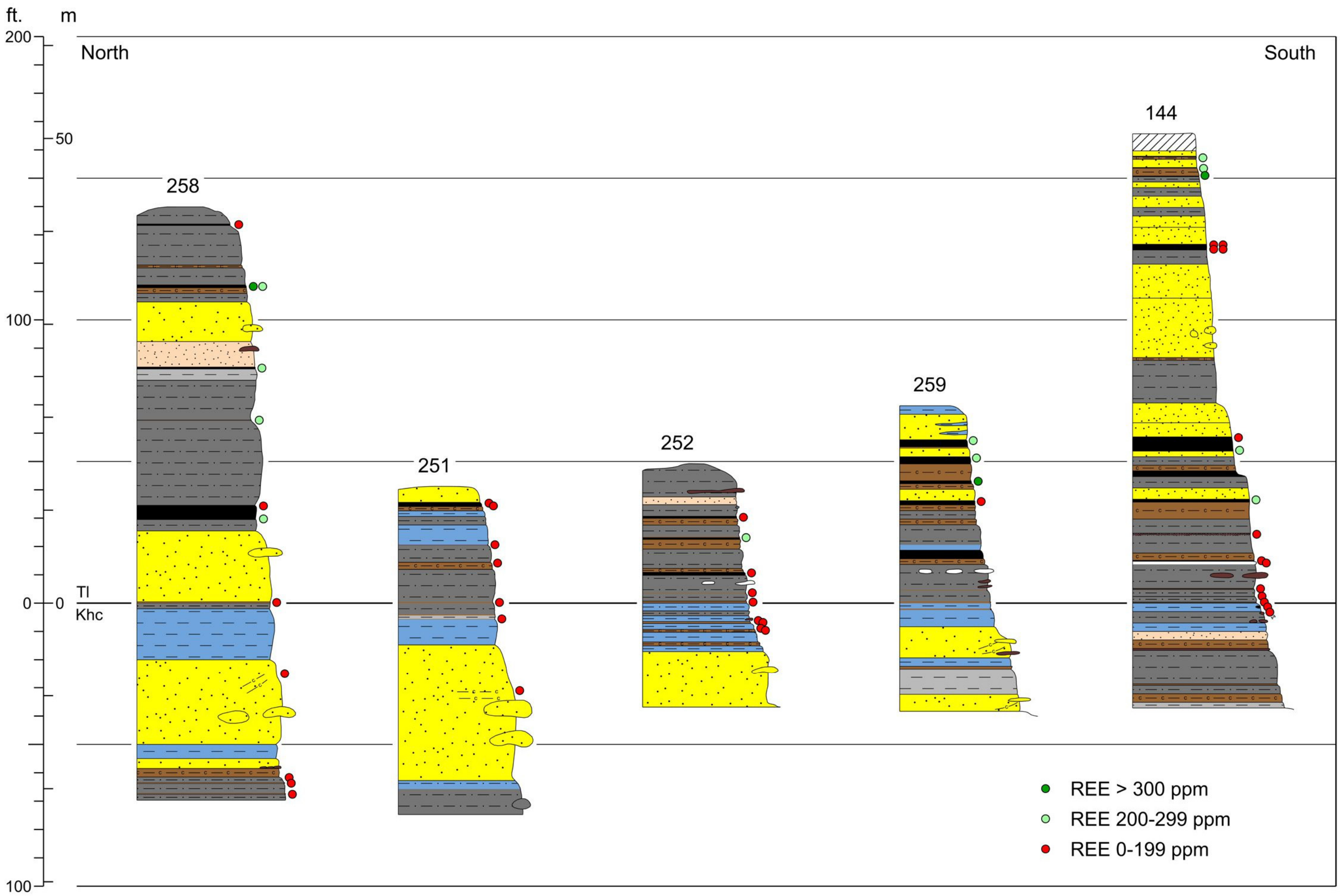
▲ **Figure 13.** The rare earth element concentration ranges for rock samples from a measured section located three miles (5 km) north of the Marmarth ash study site (120) and four measured sections in the Marmarth ash (247-250).

Five of the rock samples from the Marmarth ash site contained rare earth concentrations above 300 ppm. Four of these high REE samples were from the upper portion of the lower one-third of the Ludlow Formation exposed at this site. The fifth sample with high concentrations came from a thin lignite beneath a deposit of the Marmarth ash, the latter was primarily pods of volcanic ash encased in bentonite.

Mud Buttes Study Site

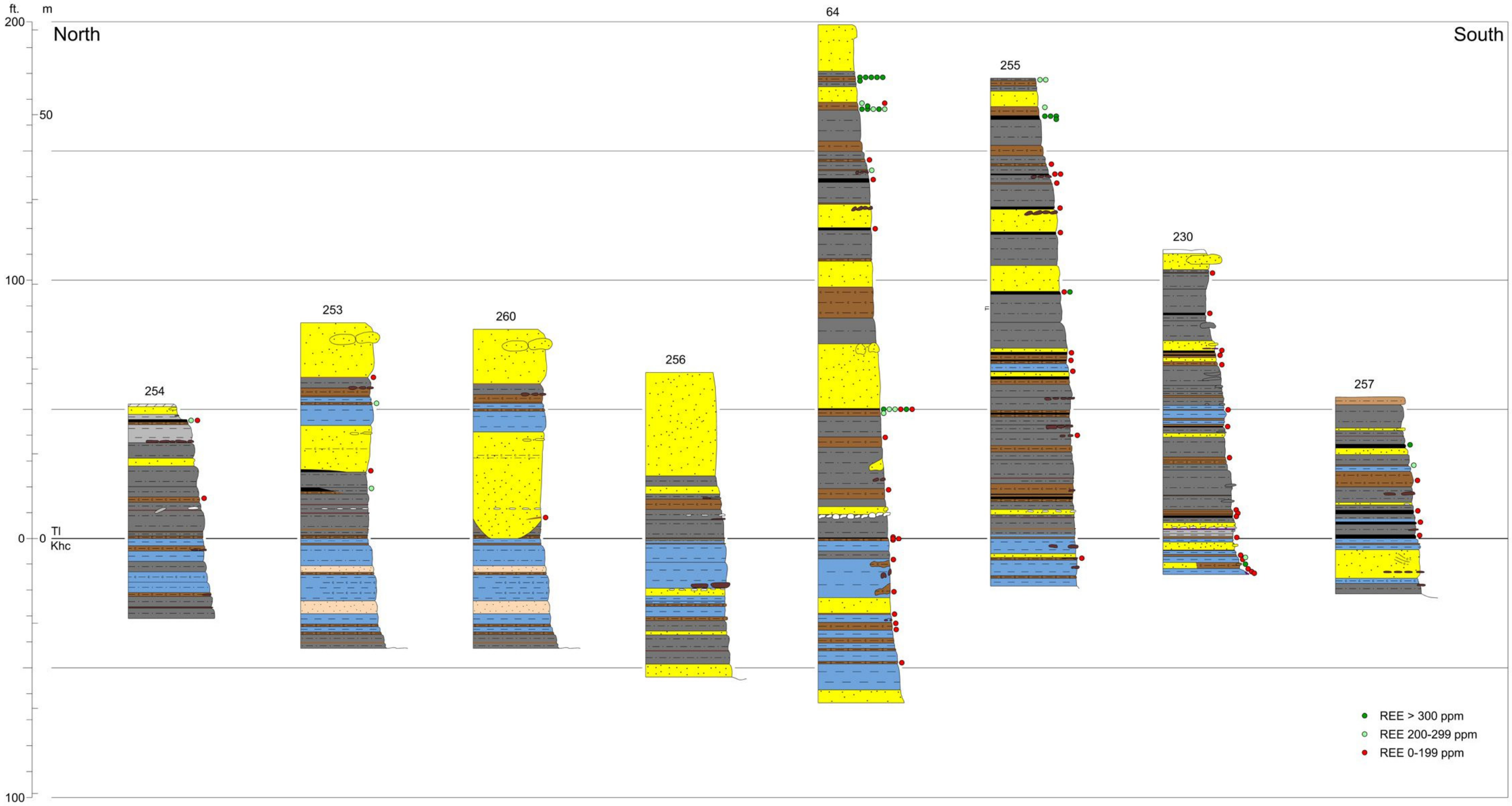
The Mud Buttes cover an area of approximately four-square miles (10 km^2) in southwestern Bowman County (Figures 1 and 3). Mud Buttes is split into a north half and a south half by a southwest-northeast trending county road. The north half is dominated by a half dozen or so major buttes with relief of 120-200 feet (37-61 m) and the south half by two, 200-foot- (61 m) high buttes along the edge of a northwest-southeast trending escarpment. A total of 11 geologic sections were measured in Mud Buttes and 123 samples were submitted for analysis.

The Mud Buttes measured sections were separated into north and south cross-sections (Figures 14 and 15). The northern half of Mud Buttes contain four measured sections and 38 rock samples for critical mineral analysis (Figure 14). Included within the cross section is a measured section from Sunset Butte (258) situated 7.5 miles (12.1 km) to the northwest. Sunset Butte rises approximately 200 feet (7.5 m) above the surrounding countryside and occupies 32 acres (13 ha). A total of 12 samples were analyzed from Sunset Butte. Rare earth element concentrations exceeded 300 ppm in three Ludlow rock samples (Figure 14).



▲ **Figure 14.** The rare earth element concentration ranges for rock samples from measured sections at Sunset Butte (258) and the north half of Mud Buttes (144, 251, 252, and 259).

The southern half of Mud Buttes contains seven measured sections and 85 rock samples for critical mineral analysis, 11 from the Hell Creek Fm. and 74 from the Ludlow Fm. (Figure 15). Included within this cross section is a measured section (257) generated approximately three miles (5 km) to the

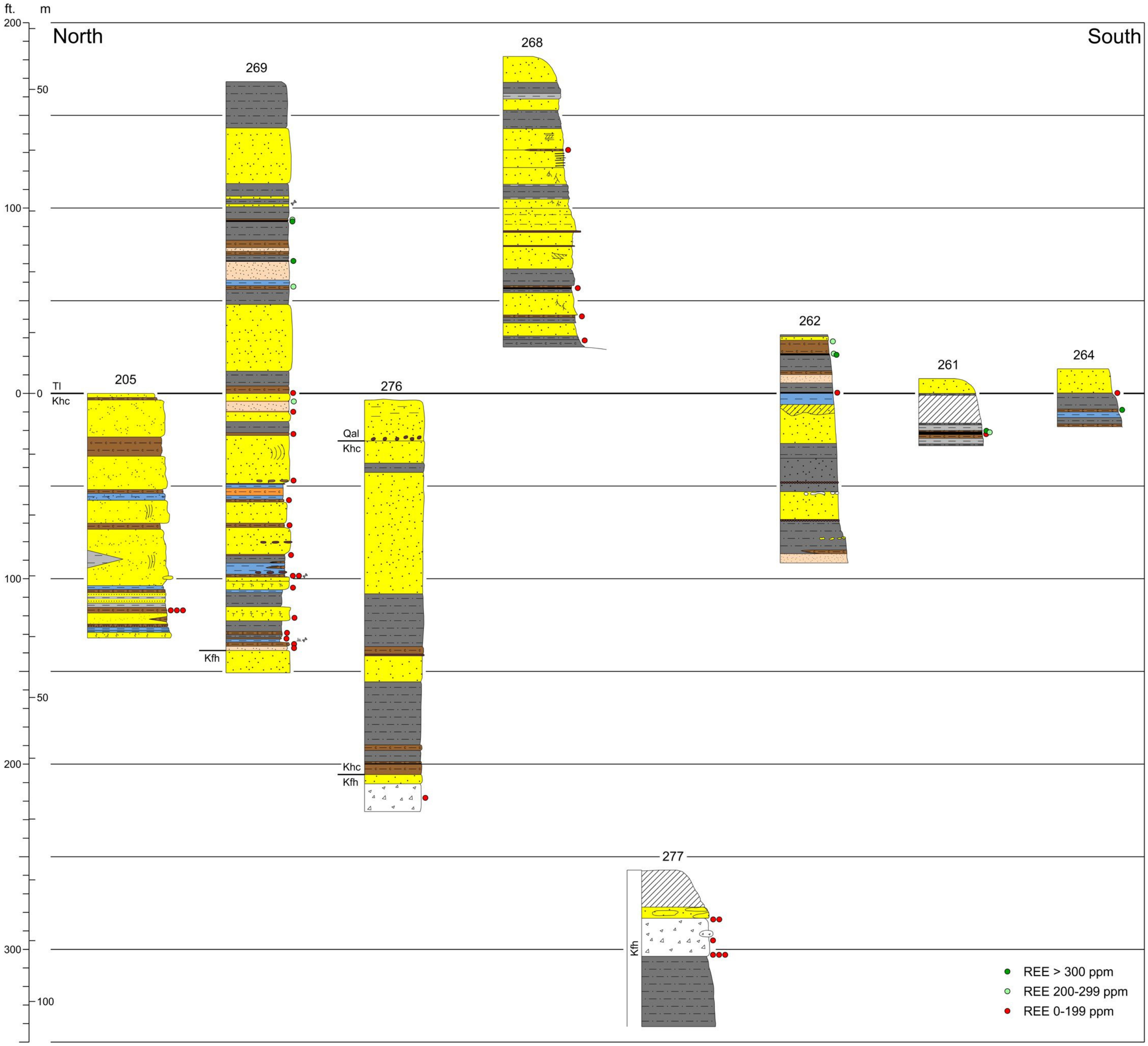


▲ **Figure 15.** The rare earth element concentration ranges for rock samples from measured sections located in the south half of Mud Buttes (64, 230, 253-256, and 260) and section 257 located 3 miles (5 km) to the southeast.

southeast of Mud Buttes and two miles (3 km) from the South Dakota border. Section 257 was measured across an 80-foot- (24 m) high, two-mile- (3 km) long, northwest-southeast trending escarpment, from which six samples were analyzed. Rare earth element concentrations exceeded 300 ppm in one Hell Creek rock sample and 18 Ludlow samples (Figure 15).

South-Central North Dakota Study Site

Eight geologic sections were measured across a 2,400 square mile (6,200 km^2) area in south-central North Dakota, encompassing portions of Morton, Sioux, and Emmons Counties (Figures 1 and 3). Most of these sections were measured on isolated buttes and/or along the sides of drainages. A total of 43 rock samples were collected for critical mineral analysis (Figure 16). The Linton ash samples were the only Fox Hills samples analyzed under this study. Rare earth element concentrations exceeded 300 ppm in two Hell Creek rock samples and three Ludlow samples (Figure 16).



▲ **Figure 16.** The rare earth element concentration ranges for rock samples from measured sections located in the south-central part of North Dakota (205, 261, 262, 264, 268, 269, 276, and 277).

Other Critical Element Concentrations

For most elements, the highest concentrations were found in carbonaceous beds, with only a few exceptions (Table 4). Sample 249(nod), a few small nodules collected from a bed of bentonite in the uppermost Hell Creek Formation, contained antimony, arsenic, and tungsten concentrations several times higher than any other sample in this report. The top strontium and all of the top ten manganese concentrations come from Fe/Mn oxide nodules in both the Hell Creek and Ludlow Formations. The outer

▼ **Table 4.** Results by major lithologic group. Maximum and mean concentrations are listed for each major lithology, with enrichment coefficients vs carbonaceous beds analyzed in this report. E.g., the maximum manganese concentration identified in nodules (22,000 ppm) is 47.1 times higher than the most Mn-enriched coal or carbonaceous mudstone (467 ppm). Abbreviations: n is the number of samples analyzed.

	Coals & Carbs			Bentonites					Volcanic Ash					Nodules & Concretions				
		Conc. (ppm)			Conc. (ppm)		vs Coal/Carb			Conc. (ppm)		vs Coal/Carb			Conc. (ppm)		vs Coal/Carb	
Element	n	MAX	MEAN	n	MAX	MEAN	MAX	MEAN	n	MAX	MEAN	MAX	MEAN	n	MAX	MEAN	MAX	MEAN
Cerium	201	273	64	12	97.3	67.8	0.36	1.06	14	77.8	56.5	0.28	0.89	12	61.2	22.7	0.22	0.36
Erbium	201	14.6	3.8	12	3.53	2.12	0.24	0.56	14	2.73	1.53	0.19	0.40	12	4.41	2.26	0.30	0.59
Gadolinium	201	30.3	6.5	12	7.7	4.3	0.25	0.66	14	3.6	2.9	0.12	0.44	12	6.7	2.9	0.22	0.45
Lanthanum	201	128	31	12	50.7	38.1	0.40	1.22	14	46.4	33.5	0.36	1.07	12	26.7	13.1	0.21	0.42
Neodymium	201	129	31	12	42.9	26.1	0.33	0.85	14	25.9	19.6	0.20	0.64	12	25.4	10.7	0.20	0.35
Scandium	201	35.7	14.8	12	18.7	11.2	0.52	0.76	14	5.5	4.2	0.15	0.28	12	10.3	5.7	0.29	0.38
Yttrium	201	129	34	12	29.8	19.1	0.23	0.56	14	32.1	13.8	0.25	0.41	12	65.9	25.2	0.51	0.74
Total REE	201	846	214	12	282	189	0.33	0.89	14	195	147	0.23	0.69	12	190	96	0.22	0.45
Antimony	48	11.4	4.4	5	1.71	1.47	0.15	0.34	14	2.53	1.65	0.22	0.38	10	63.5	7.0	5.57	1.61
Arsenic	8	102	33	5	22.0	10.8	0.22	0.32	14	22.2	12.0	0.22	0.36	10	657	76	6.44	2.29
Barium	42	21600	2200	5	1710	883	0.08	0.40	14	1300	900	0.06	0.41	10	1410	570	0.07	0.26
Beryllium	81	12.3	4.3	12	2.1	1.6	0.17	0.37	14	2.0	1.8	0.16	0.41	11	4.8	2.3	0.39	0.54
Bismuth	8	0.56	0.31	5	0.35	0.28	0.63	0.90	14	0.36	0.29	0.64	0.92	10	0.22	0.07	0.39	0.21
Cesium	50	12.0	4.6	5	7.15	4.39	0.60	0.96	14	4.58	3.25	0.38	0.71	11	1.94	1.18	0.16	0.26
Chromium	94	157	65	12	104	51	0.66	0.78	14	16.0	11.9	0.10	0.18	11	51	26	0.32	0.40
Cobalt	18	34.8	14.5	5	34.4	18.3	0.99	1.27	14	15.4	4.5	0.44	0.31	10	24.4	8.5	0.70	0.59
Gallium	168	37.0	18.2	12	26.1	21.2	0.71	1.16	14	19.6	16.4	0.53	0.90	12	10.7	4.9	0.29	0.27
Germanium	174	724	22	12	2	1.5	0.00	0.07	14	2	1.8	0.00	0.08	12	2	1.3	0.00	0.06
Hafnium	131	11	4	12	8.2	3.9	0.75	1.07	14	3.5	2.8	0.32	0.77	11	1.3	0.7	0.12	0.20
Indium	8	0.09	N/A	5	0.06	0.05	0.67	N/A	14	0.02	N/A	0.22	N/A	10	0.02	N/A	0.22	N/A
Lithium	61	90.5	30.7	5	37.3	32.3	0.41	1.05	14	55.3	27.2	0.61	0.89	10	16.5	10.0	0.18	0.32
Magnesium	168	28400	7800	12	20200	13000	0.71	1.67	14	19000	9300	0.67	1.19	12	9130	4330	0.32	0.56
Manganese	8	467	180	5	296	163	0.63	0.90	14	2780	500	5.95	2.78	11	22000	8800	47.1	48.9
Molybdenum	172	85.8	12.1	12	6.4	2.0	0.07	0.16	14	3.2	2.4	0.04	0.20	12	10.4	1.5	0.12	0.13
Niobium	166	51.7	13.4	12	20.7	14.2	0.40	1.06	14	16.3	12.1	0.32	0.90	12	6.6	3.5	0.13	0.26
Rubidium	10	71	41	5	83	56	1.17	1.39	14	119	80	1.68	1.96	10	35	18	0.49	0.44
Strontium	23	594	240	5	439	216	0.74	0.90	14	294	212	0.49	0.89	10	676	191	1.14	0.80
Tantalum	48	1.53	0.77	5	1.63	1.12	1.07	1.46	14	1.61	1.29	1.05	1.68	10	0.77	0.24	0.50	0.31
Tellerium	8	0.16	N/A	5	<0.1	N/A	N/A	N/A	8	<0.1	N/A	N/A	N/A	10	<0.1	N/A	N/A	N/A
Thorium	10	16.3	8.5	5	28.8	16.1	1.77	1.89	14	27.7	19.3	1.70	2.27	10	3.2	2.2	0.20	0.26
Tin	8	2.1	1.4	5	2.2	2.0	1.05	1.40	14	2.1	1.7	1.00	1.22	10	0.9	0.6	0.43	0.42
Titanium	152	8880	2750	12	4780	3240	0.54	1.18	14	2290	1700	0.26	0.62	12	1690	910	0.19	0.33
Tungsten	48	18.5	3.3	5	13.4	3.9	0.72	1.19	14	4.5	1.8	0.24	0.55	10	46.1	6.0	2.49	1.82
Uranium	168	53.9	9.4	12	10.2	6.5	0.19	0.70	14	8.7	6.6	0.16	0.70	12	5.6	2.1	0.10	0.23
Vanadium	166	407	132	12	171	85	0.42	0.64	14	36	27	0.09	0.20	12	101	40	0.25	0.30
Zirconium	166	794	204	12	243	116	0.31	0.57	14	102	78	0.13	0.38	12	48.8	30.3	0.06	0.15

rinds of several nodules collected as float from the Hell Creek Formation (Sample 230(nod)B) contained the highest manganese concentrations at 22,000 ppm, while the cores of the same nodules (Sample 230(nod)A) were also high, but lower at 13,400 ppm. The top 11 rubidium concentrations were from volcanic ashes and bentonites, including the six highest being the six Linton Ash samples from the Fox Hills Fm., followed by samples from the Breien Ash and Marmarth Ash (Hell Creek Fm.). Volcanic ashes and bentonites also accounted for 15 of the top 18 tantalum concentrations, 15 of the top 16 thorium concentrations, and 18 of the top 20 tin concentrations, including the top sample for each. Only the REEs were examined in the K/Pg ejecta layer.

Non-REE critical mineral concentrations were included in more recent results from Tracy Mountain in Billings County (Moxness et al., 2021). Sampling at Tracy Mountain focused heavily on lateral sampling of several REE-enriched beds in the Sentinel Butte Formation, and as a result that dataset is biased toward elements found in environments of REE mineralization and is generally more enriched in associated critical elements. Individual samples from carbonaceous beds in the Ludlow Formation contained the highest concentrations of barium, beryllium, cesium, lithium, magnesium, strontium, titanium, and vanadium yet identified on this project, but on average were only highest in beryllium and lithium (Table 5). Average concentrations in the Hell Creek Formation tended to be much lower, but were the highest in cesium, chromium, germanium, manganese, niobium, tantalum, and titanium. Many of these elements were identified in Moxness and others (2021) as correlating with the clay fraction, which is higher in the lower grade beds in the Hell Creek Fm. Individual samples from the Hell Creek Fm. contained the highest concentrations of niobium and germanium yet identified in this study.

▼ **Table 5.** The critical mineral concentrations (in ppm) in carbonaceous beds from the Hell Creek and Ludlow Formations, compared to samples of the same lithologies from the Sentinel Butte Formation in the Tracy Mountain area. Abbreviations: n is the number of samples analyzed.

Elemental concentrations in carbonaceous lithologies (coal and carbonaceous mudstone)

		This Report						Tracy Mtn. (Moxness et al., 2021)		
		Hell Creek Formation			Ludlow Formation			Sentinel Butte Formation		
		n	MAX	MEAN	n	MAX	MEAN	n	MAX	MEAN
Rare Earth Elements	Cerium	53	140	53	148	273	68	156	361	81
	Dysprosium	10	12.0	6.2	61	26.7	8.8	70	34.8	13.9
	Erbium	53	7.99	2.89	148	14.6	4.1	156	16.7	5.0
	Europium	10	3.28	1.62	61	6.83	2.37	70	11.5	3.9
	Gadolinium	53	14.4	4.9	148	30.3	7.1	156	42.2	9.9
	Holmium	10	2.62	1.28	61	5.20	1.77	70	6.19	2.67
	Lanthanum	53	68.1	27.0	148	128	33	156	148	35
	Lutetium	10	1.23	0.57	61	1.83	0.71	70	2.00	0.98
	Neodymium	53	66.3	24.4	148	129	33	156	199	44
	Praseodymium	10	15.1	7.9	61	31.9	11.1	70	46.7	16.6
	Samarium	10	14.3	6.6	61	27.8	9.7	70	49.3	16.5
	Scandium	53	21.0	14.3	148	35.7	15.0	150	41.5	18.3
	Terbium	10	1.91	1.04	61	4.66	1.48	70	6.46	2.47
	Thulium	10	1.16	0.55	61	1.92	0.72	70	2.21	1.02
	Ytterbium	10	7.65	3.62	61	12.0	4.7	70	13.6	6.5
	Yttrium	53	71.8	25.0	148	129	37	156	143	42
	Total REE	53	438	173	148	846	229	156	1089	276
	Antimony	12	9.65	2.91	36	11.4	4.8	75	25.0	8.1
	Arsenic	2	13.4	11.5	6	102	40	67	698	108
	Barium	7	1070	790	35	21600	2500	75	17500	3600
	Beryllium	25	8.80	3.24	56	12.3	4.8	31	7.60	4.14
	Bismuth	2	0.11	N/A	6	0.56	0.39	21	1.21	0.63
	Cesium	14	8.95	4.81	36	12.0	4.46	31	9.88	4.76
	Chromium	25	103	71	69	157	63	98	167	70
	Cobalt	2	17.8	11.2	16	34.8	14.9	51	253	21
	Gallium	50	34.7	19.8	118	37.0	17.6	116	44.2	19.9
	Germanium	50	724	45	124	71	12	116	64	11
	Hafnium	31	6.8	3.4	100	11.0	3.7	126	19.0	5.4
	Indium	2	0.05	N/A	6	0.09	0.06	21	0.17	0.10
	Lithium	12	50.0	28.5	49	90.5	31.2	31	76.6	30.4
	Magnesium	50	13300	6200	118	28400	8400	144	23400	9000
	Manganese	2	307	241	6	467	160	21	1310	130
	Molybdenum	48	85.8	9.5	124	57.9	13.1	144	233	49
	Niobium	48	51.7	14.9	118	25.6	12.8	114	30.8	14.5
	Rubidium	4	67	29	6	71	49	21	108	62
	Strontium	5	192	122	18	594	272	31	587	316
	Tantalum	12	1.11	0.86	36	1.53	0.74	98	2.83	0.82
	Tellerium	2	<0.1	N/A	6	0.16	N/A	21	0.64	0.23
	Thorium	4	9.0	4.9	6	16.3	10.9	21	45.9	19.9
	Tin	2	1.4	0.9	6	2.1	1.6	21	2.7	2.0
	Titanium	39	5350	3440	113	8880	2510	31	3620	2010
	Tungsten	12	18.5	3.6	36	11.7	3.2	141	83.5	8.0
	Uranium	50	18.0	5.9	118	53.9	10.8	144	200	28
	Vanadium	48	326	139	118	407	130	114	405	143
	Zirconium	48	794	157	118	768	224	144	1150	330

Germanium enrichment is noteworthy in that it is considered one of the most promising elements to co-produce with the REEs from coal (Dai and Finkelman, 2018), and samples from the Hell Creek Fm. are several times higher than those from the Ludlow Fm. in this report and the Sentinel Butte Fm. at Tracy

▲ **Figure 17.** Sample 144(pod), a lens of coal in bentonitic mudstone containing 724 ppm of germanium.

Mountain. A value of 724 ppm germanium from an isolated coal pod in bentonite at Mud Buttes (Sample 144(pod), Figure 17) is 10 times higher than any sample from other formations, and a 675 ppm value from woody material within a carbonaceous mudstone in Morton County (Sample 205A) is also an order of magnitude higher than most other samples. A thin carbonaceous mudstone at Mud Buttes (Sample 230Y) also contained 360 ppm germanium. All three of these Hell Creek samples contained below average REE concentrations, which ranged between 108 and 130 ppm, which is consistent with the findings of Moxness and others (2021), which found germanium concentrations had a very low correlation with total REE.

The degree of enrichment for each element can be quantified by comparing the concentrations of carbonaceous samples in this study to the average concentrations of the upper continental crust (UCC), which can be used as background values for the abundance of elements in sediments near the Earth's surface (McLennan, 2001). Sample 144(pod) contains germanium concentrations over 450 times higher than UCC (Table 6), the highest degree of enrichment for any element identified in this report and higher than all but one arsenic-enriched sample at Tracy Mountain (465X UCC, Moxness et al., 2021). On an ash basis, Sample 205A is 4989 ppm Ge, over 3000 times higher than UCC, which is the highest degree of enrichment yet identified in this study. Other elements with especially enriched individual carbonaceous samples include arsenic (68X UCC), molybdenum (57X), antimony (57X), barium (39X), and uranium (19X). Samples of beryllium, bismuth, tungsten, and zirconium can also exceed 10X UCC on an ash basis. Carbonaceous samples were, on average, lower than UCC in cerium, cesium, chromium, cobalt, hafnium, magnesium, manganese, rubidium, strontium, tantalum, thorium, tin, and titanium.

▼ **Table 6.** Concentrations in coals and carbonaceous mudstone in this report vs upper continental crust (UCC) and average world coal (AWC). E.g., the maximum antimony concentration identified in a coal or carbonaceous mudstone is 11.4 ppm, which is 57 times higher than the average UCC value (0.2 ppm) and 12 times higher than the average world coal (0.92 ppm). Abbreviations: n is the number of samples analyzed.

Enrichment coefficients of carbonaceous samples

				Coal vs UCC		Ash vs UCC				Coal vs AWC		Ash vs AWC ash	
			UCC	Dry Coal Basis		Dry Ash Basis		AWC (ppm)		Dry Coal Basis		Dry Ash Basis	
		n	(ppm)	MAX	MEAN	MAX	MEAN	whole	ash	MAX	MEAN	MAX	MEAN
Rare Earth Elements	Cerium	201	64	4.3	1.0	14.9	1.9	23	130	11.9	2.8	7.3	0.9
Rare Earth Elements	Dysprosium	71	3.5	7.6	2.4	26.7	5.5	2.1	14	12.7	4.0	6.7	1.4
Rare Earth Elements	Erbium	201	2.3	6.3	1.7	22.2	3.4	0.93	5.5	15.7	4.1	9.3	1.4
Rare Earth Elements	Europium	71	0.88	7.8	2.6	27.1	5.7	0.47	2.5	14.5	4.8	9.6	2.0
Rare Earth Elements	Gadolinium	201	3.8	8.0	1.7	27.9	3.5	2.7	16	11.2	2.4	6.6	0.8
Rare Earth Elements	Holmium	71	0.8	6.5	2.1	22.7	4.9	0.54	4	9.6	3.2	4.5	1.0
Rare Earth Elements	Lanthanum	201	30	4.3	1.0	14.9	1.9	11	69	11.6	2.8	6.5	0.8
Rare Earth Elements	Lutetium	71	0.32	5.7	2.2	20.0	4.9	0.2	1.2	9.2	3.4	5.3	1.3
Rare Earth Elements	Neodymium	201	26	5.0	1.2	17.4	2.3	12	67	10.8	2.6	6.7	0.9
Rare Earth Elements	Praseodymium	71	7.1	4.5	1.5	15.7	3.2	3.5	20	9.1	3.0	5.6	1.1
Rare Earth Elements	Samarium	71	4.5	6.2	2.1	21.6	4.5	2	13	13.9	4.7	7.5	1.6
Rare Earth Elements	Scandium	201	13.6	2.6	1.1	6.0	2.0	3.9	23	9.2	3.8	3.5	1.2
Rare Earth Elements	Terbium	71	0.64	7.3	2.2	25.5	5.0	0.32	2.1	14.6	4.4	7.8	1.5
Rare Earth Elements	Thulium	71	0.33	5.8	2.1	20.4	4.8	0.31	2	6.2	2.2	3.4	0.8
Rare Earth Elements	Ytterbium	71	2.2	5.5	2.1	19.1	4.7	1	6.2	12.0	4.5	6.8	1.7
Rare Earth Elements	Yttrium	201	22	5.9	1.5	20.5	3.2	8.4	51	15.4	4.0	8.8	1.4
Rare Earth Elements	Total REE	201*	160	5.3	1.3	18.5	2.6	72	427	11.7	3.0	6.9	1.0
	Antimony	48	0.2	57.0	21.8	260	45.6	0.92	6.3	12.4	4.7	8.3	1.4
	Arsenic	8	1.5	68.0	22.1	160	45.4	8.3	47	12.3	4.0	5.1	1.4
	Barium	42	550	39.3	4.0	63.8	6.4	150	940	144	14.6	37.3	3.7
	Beryllium	81	3	4.1	1.4	15.3	3.3	1.6	9.4	7.7	2.7	4.9	1.0
	Bismuth	8	0.127	4.4	2.5	10.4	4.6	0.97	5.9	0.6	0.3	0.2	0.1
	Cesium	50	4.6	2.6	1.0	3.0	1.4	1	6.6	12.0	4.6	2.1	1.0
	Chromium	94	83	1.9	0.8	3.6	1.3	16	100	9.8	4.1	3.0	1.1
	Cobalt	18	17	2.0	0.9	4.6	1.8	5.1	32	6.8	2.8	2.4	0.9
	Gallium	168	17	2.2	1.1	7.0	1.8	5.8	33	6.4	3.1	3.6	0.9
	Germanium	174	1.6	453	13.6	3118	39.1	2.2	15	329	9.9	333	4.2
	Hafnium	131	5.8	1.9	0.6	4.0	1.1	1.2	8.3	9.2	3.0	2.8	0.8
	Indium	8	0.05	1.8	n/a	3.3	n/a	0.031	0.16	2.9	n/a	1.0	n/a
	Lithium	61	20	4.5	1.5	5.2	2.4	12	66	7.5	2.6	1.6	0.7
	Magnesium	168	13300	2.1	0.6	5.3	1.0	n/a	n/a	n/a	n/a	n/a	n/a
	Manganese	8	600	0.8	0.3	1.6	0.6	86	490	5.4	2.1	1.9	0.7
	Molybdenum	172	1.5	57.2	8.0	109	17.7	2.2	14	39.0	5.5	11.7	1.9
	Niobium	166	12	4.3	1.1	6.0	2.0	3.7	20	14.0	3.6	3.6	1.2
	Rubidium	10	112	0.6	0.4	0.8	0.6	14	79	5.1	2.9	1.2	0.8
	Strontium	23	350	1.7	0.7	6.1	1.5	110	740	5.4	2.2	2.9	0.7
	Tantalum	48	1	1.5	0.8	2.0	1.2	0.28	1.7	5.5	2.7	1.2	0.7
	Tellerium	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Thorium	10	10.7	1.5	0.8	3.6	1.4	3.3	21	4.9	2.6	1.8	0.7
	Tin	8	5.5	0.4	0.3	0.6	0.4	1.1	6.4	1.9	1.3	0.5	0.4
	Titanium	152	4100	2.2	0.7	2.6	1.0	800	4650	11.1	3.4	2.3	0.9
	Tungsten	48	2	9.3	1.6	49.9	3.8	1.1	6.9	16.8	3.0	14.5	1.1
	Uranium	168	2.8	19.3	3.3	39.5	6.6	2.4	16	22.5	3.9	6.9	1.1
	Vanadium	166	107	3.8	1.2	6.7	2.1	25	155	16.3	5.3	4.6	1.4
	Zirconium	166	190	4.2	1.1	10.7	2.0	36	210	22.1	5.7	9.7	1.8

The concentrations in coal and carbonaceous mudstones can also be contrasted with values for average world coal (AWC; Ketris and Yudovich, 2009). Due to the clay-rich nature of carbonaceous beds in this study, especially those in the Hell Creek Fm., samples in this report have a relatively high ash yield and are generally more competitive with world coal on a whole basis. The highest samples of individual elements on a dry coal basis in this report were germanium (329X the AWC), barium (144X), molybdenum (39X), uranium (23X), zirconium (22X), tungsten (17X), vanadium (16X), niobium (14X), antimony (12X), arsenic (12X), cesium (12X), and titanium (11X). Average concentrations of every element examined in this report were higher than the average world coal except bismuth. Despite the high clay content, the average ash basis concentrations of samples in this report were higher than the average world coal ash in roughly half of the elements examined, led by germanium (4.2x AWC ash). The highest ash basis germanium sample was 333 times the average concentration in world coal ash. Ash-basis concentrations of barium (37.3x), tungsten (14.5x), and molybdenum (11.7x) were also significantly higher than AWC ash in individual samples.

REE Enrichment

Fourteen of the 23 most REE-enriched samples (dry coal basis) were from the T-U-V sample interval at Mud Buttes, a five-foot-thick carbonaceous mudstone containing thin coals that is present at the topographic highs (sites 64 and 255). Two more of the most enriched samples are from nearby topographic highs (sites 144 and 257). An additional three are from topographic highs at site 269 in Morton County and site 262 in Sioux County. The two stratigraphically highest coals at site 248 in Slope County are also enriched, including the most REE-enriched sample in this study (846 ppm), a four-inch-thick Ludlow coal within a 10-foot carbonaceous mudstone. The prevalence of REE enrichment below upland surfaces that may have been stable for millions of years was noted at Tracy Mountain by Moxness and others (2021).

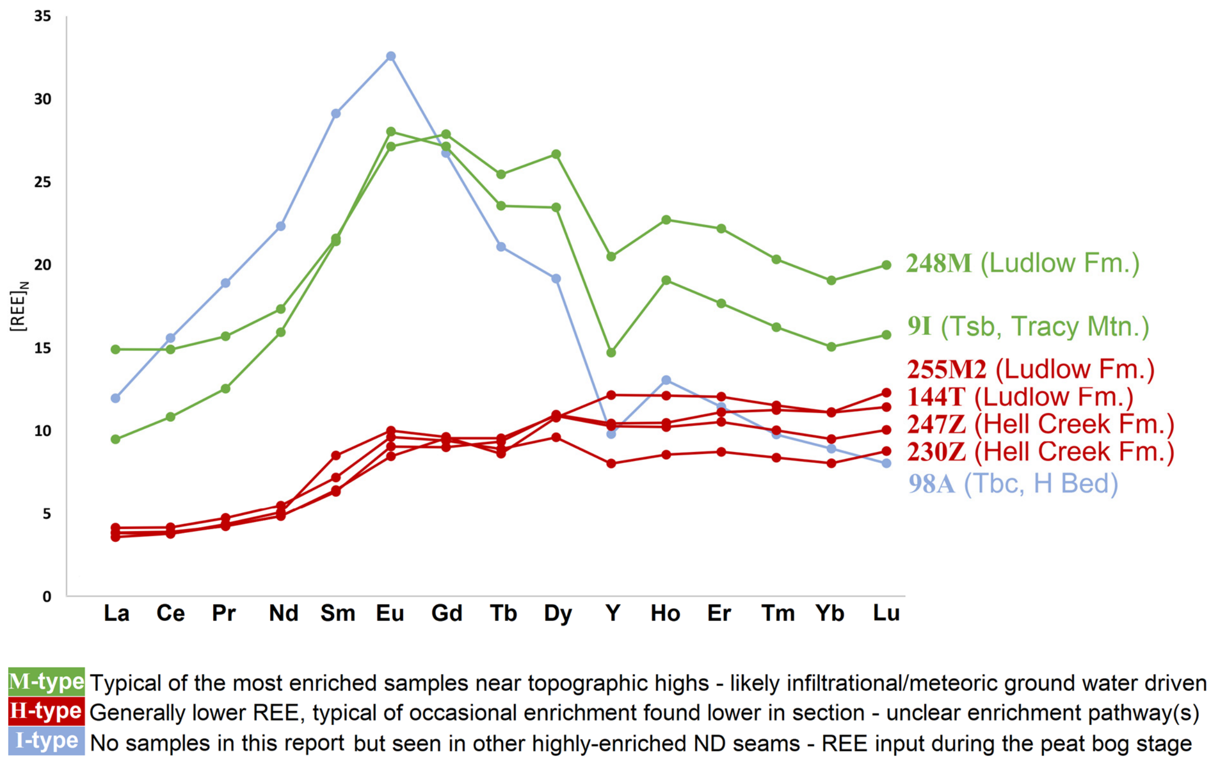
Like at Tracy Mountain, the main question for models explaining the high rare earth concentrations in the Ludlow Formation is one of stratigraphic vs topographic enrichment. In a scenario where the REE-enriched Ludlow samples are from a restricted stratigraphic zone, high REE concentrations likely represent a period of Paleocene time where REE-enriched waters were entering peat bogs or an extensive period of pedogenesis shortly thereafter. The high-REE samples occur over a wider stratigraphic range than would be expected in this model. At Mud Buttes, the T-U-V sample interval is approximately 180 feet above the K/Pg boundary, and 20 feet below the flat upland surface capping the tallest butte. Three miles away at Site 257 the upland surface is 145 feet lower stratigraphically. Here the enriched upper coal is only 35 feet above the K/Pg, but again 20 feet from the upland surface. In Slope County at Site 248, enrichment occurs from 15 to 45 feet below the top of a flat topographic high, at 85 to 55 feet above the K/Pg. At Site 269 in Morton County the enriched beds are some 75 feet below the top of the butte (95 ft above the K/Pg) but are still the highest carbonaceous beds in section.

The REE enrichment observed in this setting may have occurred as overlying volcanic sediments weathered and eroded during the Pliocene or Quaternary and descending REE-enriched groundwater encountered organic complexes in the first carbonaceous beds. Leaching in the intervening time may also have played a partial (or primary) role. Some upland surfaces in southwestern North Dakota, beyond the limits of Pleistocene continental glaciation, may have been stable since the Pliocene, subject to millions

▲ **Figure 18.** The shovel handle sticking out of the excavation marks the position of sample 258R near the summit of Sunset Butte in Bowman County. The thin coal (sample R) has a maximum of six feet (1.8 m) of cover and extends over an area of less than 2,000 square feet (185 m^2).

of years of chemical weathering from meteoric waters. Not all carbonaceous beds near topographic highs are enriched, however, and occasionally it is the second or third highest bed with the strongest enrichment. REE could be re-mobilized out of heavily weathered lignites that are very shallow, such as sample 258R at Sunset Butte (Figure 18). The geochemical and lithologic variability of the coals and overlying beds likely influence where REE are transported and deposited. It is also clear that this infiltrational model cannot explain enrichment seen in beds in lower parts of sections in this report and elsewhere, such as the H bed in Slope County, which is heavily enriched despite hundreds of feet of overburden including 25 or more feet of coal with effectively no REE enrichment (Kruger et al., 2017; Murphy et al., 2018).

Seredin and Dai (2012) described three normalized REE distribution patterns: L-type (which are preferentially enriched in the light REE), M-type (medium), and H-type (heavy) in high-REE coals (>0.1% rare earth oxide content (REO) in the ash). These patterns are classified using the ratios of individual REE concentrations (on an ash basis) normalized to upper continental crust ($[REE]_N$). Of the 25 samples projected to contain over 0.1% REO in this study, 18 were analyzed for all of the lanthanide elements (excluding promethium) and yttrium. Of these 18 samples, 12 are M-type ($La_N/Sm_N < 1$ and $Gd_N/Lu_N > 1$) and six are H-type ($La_N/Lu_N < 1$ and $Gd_N/Lu_N < 1$) using the classification of Seredin and Dai (2012), who



▲**Figure 19.** Normalized REE distribution patterns for selected samples. Most of the enriched samples near topographic highs are preferentially enriched in the medium REEs vs upper continental crust (McLennan, 2001), as are the highest samples from Tracy Mountain (Moxness et al., 2021). Samples from lower in the section tend to be less enriched overall and contain a higher proportion of the heavy REES. The most enriched bed in the overall study, the H bed, is enriched in the light REEs (Murphy et al., 2018).

linked these patterns to different genetic types of enrichment: terrigenous, tuffaceous, infiltrational, or hydrothermal. Medium REE enrichment is overwhelmingly represented in Ludlow Fm. samples near topographic highs, which was also seen in 19 of 23 samples over 0.1% REO near the Tracy Mountain highs. The highest of the 12 M-type samples in this report, Sample 248M, and the highest of the 19 comparable samples from Tracy Mountain (Sample 9I), are shown in Figure 19. Preferential enrichment of the medium REEs is what would be expected below a surface subjected to natural acidic meteoric waters in an infiltrational enrichment model.

A few enriched samples (>300 ppm REE dry coal basis or >0.1% REO ash basis) occur in lower portions of sections, with no obvious proximity to an upland surface. Where these topographically lower samples do meet the enrichment criteria, they are rarely significantly over 300 ppm, and oftentimes below it, but are particularly low in ash yield resulting in high ash-basis REE/REO values. These samples are significantly more likely to be H-types. The highest four H-type samples, two from the lower Ludlow Fm. and two from the Hell Creek Fm., are also shown in Figure 19. Preferential enrichment of the heavy rare earths can occur in any of Seredin and Dai's genetic types, so it is not a particularly diagnostic characteristic in establishing likely enrichment pathways, but it is noted as the most common distribution pattern in REE-rich coal ashes.

Conclusions

Cretaceous volcanic ashes and bentonites in southwestern North Dakota are not enriched in rare earth elements, and the lack of REE enrichment in stratigraphically adjacent lignites and carbonaceous mudstones suggests the weathering of this volcanic material did not play a major role in rare earth enrichment seen regionally. Relative to lignites, the Marmarth, Breien, and Linton volcanic ashes are also low in most of the other 28 elements examined in this report, but can contain high concentrations of manganese, rubidium, tantalum, and thorium. Elemental concentrations in bentonites, mostly from the Hell Creek Fm., were similar to those in the volcanic ashes although depleted in manganese. On average, several elements were more enriched in the 5 to 12 bentonite samples than in carbonaceous beds in this report, notably cerium, lanthanum, cobalt, gallium, hafnium, lithium, magnesium, niobium, rubidium, tantalum, thorium, tin, titanium, and tungsten. Many of these elements correlate more closely to the inorganic (clay) fraction of samples and are not considered among the most promising for production from coal (Dai and Finkelman, 2018), with the exception of gallium, magnesium, and niobium, for which the highest individual sample is from a lignite. Assorted nodules and concretions were also generally low in all elements, with the exception of manganese in Fe/Mn oxide nodules, one of which was also particularly high in tungsten. A sample of small nodules collected from a bentonite in the Hell Creek Fm. was also very high in antimony, arsenic, and tungsten.

Overall rare earth element concentrations in the carbonaceous beds were similar in their distribution and topographic context to those at Tracy Mountain (Moxness et al., 2021). REE concentrations were generally low to moderate, with occasional samples exceeding 300 ppm (dry coal basis) or 0.1% REO (ash basis), but the upper portions of many measured sections contained one or multiple REE-enriched beds with higher degrees of enrichment. These samples do not correlate to a defined stratigraphic zone, but rather were usually in close proximity to an identifiable flat, stable upland surface. This supports the idea that waters transported REE and associated elements downward from the upland surface to the uppermost carbonaceous beds, either during the erosive period(s) that created the uplands or during the long-term weathering of the surface by weakly acidic meteoric waters in the intervening time. Although this is the most likely enrichment model for the majority of elevated REE concentrations observed in this report, high REE concentrations also occur outside of this setting, represented by a few samples in this report and heavily REE-enriched examples from other sites (Murphy et al., 2018). It therefore appears clear that multiple modes of enrichment influence the REE and other critical mineral contents of North Dakota lignites.

References

Artzner, D.G., 1974, Palynology of a volcanic ash in the Fox Hills Formation (Maastrichtian) of Emmons, Morton, and Sioux Counties, North Dakota: M.S. thesis, Kent State University, 122 p.

Carlson, C.G., 1979, Geology of Adams and Bowman Counties, North Dakota: North Dakota Geological Survey, Bulletin 65, part. 1, 29 p.

Carlson, C.G., 1982, Geology of Grant and Sioux Counties, North Dakota: North Dakota Geological Survey, Bulletin 67, part 1, 32 p.

Carlson, C.G., 1983, Geology of Billings, Golden Valley, and Slope Counties, North Dakota: North Dakota Geological Survey, Bulletin 76, part 1, 40 p.

Clayton, Lee, 1980, Geologic Map of North Dakota: U.S. Geological Survey, 1:500,000 scale.

Dai, S., and Finkelman, R.B., 2018, Coal as a promising source of critical elements: Progress and future prospects; International Journal of Coal Geology, no. 186, p. 155–164

Feldmann, R.M., 1972, Stratigraphy and Paleoecology of the Fox Hills Formation (Upper Cretaceous) of North Dakota: North Dakota Geological Survey, Bulletin 61, 65 p.

Forsman, N.F., 1992, Tuffs in North Dakota in Erickson, J.M. and Hoganson, J.W., eds., Proceedings of the F.D. Holland, Jr., Geological Symposium: North Dakota Geological Survey Miscellaneous Series 76, pp. 267-272.

Groenewold, G.H., 1971, Concretions and Nodules in the Hell Creek Formation in Southwestern North Dakota: Unpublished Master's Thesis, University of North Dakota, 84 p.

Hoganson, J.W., and Murphy, E.C., 2002, Marine Breien Member (Maastrichtian) of the Hell Creek Formation in North Dakota – Stratigraphy, vertebrate fossil record, and age, in Hartman, J.H., Johnson, K.R., and Nichols, D.J., eds., The Hell Creek Formation and the Cretaceous-Tertiary boundary in the Northern Great Plains – an integrated continental record of the end of the Cretaceous: Geological Society of America Special Paper 361, pp. 247-270.

Ketris, M.P., Yudovich, Y.E., 2009, Estimation of Clarkes for carbonaceous biolithes: world average for trace element contents in black shales and coals: International Journal of Coal Geology, v. 78, p. 135-148.

Kruger, N.W, Moxness, L.D., and Murphy, E.C., 2017, Rare Earth Element Concentrations in Fort Union and Hell Creek Strata in Western North Dakota: North Dakota Geological Survey Report of Investigation no. 117, 104 p.

Kruger, N.K., 2020, Reducing Laboratory Costs by Estimating Total Rare Earth Concentrations from Seven or Fewer Analyzed Elements in Western North Dakota Coals: Geological Society of America Abstracts with Programs, v. 52, no. 6.

McLennan, S.M., 2001. Relationships between the trace element composition of sedimentary rocks and upper continental crust. Geochemistry, Geophysics, Geosystems 2, 1021.

Moxness L.D., Murphy, E.C., and Kruger, N.W., 2021, Rare Earth and Other Critical Element Concentrations in the Sentinel Butte Formation, Tracy Mountain, North Dakota: North Dakota Geological Survey Report of Investigation no. 128, 65 p.

Moxness, L.D., Kruger, N.W., and Murphy, E.C., 2022, Critical Elements in North Dakota Lignites, Lignite Research Council White Paper: North Dakota Geological Survey, 19 p.

Murphy, E.C., Nichols, D.J., Hoganson, J.W., and Forsman, N.F., 1995, The Cretaceous\Tertiary Boundary in south-central North Dakota: North Dakota Geological Survey, Report of Investigation no. 98, 74 p.

Murphy, E.C., Hoganson, J.W., and Johnson, K.R., 2002, Lithostratigraphy of the Hell Creek Formation in North Dakota: In The Hell Creek Formation and the Cretaceous-Tertiary boundary in the northern Great Plains: An Integrated continental record of the end of the Cretaceous; Special Paper 361. Hartman, J.H., Johnson, K.R., and Nichols, D.J., editors, pp. 9–34, Geological Society of America.

Murphy, E.C., 2005, Areas of Volcanic Ash, Linton 110K Sheet, North Dakota: North Dakota Geological Survey, 100K Series: Lntn-va.

Murphy, E.C., Moxness, L.D., Kruger, N.W., and Maike, C.A., 2018, Rare Earth Element Concentrations in the Harmon, Hanson, and H Lignites, in Slope County, North Dakota: North Dakota Geological Survey Report of Investigation no. 119, 46 p.

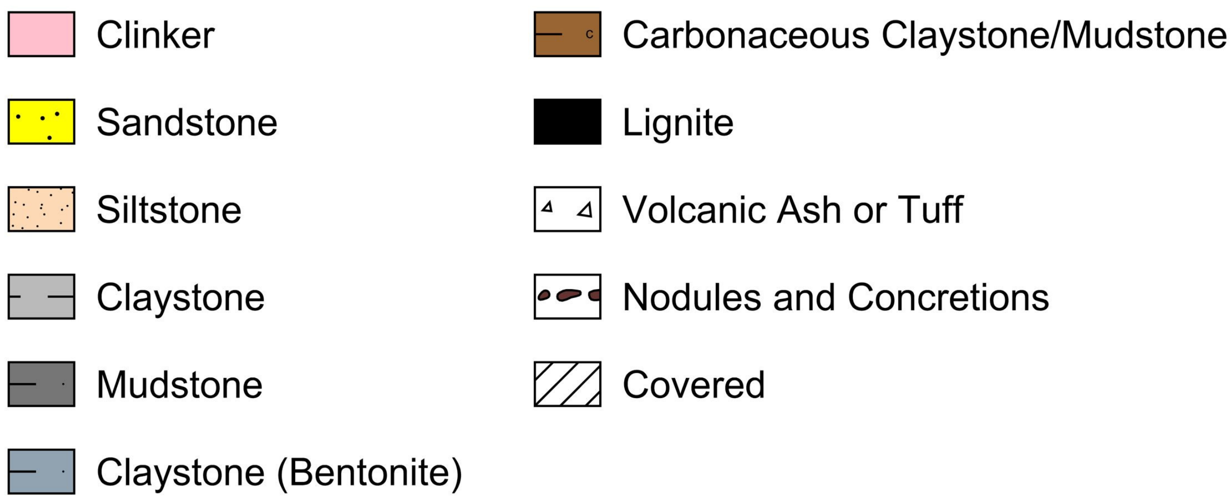
Taylor, S.R., and McLennan, S.M., 1985, The Continental Crust – Its Composition and Evolution: Blackwell, Oxford, 312p.

Seredin, V.V., and Dai, S., 2012, Coal deposits as potential alternative sources for lanthanides and yttrium: International Journal of Coal Geology, v. 94, p. 67-93.

Appendices

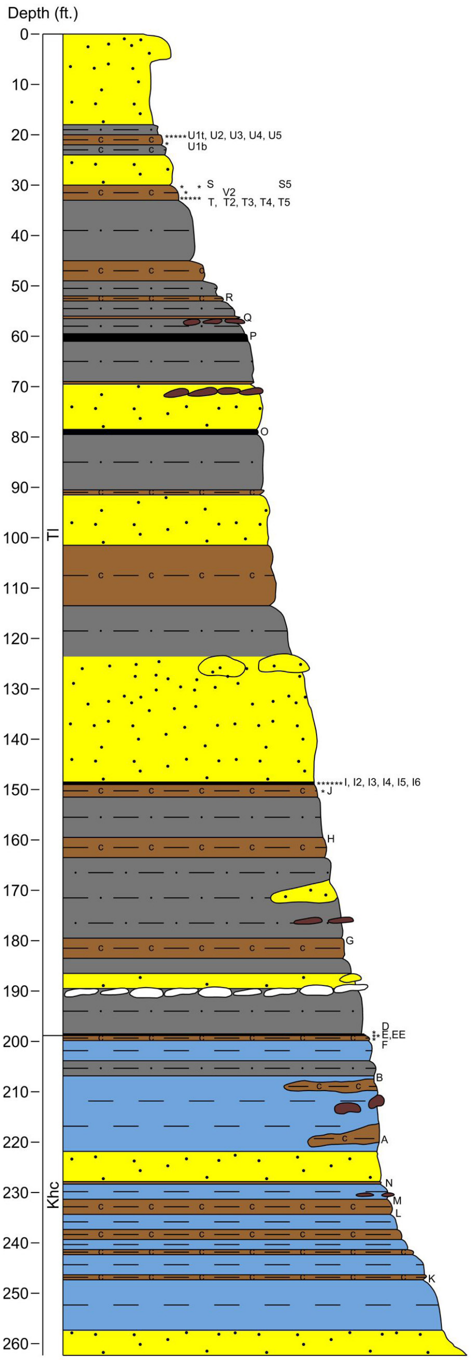
Appendix A

Legend for lithologies of measured sections



REE Section 64

T.129N., R.105W., Sec.2, SE/SE
Elevation at top 3,300 ft.

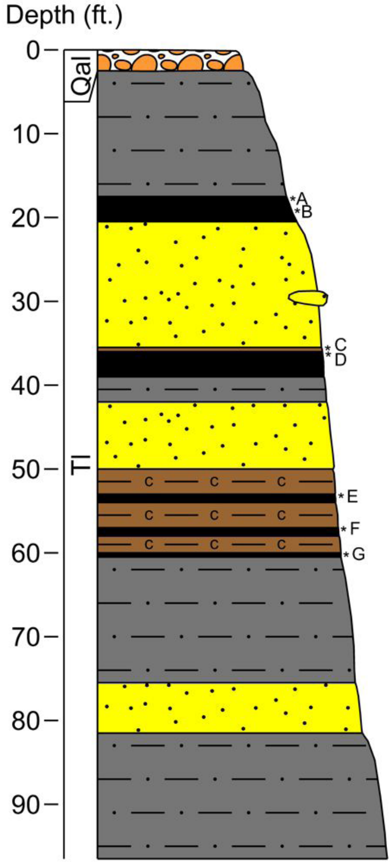


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
64U1t	120	11.9	6.23	3.42	14.3	2.24	43.9	0.80	69.6	16.7	15.2	20.2	2.08	0.84	5.34	50.2	383	668
64U2	139	15.4	9.19	3.50	15.6	3.22	62.7	1.19	63.6	15.7	13.6	27.0	2.57	1.26	7.98	91	473	1260
64U3	134	11.6	6.33	3.21	13.7	2.24	55.6	0.8	68.8	17.1	14.5	17.7	2.04	0.87	5.56	55.3	409	681
64U4	165	14.7	7.8	4.03	17.9	2.81	56.2	0.96	87.7	21.4	18.5	17.5	2.58	1.05	6.61	69	494	914
64U5	182	13.9	7.1	4.45	17.4	2.56	67.5	0.93	91.8	22.4	20.6	24.1	2.55	0.99	6.55	54.9	520	1066
64U1b	201	20.0	10.3	5.54	22.6	3.67	64.2	1.29	111	27.0	24.9	23.8	3.45	1.42	8.86	83.8	613	1443
64S	94.6	6.7	4.02	1.67	7.4	1.39	47.5	0.56	41.5	11.2	8.0	11.1	1.14	0.58	3.74	40	281	321
64S5	48.9	3	2.09	0.83	3.2	0.65	28.2	0.34	20	5.5	3.7	16.4	0.48	0.33	2.25	17.7	154	174
64V2	163	19.4	11.0	4.80	20.7	3.86	68.0	1.47	86.3	20.8	19.4	26.3	3.22	1.50	9.46	99.0	558	1432
64T	129	13.5	7.86	3.08	13.6	2.79	65.1	1.02	58.4	15.2	12.0	20.8	2.22	1.08	6.82	79	431	927
64T2	206	22.8	12.3	6.50	25.1	4.36	83.9	1.64	114	27.4	25.8	30.7	3.87	1.69	10.8	101	678	1580
64T3	83.3	8.7	5.46	2.28	9.3	1.81	42.9	0.8	41.5	10.1	9.1	20	1.44	0.78	5.26	48.6	291	720
64T4	127	13.1	7.57	3.71	15.1	2.59	62.9	1.04	65.9	16.1	14.8	20.3	2.24	1.03	6.83	63.3	424	950
64T5	82.9	8.6	5.43	2.18	8.9	1.78	39.4	0.8	40.4	10	8.9	19.6	1.4	0.78	5.24	44.3	281	1005
64R	56.1	4.8	3.29	1.13	4.8	1.08	28.9	0.50	25.1	6.7	4.9	13.9	0.77	0.48	3.23	31	187	228
64Q	83.1	9.5	6.20	2.52	9.8	2.07	38.7	0.95	43.6	10.5	9.4	19.6	1.53	0.91	5.99	52	296	547
64P	5.7	1.9	1.62	0.32	1.3	0.49	2.8	0.28	3.3	0.8	0.9	9.3	0.26	0.25	1.72	13	44	194
64O	41.6	7.0	4.71	1.40	5.9	1.56	18.1	0.70	21.8	5.4	5.2	15.8	1.05	0.68	4.54	43	178	344
64I	131	9.5	4.96	3.20	11.6	1.82	60.7	0.60	59.3	15.4	11.6	16.6	1.72	0.67	4.08	46	379	415
64I2	78.7	6.5	3.55	2.14	8.1	1.22	34.9	0.5	43.5	10.5	9.6	19.3	1.17	0.51	3.39	27.4	251	311
64I3	70.5	8.7	5.53	2.04	8.8	1.82	31	0.8	38.7	9.5	8.8	26.4	1.41	0.81	5.42	44.6	265	443
64I4	46.4	5.1	3.14	1.49	5.9	1.03	19.8	0.49	29.2	6.7	6.7	18.5	0.87	0.46	3.3	21.8	171	398
64I5	94.9	9.7	5.22	3.26	11.3	1.85	39.5	0.66	51.5	12.5	11.1	17.0	1.69	0.70	4.41	48.7	314	432
64I6	45	2.8	1.79	1.31	3.3	0.57	25.1	0.3	20.5	5.3	4	14.8	0.46	0.27	1.91	13.3	141	157
64J	63.6	6.9	4.21	1.85	7.0	1.40	27.1	0.64	32.3	8.1	7.2	13.1	1.14	0.62	4.14	35	214	409
64H	43.9	3.9	2.31	1.26	4.5	0.78	21.9	0.36	22.8	5.6	4.9	15.3	0.67	0.34	2.30	18	149	246
64G	54.6	4.3	2.67	1.17	4.5	0.88	27.8	0.41	24.1	6.4	4.8	15.0	0.72	0.39	2.59	23	173	261
64D	15.3	3.6	2.22	0.72	3.1	0.74	5.8	0.36	10.0	2.2	2.8	9.8	0.56	0.33	2.31	15	75	434
64E	6.6	1.1	0.87	0.19	0.7	0.26	4.1	0.16	2.7	0.7	0.6	23.7	0.15	0.14	0.99	6	49	57
64EE	20.8	1.9	1.32	0.47	1.7	0.42	10.3	0.23	9.3	2.5	1.9	19.0	0.30	0.21	1.41	11	83	96
64F	37.3	2.8	1.83	0.80	2.9	0.59	18.8	0.29	16.7	4.4	3.2	16.7	0.46	0.27	1.89	15	124	147
64B	52.5	4.0	2.48	1.15	4.4	0.82	26.9	0.38	24.5	6.3	4.8	19.0	0.67	0.36	2.45	21	172	188
64A	52.5	4.0	2.48	1.14	4.3	0.82	26.5	0.38	24.1	6.3	4.7	18.5	0.67	0.37	2.44	20	169	184
64N	51.0	3.7	2.11	1.20	4.3	0.71	25.0	0.32	25.0	6.4	5.0	18.7	0.64	0.31	2.06	17	163	176
64M	53.4	4.0	2.42	1.15	4.4	0.81	26.8	0.37	24.4	6.4	4.8	17.8	0.66	0.36	2.39	21	171	183
64L	34.8	3.0	1.92	0.86	3.2	0.64	15.5	0.31	16.7	4.2	3.4	17.2	0.50	0.29	1.97	14	118	138
64K	52.0	4.9	3.21	1.21	4.9	1.06	25.3	0.47	24.1	6.3	5.0	20.0	0.79	0.45	2.99	30	183	223

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
64U1t																												
64U2																												
64U3																												
64U4	6.28		2110	4.9		3.50	58		15.5	21	7.1		37.8	6910		43.0	24.3		126	0.68				1840	4.9	50.4	134	434
64U5	8.37		545	4.1		3.98	64	6.2	14.4	14	5.6		23.6	3500		57.9	14.0			0.69				1970	4.2	53.9	181	356
64U1b	8.11	102	528	6.4	0.56	2.11	71	11.4	10.7	8	3.6	0.06	19.9	7990	74	33.3	9.3	22	179	0.55	0.15	16.3	1.3	1860	3.5	24.8	87	186
64S																												
64S5	2.11		814	2.5		12.0	101		25.4	3	3.9		43.4	11700		2.5	13.6		130	0.97				4340	2.0	8.0	189	145
64V2	6.08		551	7.0		1.87	46	30.5	12.8	8	3.7		7.2	4990		26.3	8.5			0.30				908	4.6	10.2	123	172
64T																												
64T2	8.29	36.0	2230	6.9	0.39	2.53	68	32.2	30.9	10	10.0	0.07	17.3	5550	65	34.9	16.6	23	537	0.56	0.16	8.2	1.3	2010	11.7	18.4	145	768
64T3																												
64T4	9.58		1430	4.9		2.89	61		17.5	7	7.6		14.8	4550		36.5	16.9		594	0.56				1900	4.2	11.2	151	529
64T5	4.04		529	4.6		1.67	45		12.6	5	4.3		9.7	3870		19.0	7.4		286	0.30				984	4.9	11.4	60	259
64R	1.78		409	6.1		7.77	51		17.0	2	3.0		44.2	12600		3.7	15.1		416	1.30				3690	2.4	6.0	80	117
64Q																												
64P																												
64O																												
64I	1.78		14800	5.3		9.21	141		22.2	10	3.4		78.7	14800		2.6	10.6		209	0.84				3810	1.2	9.3	282	184
64I2	3.44		1140	4.0		10.2	131	11.3	20.0	7	3.4		32.3	9490		8.9	8.4			0.93				3250	1.3	13.8	247	209
64I3	2.31		1430	3.2		2.74	157		19.8	43	4.7		23.9	5840		9.0	7.2		249	0.63				2400	4.7	16.8	279	388
64I4																												
64I5	3.64	18.8	20100	3.1	0.50	7.30	148	21.7	18.3	8	4.1	0.07	35.6	9360	248	8.8	8.2	68	202	0.66	0.11	10.1	2.0	3740	2.1	35.1	407	382
64I6																												
64J																												
64H																												
64G																												
64D																												
64E																												
64EE																												
64F	1.67		853	2.5		5.04	77		22.0	2	3.4		65.3	4870		4.8	10.5		116	0.77				4910	1.6	3.8	136	133
64B	3.37		661	2.3		7.88	93		21.6	6	3.5		47.1	7340		6.4	12.3		94	0.94				4370	1.3	4.3	169	127
64A	2.67		892	1.9		7.75	82		20.0	4	3.5		34.7	6570		4.9	12.1		100	0.91				4060	1.3	4.9	142	127
64N																												
64M																												
64L	3.26		766	2.2		7.44	97		20.9	5	3.8		41.7	5630		7.2	12.2		118	0.93				4510	1.3	5.7	174	140
64K																												

REE Section 120

T.134N., R.105W., Sec.16, SE/SE
Elevation at top 2,794 ft.

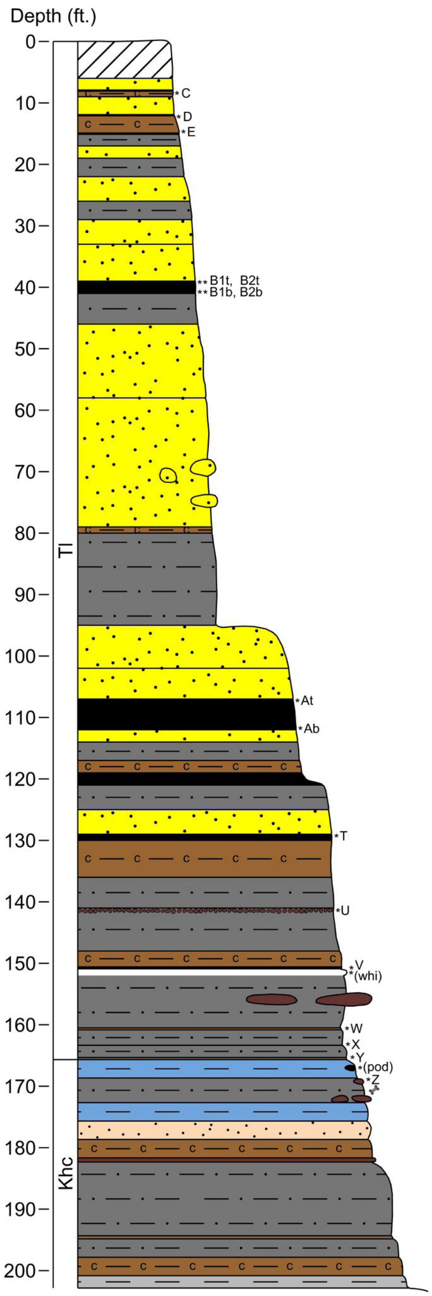


SAMPLE ID	LAB ANALYSIS (in µg/g)															TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
120A	67.2	5.0	2.80	1.51	6.0	0.95	27.4	0.40	31.9	8.1	6.2	7.3	0.84	0.38	2.54	24.9	193	574
120B	28.5	3.0	1.96	0.68	3.0	0.64	14.6	0.28	12.7	3.3	2.6	3.5	0.47	0.27	1.73	22.7	100	461
120C	81.7	3.2	1.79	1.20	4.7	0.58	38.2	0.27	33.8	9.2	6.1	7.1	0.59	0.25	1.79	15.6	206	224
120D	30.2	2.7	1.81	0.62	2.6	0.58	17.5	0.27	11.5	3.1	2.3	4.5	0.41	0.26	1.70	19.0	99	319
120E	15.2	1.5	0.99	0.42	1.6	0.31	7.1	0.15	7.4	1.9	1.6	4.3	0.23	0.14	0.94	8.7	52	142
120F	12.9	1.4	0.83	0.39	1.6	0.27	5.5	0.12	6.9	1.7	1.6	4.7	0.23	0.11	0.78	7.3	46	166
120G	40.9	2.7	1.40	1.23	3.6	0.48	18.9	0.20	21.1	5.2	4.4	8.9	0.49	0.19	1.32	11.6	123	321

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
120A								6.1		5						6.8												
120B								11.1		2						12.3												
120C	0.71	4.9	740	1.5	0.16	4.40	38	5.5	13.6	2	2.7	0.04	27.4	5950	81	0.8	14.1	71	146	1.14	<0.10	8.9	1.6	3130	1.5	3.9	52	97.6
120D								5.5		6						4.3												
120E								4.3		1						22.4												
120F								3.0		1						8.9												
120G								3.6		27						20.9												

REE Section 144

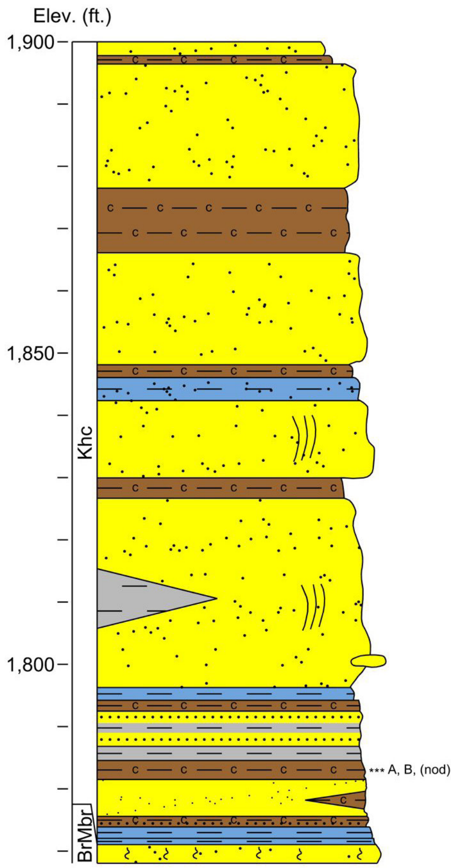
T.130N., R.105W., Sec.35, SE/SE
Elevation at top 3,328 ft.



SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
144C	80.1	4.2	2.45	1.23	5.2	0.82	41.7	0.34	33	8.8	6.2	11.6	0.74	0.35	2.35	22.4	221	248
144D	73.3	7	4.53	1.67	7.1	1.47	37.8	0.65	33.5	8.5	7.1	22.3	1.12	0.65	4.4	42.2	253	339
144E	273	21.7	11.4	6.61	25.7	4.12	124	1.4	125	30.7	26.2	35.7	3.83	1.53	9.79	107	808	1313
144B1t	48.4	6.1	4.37	1.14	5.2	1.36	26.4	0.67	21.3	5.4	4.6	12.3	0.9	0.65	4.43	42.6	186	342
144B2t	29.2	3.8	2.77	0.77	3.3	0.87	15.2	0.41	13.1	3.3	2.9	10.1	0.56	0.4	2.69	25.9	115	277
144B1b	42.3	4.2	2.9	0.96	4	0.91	26.2	0.44	18.1	4.6	3.7	7.7	0.65	0.42	2.79	27.1	147	302
144B2b	11.5	4.5	3.5	0.66	3.2	1.09	5.9	0.52	7	1.5	2.1	11.1	0.62	0.51	3.33	33.4	90	421
144At	49.6	4.9	2.98	1.4	5.4	1	22.3	0.44	25.8	6.3	5.8	8.8	0.82	0.43	2.91	24	163	405
144Ab	86.2	8.6	4.98	2.35	9.3	1.71	39.2	0.65	42	10.2	9.3	15.3	1.45	0.69	4.42	44.3	281	818
144T	62.7	7.9	4.72	1.99	8.4	1.61	29.2	0.66	33.6	7.9	7.6	12.7	1.34	0.65	4.16	41.5	227	967
144U	32.2		1.87		3.5		15.7		16.6			9.5				15.6	*110*	*203*
144V	12.7		2.17		2.2		6.8		6.7			10.0				19.2	*70*	*297*
144(whi)	19.6		0.87		1.7		13.2		8.9			4.3				9.7	*66*	*85*
144W	56.5		2.43		4.3		29.3		25.3			15.4				19.4	*173*	*205*
144X	63.2		2.87		5.3		32.6		28.6			16.9				24.2	*198*	*234*
144Y	48.8		2.72		4.1		25.7		22.0			13.7				22.8	*160*	*185*
144(pod)	32.1		2.62		3.3		17.0		15.2			14.2				22.5	*123*	*214*
144Z	49.1		2.18		4.2		25.9		22.8			17.8				18.5	*160*	*177*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
144C																												
144D																												
144E	6.79	22.4	21600	6.3	0.52	4.39	91	33.3	27.6	19	7.5	0.09	32.0	6720	24	40.2	17.2	45	310	0.80	0.11	14.5	2.1	2860	4.0	20.1	153	574
144B1t	8.11	102	528	6.4	0.56	2.11	71	11.4	10.7	8	3.6	0.06	19.9	7990	74	33.3	9.3	22	179	0.55	0.15	16.3	1.3	1860	3.5	24.8	87	186
144B2t																												
144B1b	2.11		814	2.5		12.0	101		25.4	3	3.9		43.4	11700		2.5	13.6		130	0.97				4340	2.0	8.0	189	145
144B2b	5.60		105	6.7		0.25	30		9.1	50	3.8		11.3	6520		18.6	9.1		457	0.28				794	1.9	11.3	68	436
144At																												
144Ab	6.00		1220	3.1		1.24	51		15.5	10	3.8		13.2	3270		10.0	9.2		319	0.38				1550	4.6	9.0	95	252
144T				3.3			21		9.5	4	1.4			2570		22.6	2.5							402		12.9	59	90.1
144U				2.1			58		11.8	9	3.1			5900		12.7	11.4							1670		4.6	146	236
144V				8.4			21		10.2	13	1.9			3930		12.1	5.3							987		7.9	66	118
144(whi)	0.41	3.9	402	0.6	<0.1	0.91	25	7.1	6.0	1	0.7	<0.02	9.2	4530	6290	0.3	3.4	22	167	0.23	<0.1	2.5	0.6	1350	5.9	1.6	34	23.4
144W				2.6			89		19.4	13	4.1			7700		6.0	13.9							3640		5.2	174	254
144X				3.2			91		19.6	5	4.2			9570		5.5	13.4							3920		5.3	164	206
144Y				3.2			68		17.3	5	3.5			6110		4.1	13.1							3900		5.3	113	158
144(pod)				3.4			103		26.3	724	6.0			6650		85.8	41.4							3320		12.4	326	794
144Z				2.1			92		20.5	5	3.4			8840		3.7	11.6							4110		3.8	161	125

REE Section 205
Morton County

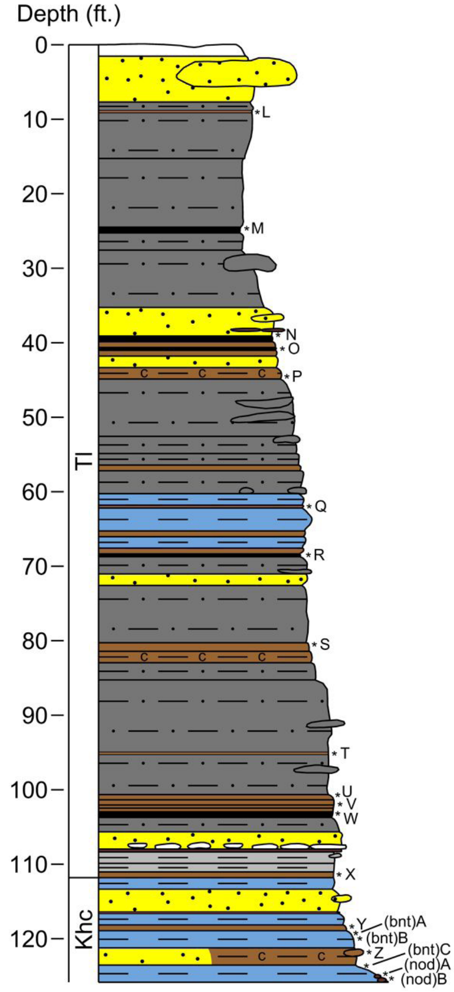


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
205A	30		2.4		4.1		12.5		17.0			6.5				18.3	*108*	*798*
205B	46.9		2.67		4.5		23.4		22.4			13.2				24.9	*158*	*175*
205(nod)	13.7		1.76		2.2		8.0		7.4			3.7				19.2	*66*	*82*

SAMPLE ID	LAB ANALYSIS (in µg/g)																										
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
205A				2.1		0.31			16.2	675			7.5	2650				4				1.8		1200		5.3		
205B				3.1		3.44			20.3	7			38.2	5000				31				9		4410		3.1		
205(nod)				2.1		1.24	17		4.0	1				7140	14800	0.2	2.1							694		1.2	22	18.7

REE Section 230

T.139N., R.105W., Sec.12, NW1/4
Elevation at top 3,239 ft.

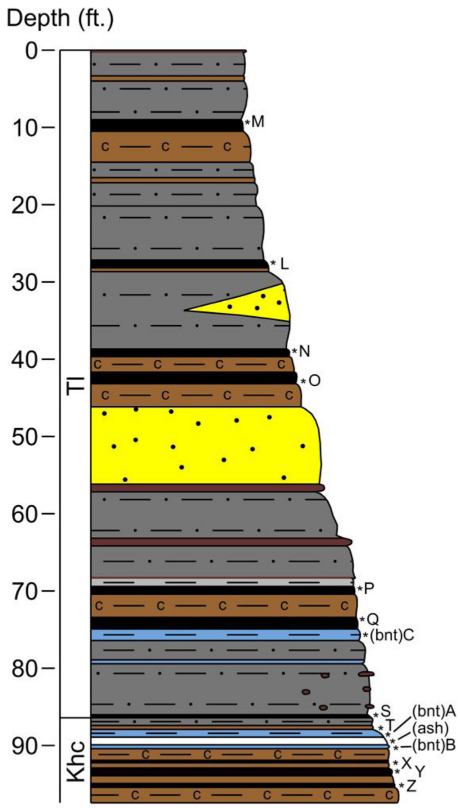


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
230L	64.0		2.40		4.7		32.0		28.7			16.5				21.5	*192*	*204*
230M	21.5		3.29		3.4		11.0		11.1			12.9				32.2	*112*	*251*
230N	26.9		2.96		3.5		13.8		13.4			11.7				29.9	*119*	*317*
230O	43.9		2.31		5.5		16.5		25.4			14.2				19.9	*149*	*706*
230P	49.4		2.59		4.5		25.2		23.1			16.0				22.9	*164*	*209*
230Q	52.6		2.16		4.3		27.1		24.1			15.4				19.7	*165*	*178*
230R	33.4		3.70		3.8		18.7		14.8			17.0				33.7	*144*	*267*
230S	43.1		2.35		4.6		19.1		24.3			16.4				19.0	*149*	*225*
230T	55.6		2.19		4.4		29.8		25.4			17.0				19.8	*174*	*200*
230U	55.5		1.91		4.0		27.8		24.1			10.9				18.5	*161*	*187*
230V	49.0		3.27		5.1		25.9		22.3			10.4				33.0	*172*	*576*
230W	27.2		2.69		3.4		13.8		13.5			8.0				27.6	*112*	*433*
230X	52.4		1.99		4.3		24.9		24.3			12.8				17.2	*157*	*166*
230Y	41.1		1.87		3.3		20.9		18.6			12.1				17.0	*130*	*189*
230(bnt)A	70.1		2.71		5.7		35.2		31.7			14.4				26.9	*212*	*225*
230(bnt)B	37.7		1.62		3.2		18.9		17.2			17.1				13.3	*123*	*129*
230Z	78.0	12.0	7.99	2.49	10.7	2.62	36.1	1.23	39.4	9.4	8.9	21.0	1.87	1.16	7.65	71.8	312	1001
230(bnt)C	42.6		1.72		3.2		21.2		19.2			17.6				15.1	*136*	*141*
230(nod)A	15.6		0.97		1.8		9.3		7.6			3.2				12.9	*59*	*70*
230(nod)B	16.6		2.84		3.0		10.3		8.5			5.1				40.3	*101*	*108*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
230L			521				88		25.3	15			33.7	9370		3.7	14.0							3880		5.1	146	190
230M			692				34		13.5	11			24.0	12900		13.4	6.3							1450		5.7	78	191
230N			282				42		12.1	12			15.3	4160		10.0	10.9							1360		6.5	118	344
230O			214				63		10.4	11			9.9	1500		12.1	14.2							825		7.4	152	236
230P			616				87		20.2	5			33.5	6760		6.8	12.1							3370		5.6	164	186
230Q			653				94		20.2	2			41.6	8940		1.6	11.1							3920		3.0	138	136
230R			1630				43		20.5	16			51.9	2950		16.9	17.4							4140		11.1	87	228
230S			924				91		19.6	12			21.8	6350		12.7	11.8							3040		11.8	233	302
230T			1120				117		23.4	5			44.2	12700		3.2	12.6							4320		5.4	233	238
230U			754				56		15.5	3			25.2	6310		3.0	9.8							3160		5.5	90	133
230V			1040				30		14.4	9			17.9	2720		14.8	14.8							982		12.6	70	118
230W			1330				21		12.2	10			13.0	2570		23.3	4.9							975		14.1	80	69.9
230X			623				80		20.9	2			25.5	10400		2.1	12.0							3610		4.1	112	125
230Y			932				57		24.6	360			17.3	7490		9.3	43.4							2810		4.4	146	438
230(bnt)A	1.28	8.9	753	2.1	0.25	5.67	80	15.5	21.4	2	3.7	0.06	37.3	10200	209	2.1	13.1	83	150	1.05	<0.1	13.2	2.2	3860	1.7	3.8	120	116
230(bnt)B	1.53	8.6	758	1.4	0.25	7.15	92	34.4	22.6	2	3.4	0.06	25.2	6300	85	1.4	12.3	79	114	0.89	<0.1	9.5	1.9	4450	2.2	3.5	146	114
230Z			1070				63		20.6	41			12.1	1760		51.2	13.0							1230		11.0	135	293
230(bnt)C	1.71	22.0	569	1.5	0.28	7.14	89	21.8	22.6	1	3.5	0.06	27.4	6560	86	1.3	11.6	72	104	0.85	<0.1	9.4	1.9	4230	1.7	2.8	149	118
230(nod)A	0.50	2.8	511	1.4	<0.1	0.99	16	5.6	3.5	1	0.4	<0.02	7.4	3000	13400	0.4	2.0	13	190	0.13	<0.1	1.5	0.4	558	0.6	1.7	25	15.1
230(nod)B	0.54	9.1	1410	1.6	<0.1	1.83	21	3.5	5.0	1	0.7	<0.02	9.0	3710	22000	<0.2	2.8	17	168	0.21	<0.1	2.3	0.5	938	0.1	1.4	25	24.1

REE Section 247

T.134N., R.105W., Secs.32 & 33
Elevation at top 2,849 ft.

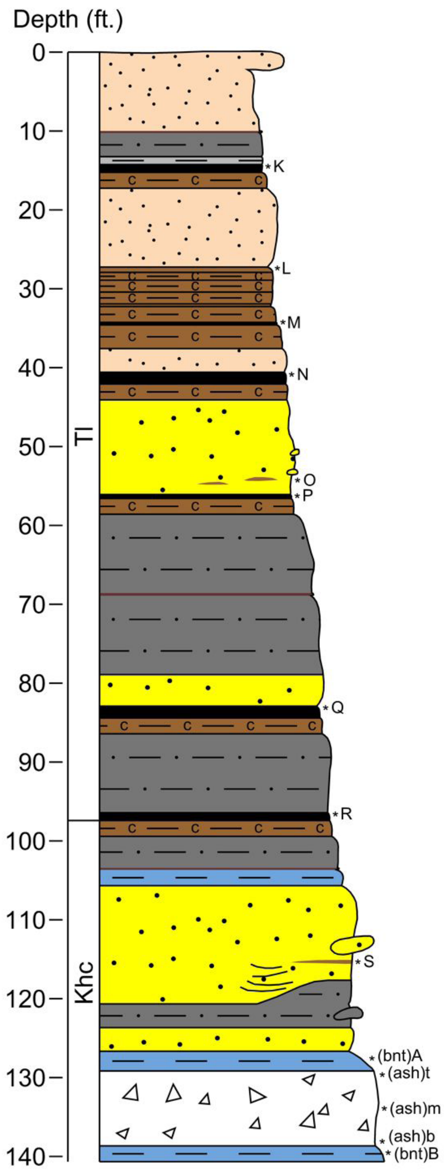


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
247M	83.3		4.10		7.4		40.8		37.2			15.6				36.9	*259*	*400*
247L	42.3		2.11		3.6		21.6		19.9			15.8				16.3	*138*	*197*
247N	39.9		3.57		4.2		19.5		17.3			13.1				32.5	*151*	*341*
247O	86.8	8.6	5.22	2.25	9.6	1.76	38.3	0.71	42.5	10.1	9.3	12.0	1.50	0.72	4.57	48.7	283	1688
247P	23.2		2.49		3.8		8.5		14.8			10.5				18.2	*98*	*370*
247Q	59.3		3.86		5.7		32.2		27.1			16.1				33.7	*205*	*357*
247(bnt)C	97.3		3.53		7.7		50.7		42.9			15.2				29.8	*282*	*299*
247S	15.5		3.05		2.2		8.6		7.5			8.0				24.0	*81*	*305*
247T	73.2		3.15		5.1		40.7		28.3			10.4				26.1	*212*	*271*
247(bnt)A	66.9		1.97		3.3		42.4		22.0			4.9				19.9	*180*	*213*
247(ash)	49.5		2.73		3.2		40.8		16.6			1.8				32.1	*164*	*218*
247(bnt)B	72.6		1.82		3.7		42.0		24.7			6.2				17.5	*188*	*203*
247X	119	10.7	5.86	3.28	12.9	2.01	49.4	0.94	63.3	15.1	14.3	20.7	1.91	0.84	5.72	42.9	369	652
247Y	40.0		1.64		3.3		20.4		19.0			10.7				13.8	*124*	*188*
247Z	52.8	8.3	5.27	1.62	7.9	1.78	23.4	0.70	27.4	6.6	6.3	11.6	1.33	0.72	4.55	49.2	209	965

SAMPLE ID	LAB ANALYSIS (in µg/g)																										
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
247M				4.5			37		26.6	11	5.2			14800		8.1	19.4							2740		9.9	97	251
247L				3.0			74		21.6	26	3.7			13900		6.1	18.3							2830		7.5	165	336
247N				6.5			35		9.8	5	2.6			9170		7.2	8.1							1340		8.8	86	162
247O				5.2			33		6.7	7	1.6			4030		3.8	6.3							370		3.3	118	58.7
247P				2.6			27		6.3	5	1.0			5400		9.0	15.2							294		5.8	74	113
247Q				3.6			67		18.6	6	2.6			7970		12.0	14.3							2440		6.2	165	124
247(bnt)C				1.5			42		26.1	2	8.2			13400		1.6	20.7							3680		7.6	67	243
247S				12.3			30		8.5	27	1.1			5330		9.6	14.9							1130		4.2	59	73.0
247T				3.4			46		19.9	27	3.7			11400		12.4	51.7							2120		16.4	138	196
247(bnt)A				1.0			15		17.2	1	3.1			13800		1.8	13.2							1760		7.8	30	84.5
247(ash)	0.59	1.5	355	0.6	0.13	0.32	7	1.7	8.1	1	1.2	<0.02	10.9	8560	2780	0.5	5.6	7	179	0.64	<0.1	7.9	0.9	944	0.5	4.4	14	32.2
247(bnt)B				0.8			18		21.7	1	4.0			17400		1.0	14.1							2610		9.0	36	99.1
247X				4.3			73		17.9	7	3.0			7070		31.1	13.7							2310		18.0	265	129
247Y				1.4			54		14.3	2	2.3			5720		22.2	8.6							2700		6.0	150	77.3
247Z				8.8			22		6.1	3	1.6			1880		5.6	8.6							546		4.4	62	76.0

REE Section 248

T.133N., R.105W., Sec.4, Center S
Elevation at top 2,979 ft.

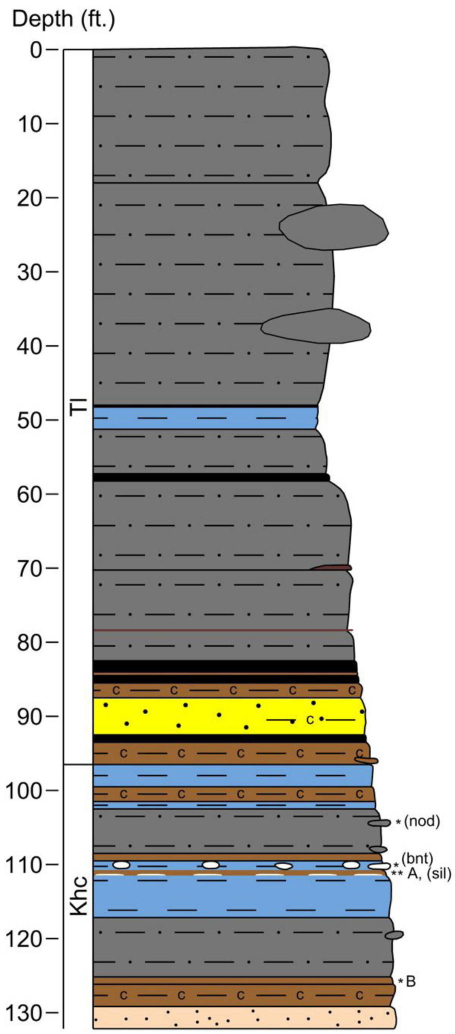


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
248K	129	13.0	7.14	3.59	15.7	2.51	56.9	0.88	66.9	15.9	14.8	14.1	2.35	0.94	5.74	61.7	411	1006
248L	40.3		3.99		4.4		22.6		17.8			17.8				36.0	165	214
248M	273	26.7	14.6	6.83	30.3	5.20	128	1.83	129	31.9	27.8	23.2	4.66	1.92	12.00	129	846	2959
248N	91.1	12.5	7.95	2.97	13.1	2.65	42.7	1.14	50.6	12.0	11.6	19.5	2.06	1.10	7.06	68.1	346	885
248O	49.2		1.91		4.1		26.2		23.3			12.3				15.5	151	161
248P	84.1	9.2	6.11	2.33	9.7	2.02	50.9	0.82	40.2	9.9	7.9	15.1	1.48	0.84	5.31	62.1	308	502
248Q	19.3		1.91		2.9		9.4		10.4			8.7				17.2	82	191
248R	31.9		4.83		4.5		17.8		14.6			11.5				47.8	156	369
248S	59.3		2.24		4.8		32.3		26.7			12.0				19.6	178	191
248(bnt)A	79.9		1.85		3.6		49.1		25.9			5.2				16.5	202	211
248(ash)t	77.8		1.72		3.6		46.4		25.9			5.5				14.9	195	204
248(ash)m	67.1		1.50		3.0		38.9		21.1			4.6				12.9	166	174
248(ash)b	69.3		1.47		3.2		40.7		22.6			5.1				12.9	172	181
248(bnt)B	81.3		1.95		4.1		49.3		28.0			7.0				17.1	210	217

SAMPLE ID	LAB ANALYSIS (in μg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
248K				5.8			41		15.9	16	4.9			6850		9.9	17.6							2320		6.7	91	205
248L				6.6			82		23.7	4	4.4			16900		5.8	20.3							4510		11.3	116	312
248M				7.3			61		20.2	7	3.0			5230		17.7	7.6							831		16.3	72	103
248N				4.6			104		15.9	15	3.6			9070		15.2	19.2							1310		10.6	196	387
248O				1.7			74		15.4	2	2.1			12600		0.6	7.6							3100		2.2	101	75.0
248P				10.5			56		21.8	17	3.6			12200		8.1	12.5							2400		9.2	100	164
248Q				2.8			21		7.5	1	3.5			8060		5.6	6.8							1620		3.4	44	109
248R				12.2			39		10.0	6	1.9			9450		7.0	13.1							2880		5.9	66	87.1
248S				2.2			92		17.7	4	2.2			7530		2.1	6.9							3260		3.2	150	142
248(bnt)A	1.45	4.6	624	2.1	0.35	0.80	14	12.0	20.7	1	3.6	0.02	37.2	20200	296	1.2	15.9	19	272	1.63	<0.1	28.8	2.1	2170	0.6	7.5	29	101
248(ash)t	0.75	2.1	682	2.0	0.35	1.44	16	4.3	19.6	2	3.5	0.02	55.3	19000	150	0.6	16.3	28	268	1.61	<0.1	27.7	2.1	2290	1.0	7.7	32	102
248(ash)m	1.02	5.5	858	2.0	0.31	2.98	13	3.6	16.6	2	3.1	0.02	29.2	10600	237	3.1	13.9	61	252	1.38	<0.1	24.0	1.8	1950	1.9	8.0	27	90.4
248(ash)b	0.91	4.0	835	1.9	0.35	2.15	12	4.0	17.6	1	3.3	0.02	48.9	15000	182	1.6	14.1	45	294	1.51	<0.1	26.3	1.9	1980	1.0	8.2	28	96.9
248(bnt)B	1.39	9.7	1710	2.0	0.28	1.21	33	7.9	18.0	2	2.8	0.03	34.5	14300	138	6.4	14.4	29	439	1.18	<0.1	19.5	1.8	2510	13.4	10.2	46	89.5

REE Section 249

T.133N., R.105W., Sec.4, SW/SW
Elevation at top 2,949 ft.

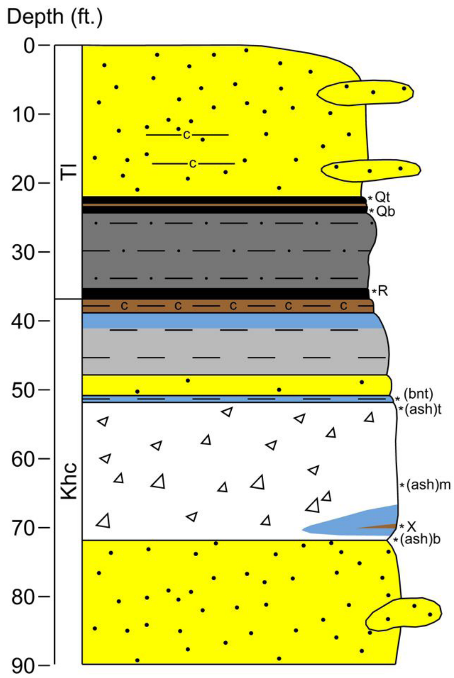


SAMPLE ID	LAB ANALYSIS (in µg/g)															TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
249(nod)	20.5		2.02		2.9		11.1		10.3			6.1				18.6	*84*	*117*
249(bnt)	84.4		1.81		4.0		49.2		27.7			6.1				16.2	*211*	*226*
249A	54.0		2.67		3.6		29.2		21.8			12.2				20.4	*163*	*224*
249(sil)	2.9		0.73		0.4		1.9		1.1			0.8				6.9	*17*	*21*
249B	56.4		2.86		5.2		30.1		25.9			15.0				25.2	*184*	*236*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
249(nod)	63.5	657	268	0.9	<0.1	0.80	51	11.5	2.5	1	0.2	<0.02	5.4	1970	3500	10.4	1.9	8	59	0.14	<0.1	2.5	0.9	499	46.1	1.0	36	15.5
249(bnt)				1.2			19		22.3	1	4.5			18700		1.6	15.2							2350		10.2	39	111
249A				5.5			63		19.3	6	2.8			10000		17.3	15.7							2680		9.1	148	109
249(sil)	1.32	9.4	249	4.8	<0.1	0.04	12	1.0	<1	2	0.2	<0.02	3.1	525	90	3.6	5.2	1	75	0.04	<0.1	0.6	0.5	68	2.0	3.6	15	33.3
249B				3.2			80		19.9	5	3.4			8880		6.0	14.4							3440		5.0	148	151

REE Section 250

T.133N., R.105W., Sec.4, SW/NE/SW
Elevation at top 2,899 ft.

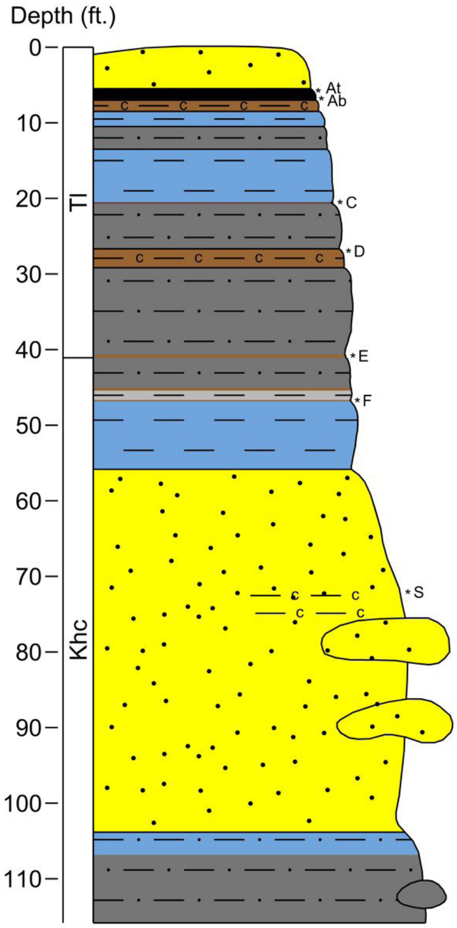


	LAB ANALYSIS (in µg/g)																TOTAL REE	
SAMPLE ID	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
250Qt	12.2		2.70		2.4		5.8		6.6			7.6				25.1	*74*	*202*
250Qb	55.7		4.21		7.0		24.9		28.7			7.0				38.0	*195*	*507*
250R	9.9		3.80		3.6		4.8		6.9			7.2				42.3	*95*	*386*
250(bnt)	78.8		1.77		3.7		46.8		25.7			5.8				16.5	*199*	*209*
250(ash)t	67.0		1.56		3.3		37.7		22.5			5.0				12.8	*167*	*176*
250(ash)m	63.0		1.51		3.0		38.0		20.7			4.7				13.2	*160*	*170*
250X	38.8		1.63		2.8		21.1		16.9			11.2				14.6	*121*	*130*
250(ash)b	52.9		1.25		2.4		30.8		17.2			5.0				10.5	*133*	*140*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
250Qt				5.1			23		5.6	15	1.6			8610		12.5	4.6							493		5.8	69	70.5
250Qb				3.4			26		8.3	7	1.4			4320		18.8	5.7							775		7.5	72	49.1
250R				8.5			12		3.3	8	0.7			14200		5.9	5.4							453		7.3	27	54.0
250(bnt)				2.0			16		18.4	1	3.5			18200		0.9	14.6							2100		7.7	35	99.3
250(ash)t	0.82	4.6	628	2.0	0.30	1.62	15	5.5	16.6	2	3.2	0.02	45.7	17100	239	1.5	13.7	32	249	1.47	<0.1	25.8	2.0	2080	1.3	6.6	36	96.6
250(ash)m	2.53	16.5	1300	1.8	0.36	4.13	12	4.2	15.7	2	2.9	0.02	15.5	5890	327	3.2	13.2	93	244	1.35	<0.1	22.4	1.8	1790	4.5	8.7	28	83.4
250X				1.8			62		14.2	10	2.0			9310		3.5	8.8							2770		3.4	113	78.4
250(ash)b	1.61	6.3	1140	1.9	0.34	2.77	15	15.4	16.2	1	3.2	0.02	39.3	12800	290	1.8	13.0	58	257	1.48	<0.1	21.5	1.8	1890	1.3	6.9	33	90.9

REE Section 251

T.130N., R.105W., Sec.35, NE/SW/NW
Elevation at top 3,189 ft.

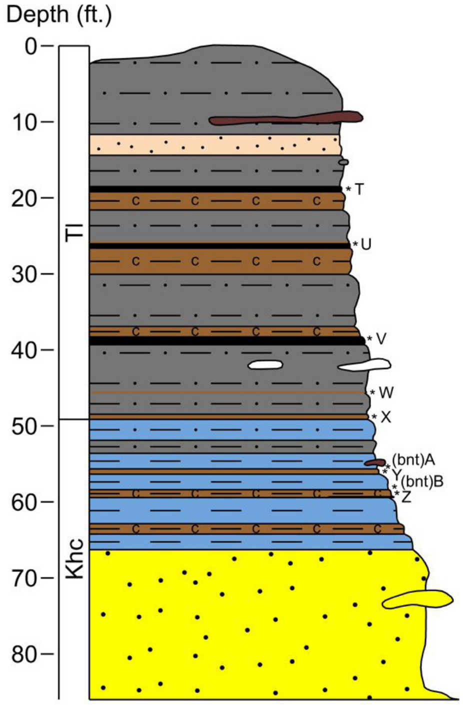


SAMPLE ID	LAB ANALYSIS (in µg/g)															TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
251At	8.5		2.00		2.0		4.5		6.2			5.4				20.1	*58*	*144*
251Ab	49.1		4.68		6.1		27.1		23.6			12.8				44.3	*196*	*668*
251C	37.3		1.70		2.9		17.5		16.6			12.3				13.9	*116*	*135*
251D	43.8		2.48		3.7		22.5		19.1			11.6				21.9	*143*	*167*
251E	55.3		2.45		4.5		27.8		25.2			13.1				21.6	*171*	*196*
251F	45.5		2.50		4.2		22.8		21.2			13.3				21.2	*150*	*172*
251S	49.8		2.29		4.6		26.9		23.4			12.0				20.0	*159*	*172*

SAMPLE ID	LAB ANALYSIS (in µg/g)																										
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
251At				4.9			30		13.4	25	3.0			28400		21.9	11.3							680		7.9	91	372
251Ab				7.3			29		11.0	7	3.8			20400		2.8	15.0							1110		5.1	49	256
251C				3.4			77		17.2	2	3.0			12800		1.1	12.1							3740		10.5	117	149
251D				4.8			48		17.6	5	3.3			9140		2.5	12.0							2610		13.0	84	182
251E				2.7			72		19.1	4	3.5			10000		2.9	13.0							3860		5.2	109	154
251F				3.2			71		19.2	6	3.3			9630		3.0	12.5							3660		4.9	113	144
251S				1.7			67		16.6	6	2.5			9520		0.8	8.0							2980		3.4	118	118

REE Section 252

T.130N., R.105W., Sec.35, SW/SW/SW
Elevation at top 3,190 ft.

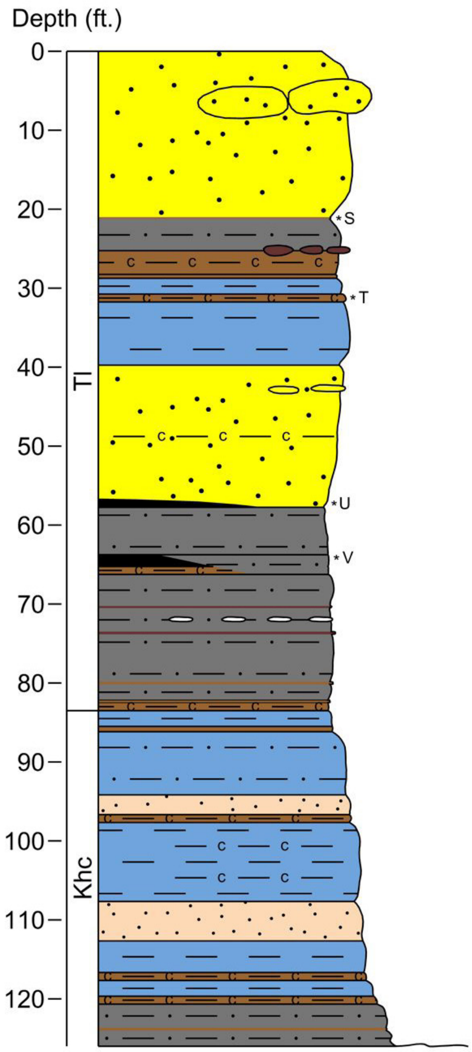


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
252T	44.4		2.59		4.1		23.0		20.6			11.7				23.2	*149*	*279*
252U	83.1		3.24		7.7		45.4		40.2			14.8				29.1	*256*	*373*
252V	18.9		1.82		2.2		10.3		9.2			7.9				16.5	*77*	*239*
252W	46.1		2.16		3.9		24.3		20.2			12.3				19.2	*146*	*163*
252X	52.6		2.87		4.6		28.7		23.5			15.6				25.1	*175*	*196*
252(bnt)A	56.4		2.39		4.8		29.7		25.6			16.4				20.9	*178*	*188*
252Y	59.1		2.74		5.2		30.7		28.0			19.0				24.1	*192*	*205*
252(bnt)B	45.2		2.34		4.4		22.5		22.0			18.7				19.0	*154*	*162*
252Z	47.2		2.28		4.1		25.0		21.7			17.6				18.9	*156*	*173*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
252T				5.0			58		19.9	24	3.8			4860		5.9	14.4							2610		6.9	107	269
252U				2.8			66		23.6	22	3.6			6990		13.2	16.5							2590		13.9	163	215
252V				5.3			26		10.0	12	1.4			4950		10.3	4.4							1220		6.6	69	54.5
252W				4.1			57		17.8	4	3.4			8600		1.6	11.4							3050		7.0	104	176
252X				3.8			80		21.2	7	3.7			9200		1.9	13.3							3980		6.0	126	170
252(bnt)A				1.8			89		21.0	2	3.3			6280		2.1	12.7							4390		3.9	149	113
252Y				2.3			100		23.1	5	3.6			5670		5.2	12.7							4700		5.8	169	137
252(bnt)B				2.0			104		22.4	2	3.3			11100		2.3	12.2							4780		4.1	171	107
252Z				1.8			92		21.6	12	3.5			6560		10.8	11.5							4100		5.7	173	148

REE Section 253

T.129N., R.105W., Sec.2, SW/NE/SE
Elevation at top 3,226 ft.

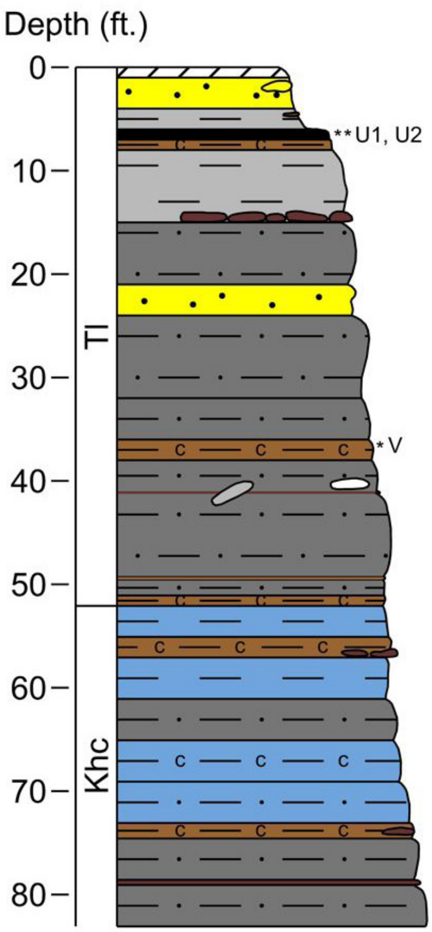


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
253S	52.3		2.24		4.8		25.7		28.4			18.2				14.3	*167*	*193*
253T	72.9		4.34		7.9		35.5		37.7			14.2				35.6	*242*	*387*
253U	22.5		4.28		3.7		11.8		12.8			13.2				31.6	*119*	*323*
253V	67.2		4.56		7.8		32.5		35.0			11.1				37.3	*229*	*460*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
253S									37.0	71	5.7			8960		35.4	17.0							2920		12.2	299	445
253T									21.5	30	3.6			7710		46.6	11.3							1780		27.6	197	324
253U									21.3	51	3.8			4020		19.0	11.9							999		24.0	141	469
253V									20.1	11	3.8			5410		53.3	21.2							1540		20.4	173	345

REE Section 254

T.129N., R.105W., Sec.2, NW/SE/NE
Elevation at top 3,184 ft.

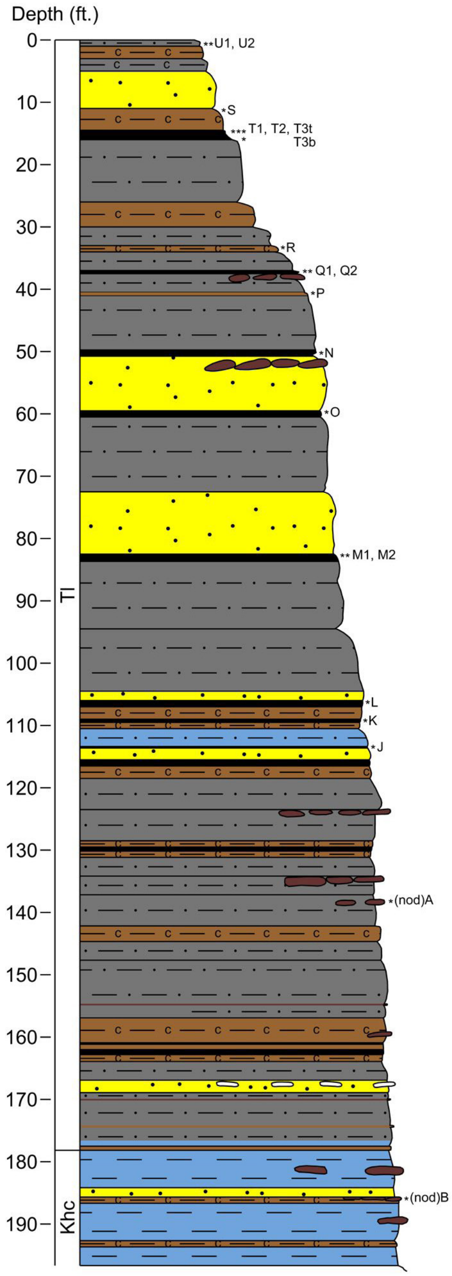


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
254U1	76.6		4.65		9.1		36.1		39.2			14.2				39.3	*257*	*479*
254U2	56.1		3.14		6.2		25.9		29.9			18.4				25.7	*192*	*273*
254V	57.1		2.98		5.5		28.7		26.0			13.3				27.3	*185*	*352*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
254U1									16.8	24	3.2			3530		55.8	7.5							1100		28.2	124	269
254U2									15.8	35	3.9			5410		31.4	11.1							2230		13.1	165	294
254V									13.8	18	2.8			4800		23.4	11.7							2170		10.6	120	185

REE Section 255

T.129N., R.105W., Sec.1, SE/SW/SW
T.129N., R.105W., Sec.12, NE/NW/NW
Elevation at top 3,280 ft.

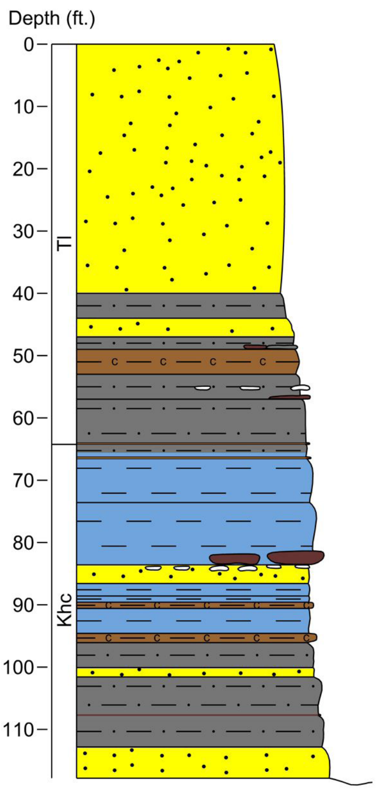


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
255U1	79.2	6.3	3.64	1.74	7.5	1.25	37	0.49	39.8	10.1	8.3	8.4	1.1	0.51	3.38	31.4	240	278
255U2	81.6		2.93		6.4		40.7		36.6			15.5				25.1	*238*	*262*
255S	46.7		4.51		5.4		47.4		27.0			22.5				46.2	*226*	*277*
255T1	125	12.8	7.67	3.45	13.9	2.58	61.2	1.07	62.6	15.6	14.1	23.5	2.13	1.07	7.08	67.5	421	803
255T2	148	14.4	8.41	4.27	16.5	2.86	67.9	1.15	78.4	19	17.5	26.3	2.52	1.16	7.77	72.2	488	974
255T3t	110	11.0	6.73	2.90	12.0	2.35	56.4	0.89	53.3	13.5	12.6	20.5	1.80	0.93	5.96	65.4	376	685
255T3b	160	16.5	10.0	4.43	18.2	3.51	73.0	1.31	82.0	20.1	19.3	29.4	2.70	1.37	8.76	91.8	542	1018
255R	58.5		3.39		5.1		30.4		26.3			15.4				33.0	*197*	*254*
255Q1	39.6	3.6	2.54	0.99	3.6	0.78	21.2	0.43	18.5	4.7	3.8	16.3	0.55	0.39	2.75	19.9	140	197
255Q2	24.4		3.18		3.3		12.8		11.8			12.6				29.2	*114*	*196*
255P	61.2		2.75		5.3		31.4		28.7			17.5				22.7	*193*	*226*
255N	10.7		2.99		2.5		5.8		6.3			14.1				26.7	*82*	*273*
255O	32.3		2.05		3.6		15.4		16.8			10.4				16.1	*112*	*179*
255M1	34	5.2	3.53	1.41	5.1	1.13	16.1	0.55	20.3	4.7	4.9	13	0.81	0.51	3.54	29.8	145	562
255M2	69.4	10.8	7.95	2.53	10.5	2.78	33.0	1.05	37.9	8.9	11.0	22.1	1.58	1.09	7.00	76.7	304	1063
255L	38.6		2.92		3.3		21.3		16.5			17.7				25.4	*143*	*189*
255K	31.6		3.95		4.0		15.7		14.7			17.3				35.6	*143*	*364*
255J	55.9		3.13		5.6		29.0		26.0			17.9				29.7	*192*	*239*
255(nod)A	18.7		1.30		2.2		11.9		9.1			3.8				16.6	*73*	*94*
255(nod)B	29.4		4.41		4.3		26.7		13.8			9.7				65.9	*176*	*198*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
255U1	3.49		438	2.8		4.03	49		12.2	7	3.9		31.5	5300		12.5	13.0		120	0.96				2830	2.1	9.1	70	174
255U2									22.1	5	3.8			18500		14.2	13.1							3220		11.0	159	142
255S									26.4	4	5.1			16200		1.8	18.4							4660		35.2	191	202
255T1																												
255T2	6.39		2930	4.5		2.12	84	17.2	19.3	7	11.0		20.0	5460		19.9	23.6			1.01				2720	4.5	12.0	152	678
255T3t									10.8	5	2.9			5740		23.3	6.7							1600		8.9	157	134
255T3b									17.8	7	8.0			6130		17.6	17.4							3030		12.0	120	470
255R									15.6	2	3.2			12700		3.8	14.6							3480		5.2	82	133
255Q1	5.03		1170	2.8		7.47	108		19.7	10	4.9		28.1	9360		12.3	13.2		247	0.66				3400	1.3	6.8	272	323
255Q2									15.5	3	4.2			13100		10.1	8.7							2170		11.1	72	209
255P									21.1	3	3.7			10500		5.8	12.6							3600		9.1	136	149
255N									13.4	15	4.3			11900		9.1	10.1							887		6.7	90	377
255O									12.7	13	3.2			5950		18.5	12.0							1370		5.2	109	223
255M1																												
255M2									8.6	8	3.9			6260		9.5	15.1							2850		19.9	204	337
255L									29.3	5	3.4			13400		6.2	20.0							5780		5.6	132	140
255K									16.9	11	3.8			7960		18.4	9.6							1650		11.0	95	249
255J									18.7	2	3.2			9980		10.3	10.0							3430		6.5	216	161
255(nod)A	0.29	3.9	527	1.2	<0.1	1.21	21	3.9	4.0	1	0.4	<0.02	11.0	3430	11500	0.2	2.3	16	129	0.14	<0.1	1.5	0.6	647	1.1	0.9	24	16.8
255(nod)B	0.25	4.1	1230	4.2	0.22	1.94	28	6.2	5.8	1	1.2	0.02	14.3	5330	3990	1.0	4.1	26	676	0.28	<0.1	2.3	0.8	1270	1.0	5.6	41	48.8

REE Section 256*

T.129N., R.105W., Sec.2, NE/SE
Elevation at top 3,204 ft.



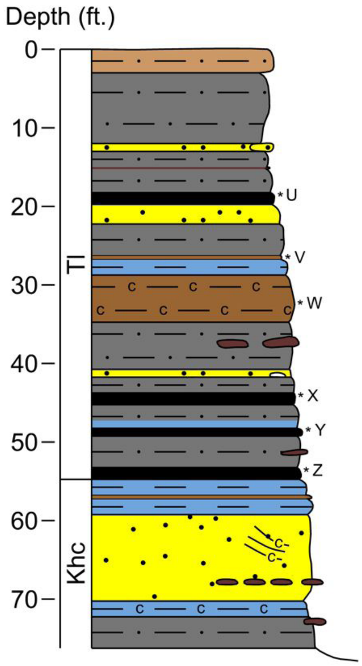
SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash

** No samples were collected at this section.*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium

REE Section 257

T.129N., R.105W., Sec.24, SE/SW/SE
Elevation at top 3,212 ft.

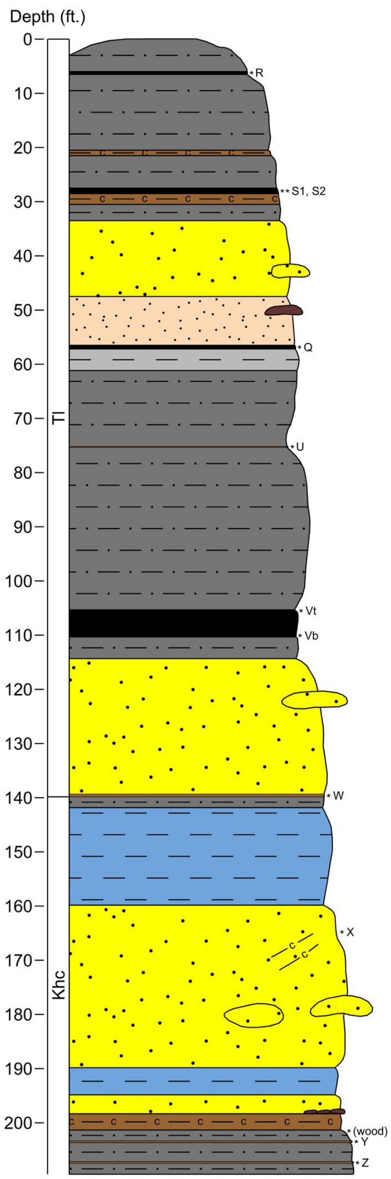


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
257U	212	18.3	9.90	5.24	21.5	3.48	102	1.30	102	26.0	22.9	22.6	3.18	1.36	8.67	101	*661*	*1072*
257V	61.7		3.74		5.9		33.4		29.3			19.9				31.6	*213*	*284*
257W	56.0		2.08		4.4		29.1		25.0			15.8				18.5	*171*	*193*
257X	27.3		2.21		2.8		14.5		12.5			10.5				20.2	*104*	*223*
257Y	15.7		2.91		2.6		8.4		8.0			9.9				25.7	*86*	*313*
257Z	13.7		2.51		2.4		6.6		7.5			11.1				23.1	*79*	*273*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
257U	2.68					3.37			23.0	8	5.3		41.4	6010		7.2	10.1			1.10				3130	1.6	11.9	110	231
257V	4.03					7.40			26.5	18	4.7		36.9	10600		2.8	17.7			0.69				2950	2.0	23.3	158	349
257W	1.58					8.91			21.0	3	3.0		54.8	11300		2.0	12.9			0.94				4480	1.6	4.7	142	107
257X	3.74					1.22			10.8	9	2.9		17.6	3670		9.4	11.5			0.48				1950	2.9	6.4	111	226
257Y	4.92					0.74			11.0	11	1.8		9.0	6570		11.9	11.8			0.28				1140	4.5	9.8	57	151
257Z	5.56					0.56			8.7	11	2.3		8.1	2430		11.1	13.7			0.22				832	3.0	6.2	76	240

REE Section 258

T.131N., R.105W., Sec.21, SW/SW
Elevation at top 3,156 ft.

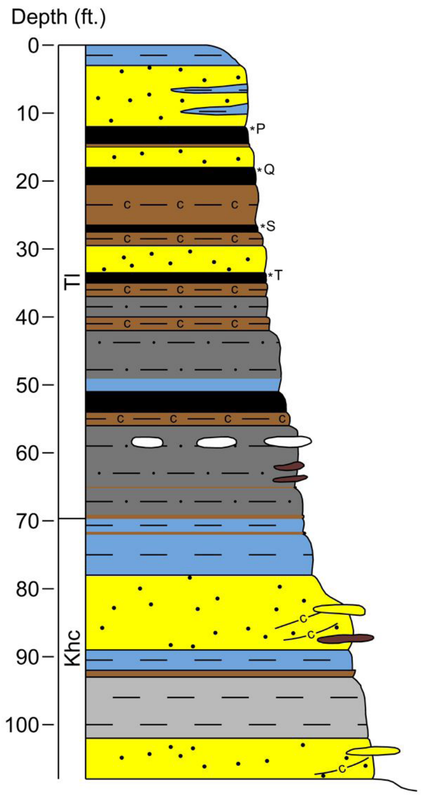


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
258R	44.0		5.62		5.4		24.2		19.8			19.8				49.7	*196*	*300*
258S1	119		4.96		10.3		56.0		51.5			13.2				46.2	*347*	*394*
258S2	83.4		3.55		7.5		41.2		39.6			11.9				32.2	*252*	*298*
258Q	77.5		3.40		6.6		42.3		35.7			16.3				30.3	242	270
258U	38.3		6.80		6.6		20.2		19.3			22.9				62.5	*209*	*344*
258Vt	65.2		3.40		6.6		33.2		30.9			12.6				29.5	*210*	*346*
258Vb	49.1		3.13		5.1		28.4		20.5			15.2				33.1	*177*	*492*
258W	57.7		2.27		4.9		32.2		27.3			17.4				21.4	*185*	*196*
258X	50.4		2.58		5.1		26.4		25.7			11.9				23.1	*167*	*183*
258(wood)	63.6		2.74		5.5		32.5		29.7			10.0				23.8	*192*	*210*
258Y	51.1		2.94		4.6		26.8		22.6			16.2				26.2	*172*	*206*
258Z	49.2		3.43		4.5		27.6		22.1			15.4				31.5	*176*	*203*

SAMPLE ID	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
	LAB ANALYSIS (in µg/g)																											
258R	11.4					4.21			29.8	50	3.4		27.2	21000		15.7	15.4			0.58				2310	8.3	12.9	132	284
258S1	3.01					4.91			23.0	6	5.6		90.5	13800		9.0	12.0			1.53				3110	1.5	13.2	74	226
258S2	3.14					3.90			21.5	7	5.5		67.5	10600		9.3	13.6			1.45				3000	1.7	11.2	74	231
258Q	7.07					8.44			31.7	60	4.4		49.3	17400		8.1	17.4			0.95				3570	3.2	9.3	154	307
258U	8.94					1.64			25.3	34	5.9		53.1	27000		7.6	16.8			0.94				2520	2.7	6.9	129	411
258Vt	3.65					4.12			13.2	8	2.8		17.2	12800		6.3	10.9			0.64				2840	1.2	8.6	99	152
258Vb	5.75					3.87			14.1	4	2.4		37.2	6930		35.1	9.9			0.51				1870	3.5	11.1	121	81.0
258W	1.12					5.78			18.4	2	3.4		23.5	13000		1.6	10.6			0.73				3850	1.6	5.1	153	122
258X	1.77					2.76			15.7	12	2.9		23.1	13300		2.2	10.0			0.64				3230	0.9	3.3	103	141
258(wood)	2.07	13.4	1010	2.1	0.11	4.05	56	17.8	19.5	16	3.2	0.05	27.9	5190	307	2.6	12.5	67	192	0.77	<0.1	7.5	1.4	2810	5.5	4.6	92	136
258Y	2.49					5.11			20.8	4	4.5		50.0	7400		3.9	15.5			1.11				4200	1.7	8.0	118	192
258Z	4.26					8.95			23.3	8	3.5		35.7	5460		5.6	15.9			1.04				4730	2.3	6.7	131	142

REE Section 259

T.130N., R.105W., Sec.35, SE/NW/SE
Elevation at top 3,196 ft.

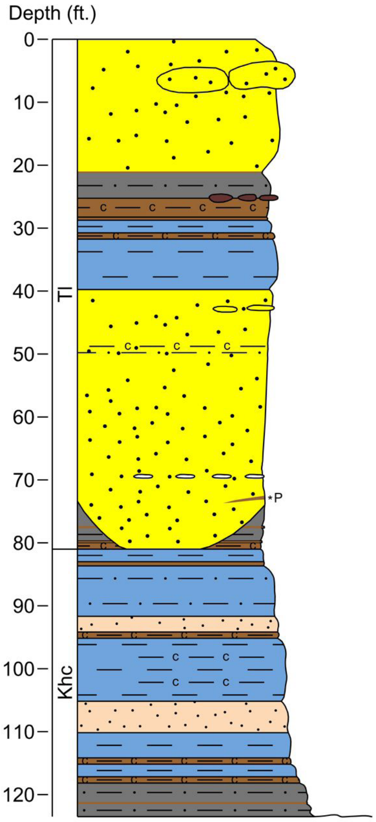


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
259P	75.3		4.77		9.2		31.3		43.2			18.9				36.3	*257*	*593*
259Q	52.5		4.43		7.2		25.7		26.8			14.1				47.2	*208*	*752*
259S	104		7.48		13.3		49.3		52.3			12.7				72.7	*367*	*1682*
259T	25.1		2.41		2.9		13.7		11.7			10.2				22.1	*102*	*199*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
259P									15.0	28	4.7			5270		22.9	18.8							1540		22.4	129	400
259Q									6.2	3	2.9			4590		5.2	9.5							968		6.4	72	157
259S									10.3	5	1.1			4760		33.8	2.1							378		10.2	53	50.8
259T									13.1	15	2.4			5060		14.3	8.7							1840		8.9	99	166

REE Section 260

T.129N., R.105W., Sec.2, SW/NE/SE
Elevation at top 3,226 ft.

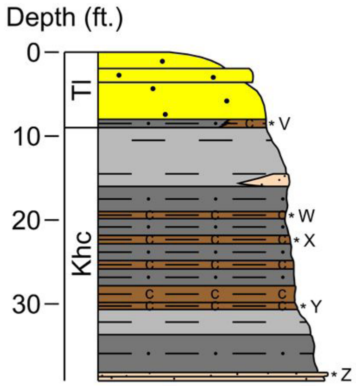


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
260P	35.9		2.07		3.0		19.4		16.4			11.5				15.4	*118*	*176*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
260P	6.49	58.2	606	4.5	0.22	4.73	101	34.8	20.9	43	3.5	0.04	20.5	9160	467	4.8	22.9	62	258	0.60	<0.1	7.2	1.3	2440	3.0	5.6	227	298

REE Section 261-West

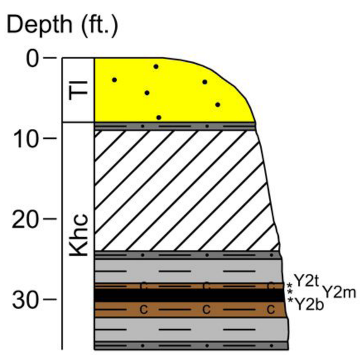
T.129N., R.87W., Sec.16, NE1/4
Elevation at top 2,105 ft.



SAMPLE ID	LAB ANALYSIS (in µg/g)															TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
261V	64.8		4.05		6.4		30.2		32.3			21.2				37.8	*226*	*267*
261W	71.2		3.43		6.8		35.7		34.1			18.1				30.7	*230*	*248*
261X	85.6		3.99		8.9		42.6		43.7			17.1				32.6	*272*	*296*
261Y	32.1		2.65		3.9		17.1		15.5			15.3				23.8	*128*	*144*
261Z	23.6		2.28		2.9		14.1		11.9			7.5				23.0	*99*	*109*

REE Section 261-East

T.129N., R.87W., Sec.16, NE1/4
Elevation at top 2,130 ft.



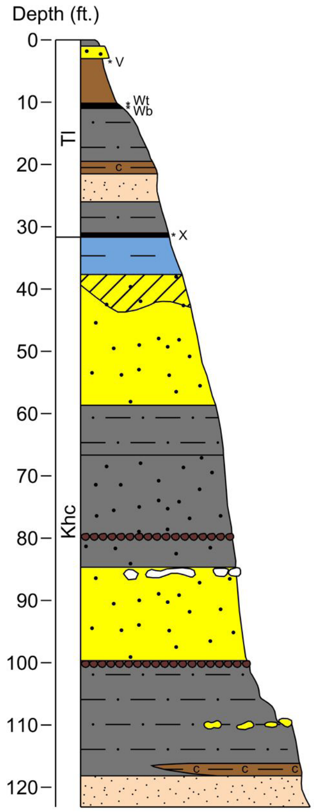
SAMPLE ID	LAB ANALYSIS (in µg/g)															TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
261Y2t	140.0		6.70		14.4		68.1		66.3			19.2				62.8	*438*	*575*
261Y2m	78.8		4.74		7.6		42.2		35.9			10.5				45.4	*260*	*560*
261Y2b	38.1		3.06		4.0		21.4		17.7			13.4				28.5	*145*	*237*

SAMPLE ID	LAB ANALYSIS (in µg/g)																										
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
261V									33.2	12	4.2			5960		6.3	24.6							8880		7.3	204	217
261W									22.2	9	3.5			7620		3.5	13.2							4430		5.4	167	134
261X									25.1	6	3.4			6230		2.7	12.6							4350		6.3	163	134
261Y									25.0	3	3.4			3180		2.4	17.2							5350		5.8	141	138
261Z									10.7	2	1.3			5600		0.2	5.4							1690		1.7	42	48.1

SAMPLE ID	LAB ANALYSIS (in µg/g)																										
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
261Y2t									34.7	3	6.8			3110		4.4	25.0							4900		10.7	110	237
261Y2m									25.8	24	3.9			2680		41.3	8.0							1430		17.0	90	188
261Y2b									23.7	25	3.0			3190		4.3	12.3							3430		4.9	135	105

REE Section 262 Top

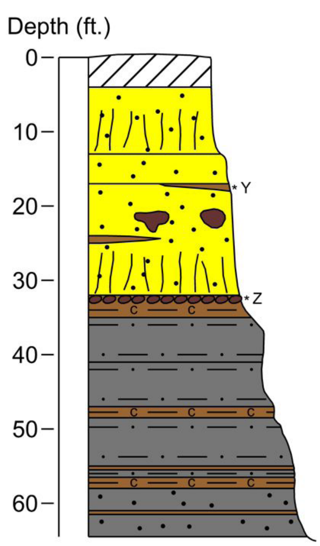
T.131N., R.82W., Sec.16, SW/SE/NW
Elevation at top 2,115 ft.



SAMPLE ID	LAB ANALYSIS (in µg/g)															TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
262V	89.8		4.09		6.9		54.5		36.2			15.0				38.3	*278*	*349*
262Wt	74.2		4.28		7.6		38.1		35.2			15.5				39.8	*248*	*315*
262Wb	163.0		11.20		19.0		80.0		77.3			16.9				104.0	*553*	*1853*
262X	28.6		3.15		2.9		17.4		11.5			10.3				30.0	*120*	*235*

REE Section 262 Base

T.131N., R.82W., Sec.16, SW/SW/NE
Elevation at top 1,940 ft.



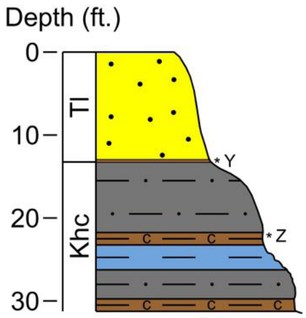
SAMPLE ID	LAB ANALYSIS (in µg/g)															TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
262Y	64.5		2.08		4.4		33.6		28.5			13.8				17.2	*185*	*196*
262Z	55.7		1.93		4.1		29.4		24.1			15.2				17.1	*166*	*175*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
262V									32.6	60	4.1			8590		4.1	25.6							5000		8.1	191	260
262Wt									27.5	3	3.2			7100		9.4	14.0							4330		7.0	178	111
262Wb									18.4	10	3.3			3560		11.3	17.6							1280		17.1	104	318
262X									15.2	7	2.9			9890		6.9	22.8							3700		8.0	84	109

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
262Y									20.0	2	3.0			5040		1.0	14.3							4360		4.4	128	119
262Z									21.0	2	3.4			6170		1.4	14.4							4030		3.6	157	124

REE Section 264

T.129N., R.85W., Sec.16, NW/NW/SE
Elevation at top 2,190 ft.

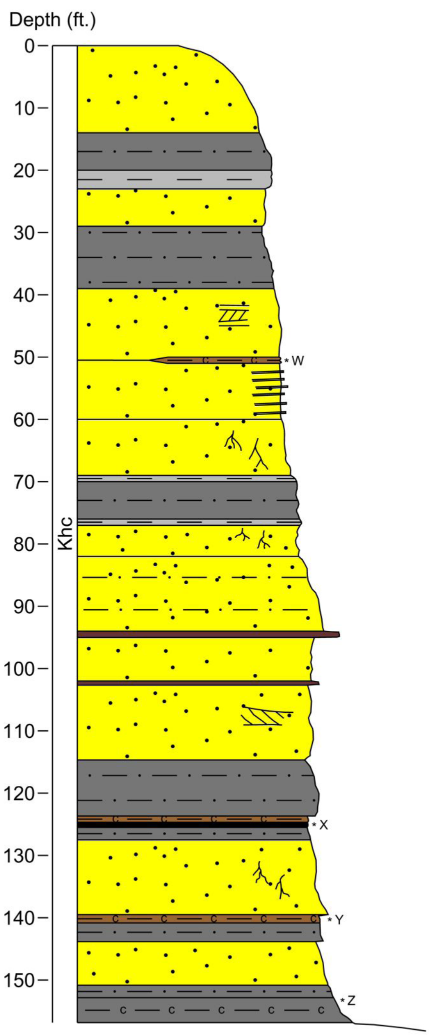


SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
264Y	60.8		2.89		5.9		32.7		30.1			13.2				26.0	*197*	*206*
264Z	97.3	7.8	4.45	2.11	8.8	1.54	48.7	0.61	45.2	11.8	9.1	20.1	1.34	0.62	4.00	40.9	*304*	*369*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
264Y									20.9	7	3.0			7270		4.0	11.4							3500		3.3	122	117
264Z									32.6	6	5.0			4960		5.0	17.2							4520		8.8	164	217

REE Section 268

T.133N., R.82W., Sec.16
Elevation at top 1,947 ft.

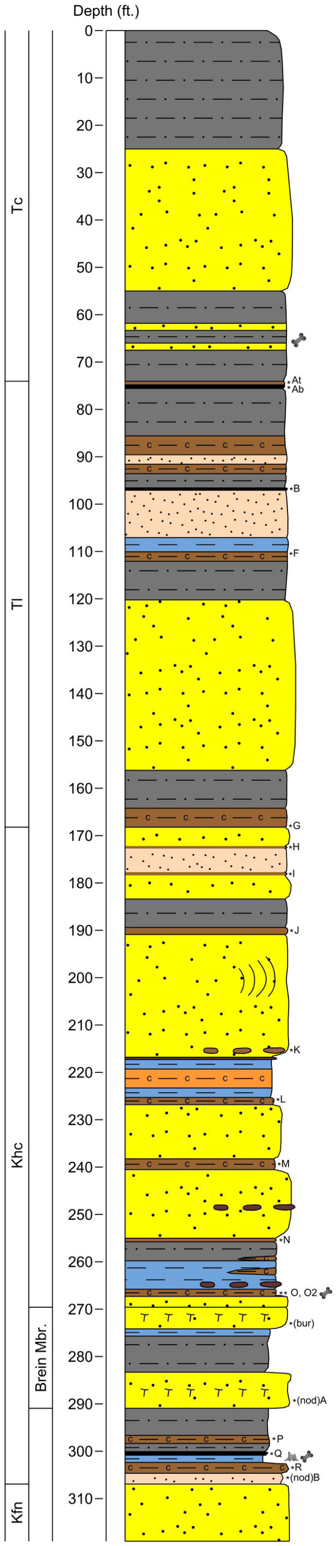


SAMPLE ID	LAB ANALYSIS (in µg/g)															TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
268W	45.7		2.8		4.3		24.5		21.0			13.4				23.7	*155*	*200*
268X	37.2		3.82		4.4		18.3		17.5			11.7				32.7	*147*	*209*
268Y	32.8		3.32		3.4		18.6		15.0			14.9				25.9	*132*	*178*
268Z	46.9		2.11		3.5		25.2		19.9			14.7				16.5	*146*	*160*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
268W	1.46			2.8		5.53	75		18.0	5				4820		1.8	12.7			0.91				4570	2.2	2.5	111	128
268X	1.01			7.3		1.51	53		20.6	2				3750		1.4	12.9			1.05				3680	3.5	2.5	84	108
268Y	1.79			7.6		4.95	88		16.7	8				6120		2.8	12.7			0.81				3650	2.0	7.5	126	131
268Z	1.15			3.2		6.67	84		22.2	2				6280		1.4	13.1			0.99				4420	2.2	3.1	151	113

REE Section 269

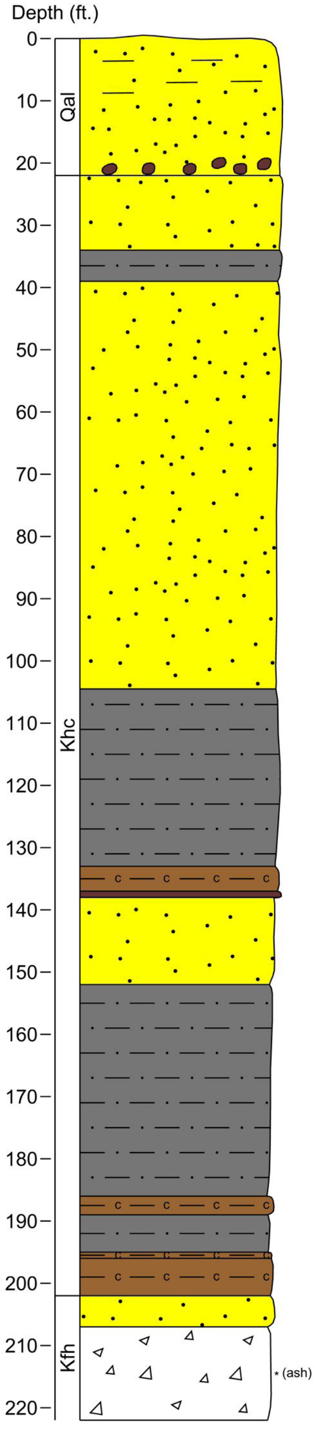
T.134N., R.81W., Sec.16, SE/NE/SE
Elevation at top 2,045 ft.



SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
269At	69.3		3.52		6.5		35.5		33.1			18.7				29.2	*225*	*273*
269Ab	187		9.71		18.8		99.2		85.2			16.9				98.1	*596*	*915*
269B	147		7.66		15.3		79.5		63.4			16.7				74.0	*468*	*1105*
269F	88.5		3.31		6.9		46.3		38.0			14.3				28.8	*258*	*280*
269G	55.1		1.78		3.9		28.0		24.5			10.3				14.5	*156*	*168*
269H	75.8		2.77		5.8		39.9		32.1			15.7				23.3	*222*	*244*
269I	53.3		2.86		4.4		29.2		23.3			16.8				22.4	*173*	*198*
269J	54.6		2.44		4.4		29.1		24.2			13.5				19.5	*168*	*182*
269K	27.0		1.42		1.9		15.6		11.3			16.2				11.4	*95*	*104*
269L	51.3		1.84		3.9		27.8		22.6			12.8				14.8	*153*	*162*
269M	32.5		2.19		2.5		17.8		13.8			14.4				18.5	*115*	*136*
269N	38.2		1.61		2.7		18.1		15.5			13.2				12.6	*115*	*142*
269O	34.7		2.31		3.1		18.6		15.8			10.6				19.6	*120*	*157*
269O2	8.6		1.18		1.1		4.4		4.1			3.5				9.6	*38*	*206*
269(bur)	29.5		3.03		3.6		16.6		14.2			7.8				25.2	*117*	*130*
269(nod)A	20.8		2.78		3.4		12.0		10.6			5.7				32.8	*103*	*133*
269P	42.0		2.12		3.4		23.9		18.5			10.5				19.6	*136*	*147*
269Q	17.1		4.03		3.1		10.2		9.0			4.9				40.5	*106*	*430*
269R	44.2		2.14		3.7		23.8		20.2			13.9				18.6	*144*	*156*
269(nod)B	61.2		4.09		6.7		21.7		25.4			10.3				31.2	*190*	*207*

SAMPLE ID	LAB ANALYSIS (in µg/g)																										
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
269At									25.2	10				10700		8.1	14.7									11.0	196	136
269Ab									13.9	9				3990		12.5	18.0									19.4	153	188
269B									15.2	15				4970		24.3	7.8									12.2	166	151
269F									23.6	3				4260		4.4	17.0									4.5	132	151
269G									18.0	4				4410		1.3	12.3									2.3	91	89.8
269H									21.8	12				6460		3.8	12.9									5.5	169	199
269I									22.2	10				7130		18.1	15.2									7.3	196	268
269J									18.0	3				5280		3.2	13.4									3.3	115	115
269K									17.5	6				5790		1.0	13.1									6.3	224	180
269L									17.8	2				5910		2.1	12.1									4.2	113	112
269M									17.3	9				5440		1.9	15.4									2.5	148	132
269N									16.0	60				5140		0.8	14.9									3.1	137	127
269O									16.0	9				6600		6.8	10.3									2.7	90	82.0
269O2	9.65	9.6	211	1.3	<0.1	1.03	21	4.6	10.5	44	0.8	<0.02	6.5	1820	175	13.7	12.0	14	106	0.16	<0.1	1.4	0.3	667	18.5	1.0	59	40.7
269(bur)	2.37	41.2	326	2.8	<0.1	1.18	34	24.4	5.2	1	1.1	<0.02	16.5	4120	5180	1.1	3.8	22	189	0.25	<0.1	3.0	0.4	1100	0.2	3.9	101	48.0
269(nod)A	0.39	1.4	307	2.4	<0.1	1.45	26	4.0	4.0	2	0.7	<0.02	15.3	9130	9860	0.4	2.6	19	115	0.20	<0.1	2.3	0.7	838	0.4	1.0	37	24.6
269P									17.5	3				7480		2.1	17.2									3.6	102	130
269Q									8.7	13				5380		17.8	7.8									5.3	26	42.0
269R									18.8	14				8370		7.9	10.9									4.7	129	90.3
269(nod)B	0.87	27.3	453	3.8	<0.1	1.44	39	17.7	7.5	2	1.3	0.02	8.4	3490	6170	0.2	6.6	35	140	0.77	<0.1	3.2	0.6	1300	2.6	2.1	73	47.0

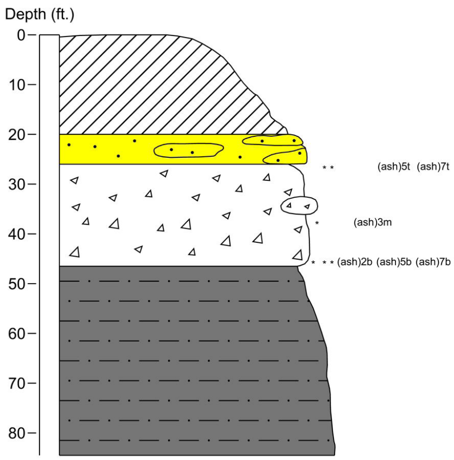
REE Section 276
Morton County



SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
276(ash)	50.6		1.46		2.8		28.3		19.1			4.4				12.8	*134*	*141*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
276(ash)	2.15	15.0	989	1.9	0.25	3.77	13	4.2	17.3	2	2.6	0.02	14.0	5920	324	2.5	12.1	99	215	1.17	<0.1	15.4	1.6	1760	2.1	5.6	28	71.1

REE Section 277
Emmons County



SAMPLE ID	LAB ANALYSIS (in µg/g)																TOTAL REE	
	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Whole Coal	Ash
277(ash)5t	50.8		1.49		2.8		28.6		19.1			4.2				12.5	*134*	*142*
277(ash)7t	47.9		1.22		2.5		26.9		17.3			3.3				11	*123*	*130*
277(ash)3m	48.1		1.32		2.6		27.3		17.9			3.5				11.4	*126*	*133*
277(ash)2b	49.8		1.48		2.8		28.1		18.5			4.3				12.6	*132*	*142*
277(ash)5b	50.2		1.39		2.7		28.9		18.5			3.7				12.1	*132*	*139*
277(ash)7b	47.5		1.27		2.5		26.9		17.3			3.6				11.1	*123*	*131*

SAMPLE ID	LAB ANALYSIS (in µg/g)																											
	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellurium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
277(ash)5t	2.15	20.1	997	1.9	0.28	4.58	13	4.1	17.4	2	2.8	0.02	19.5	6030	386	3.1	11.7	119	167	1.25	<0.1	16.2	1.8	1640	2	5.9	28	73.7
277(ash)7t	2.03	18.0	987	1.8	0.27	4.29	8	2.4	16.5	2	2.7	0.02	17.6	5360	352	3.1	10.6	116	167	1.25	<0.1	16.7	1.7	1370	1.9	6.4	19	69.7
277(ash)3m	2.21	22.2	1010	1.8	0.26	4.36	8	2.5	16.7	2	2.7	0.02	19.7	4760	344	3.1	11	118	173	1.23	<0.1	16.2	1.7	1440	2	5.8	21	70.9
277(ash)2b	2.04	17.6	1040	1.8	0.29	4.41	15	3.9	17.2	2	2.7	0.02	25.4	6560	408	3.0	11.6	112	175	1.24	<0.1	16.1	1.7	1700	2.2	5.9	31	72.8
277(ash)5b	2.19	18.0	988	1.8	0.29	4.46	10	3.7	17.2	2	2.7	0.02	17.7	6000	517	3.2	11.4	118	166	1.25	<0.1	16.8	1.7	1470	2	5.8	23	70.7
277(ash)7b	2.07	16.6	949	1.8	0.26	4.2	10	3.5	16.9	2	2.7	0.02	22.2	6640	519	3.2	10.6	110	167	1.25	<0.1	17	1.7	1480	1.9	6.2	24	72.7

Appendix B - Analytical Results

Concentrations are reported on a whole rock basis (dry) as ug/g or parts per million

Sample ID	NDGS Field ID	Ash (wt%)	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium
120A	120A	33.67%	67.2	5.0	2.80	1.51	6.0	0.95	27.4	0.40	31.9	8.1	6.2	7.3	0.84	0.38	2.54	24.9
120B	120B	21.69%	28.5	3.0	1.96	0.68	3.0	0.64	14.6	0.28	12.7	3.3	2.6	3.5	0.47	0.27	1.73	22.7
120C	120C	91.96%	81.7	3.2	1.79	1.20	4.7	0.58	38.2	0.27	33.8	9.2	6.1	7.1	0.59	0.25	1.79	15.6
120D	120D	31.09%	30.2	2.7	1.81	0.62	2.6	0.58	17.5	0.27	11.5	3.1	2.3	4.5	0.41	0.26	1.70	19.0
120E	120E	36.87%	15.2	1.5	0.99	0.42	1.6	0.31	7.1	0.15	7.4	1.9	1.6	4.3	0.23	0.14	0.94	8.7
120F	120F	27.92%	12.9	1.4	0.83	0.39	1.6	0.27	5.5	0.12	6.9	1.7	1.6	4.7	0.23	0.11	0.78	7.3
120G	120G	38.17%	40.9	2.7	1.40	1.23	3.6	0.48	18.9	0.20	21.1	5.2	4.4	8.9	0.49	0.19	1.32	11.6
144At	144A	57.52%	49.6	4.9	2.98	1.4	5.4	1	22.3	0.44	25.8	6.3	5.8	8.8	0.82	0.43	2.91	24
144Ab	144A2	77.33%	86.2	8.6	4.98	2.35	9.3	1.71	39.2	0.65	42	10.2	9.3	15.3	1.45	0.69	4.42	44.3
144B1t	144B	34.33%	48.4	6.1	4.37	1.14	5.2	1.36	26.4	0.67	21.3	5.4	4.6	12.3	0.9	0.65	4.43	42.6
144B1b	144B2	40.23%	42.3	4.2	2.9	0.96	4	0.91	26.2	0.44	18.1	4.6	3.7	7.7	0.65	0.42	2.79	27.1
144(pod)	144POD	48.70%	32.1		2.62		3.3		17.0		15.2			14.2				22.5
144T	144T	54.30%	62.7	7.9	4.72	1.99	8.4	1.61	29.2	0.66	33.6	7.9	7.6	12.7	1.34	0.65	4.16	41.5
144U	144U	21.46%	32.2		1.87		3.5		15.7		16.6			9.5				15.6
144V	144V	41.67%	12.7		2.17		2.2		6.8		6.7			10.0				19.2
144W	144W	89.31%	56.5		2.43		4.3		29.3		25.3			15.4				19.4
144(whi)	144WHI	74.78%	19.6		0.87		1.7		13.2		8.9			4.3				9.7
144X	144X	61.53%	63.2		2.87		5.3		32.6		28.6			16.9				24.2
144Y	144Y	23.45%	48.8		2.72		4.1		25.7		22.0			13.7				22.8
144Z	144Z	54.23%	49.1		2.18		4.2		25.9		22.8			17.8				18.5
144B2t	145B	23.69%	29.2	3.8	2.77	0.77	3.3	0.87	15.2	0.41	13.1	3.3	2.9	10.1	0.56	0.4	2.69	25.9
144B2b	145B2	84.49%	11.5	4.5	3.5	0.66	3.2	1.09	5.9	0.52	7	1.5	2.1	11.1	0.62	0.51	3.33	33.4
144C	145C	84.56%	80.1	4.2	2.45	1.23	5.2	0.82	41.7	0.34	33	8.8	6.2	11.6	0.74	0.35	2.35	22.4
144D	145D	86.19%	73.3	7	4.53	1.67	7.1	1.47	37.8	0.65	33.5	8.5	7.1	22.3	1.12	0.65	4.4	42.2
144E	145E	90.15%	273	21.7	11.4	6.61	25.7	4.12	124	1.4	125	30.7	26.2	35.7	3.83	1.53	9.79	107
205A	205A	80.06%	30		2.4		4.1		12.5		17.0			6.5				18.3
205B	205B	13.53%	46.9		2.67		4.5		23.4		22.4			13.2				24.9
205(nod)	205Mn	90.45%	13.7		1.76		2.2		8.0		7.4			3.7				19.2
230(bnt)A	230BENT1	94.25%	70.1		2.71		5.7		35.2		31.7			14.4				26.9
230(bnt)B	230BENT2	95.84%	37.7		1.62		3.2		18.9		17.2			17.1				13.3
230(bnt)C	230BENT3	96.19%	42.6		1.72		3.2		21.2		19.2			17.6				15.1
230(nod)A	230CORE	84.04%	15.6		0.97		1.8		9.3		7.6			3.2				12.9
230(nod)B	230CRST	92.86%	16.6		2.84		3.0		10.3		8.5			5.1				40.3
230L	230L	94.31%	64.0		2.40		4.7		32.0		28.7			16.5				21.5
230M	230M	44.46%	21.5		3.29		3.4		11.0		11.1			12.9				32.2
230N	230N	37.44%	26.9		2.96		3.5		13.8		13.4			11.7				29.9
230O	230O	21.17%	43.9		2.31		5.5		16.5		25.4			14.2				19.9
230P	230P	78.40%	49.4		2.59		4.5		25.2		23.1			16.0				22.9
230Q	230Q	92.62%	52.6		2.16		4.3		27.1		24.1			15.4				19.7
230R	230R	54.19%	33.4		3.70		3.8		18.7		14.8			17.0				33.7
230S	230S	66.16%	43.1		2.35		4.6		19.1		24.3			16.4				19.0
230T	230T	87.02%	55.6		2.19		4.4		29.8		25.4			17.0				19.8
230U	230U	86.32%	55.5		1.91		4.0		27.8		24.1			10.9				18.5
230V	230V	29.88%	49.0		3.27		5.1		25.9		22.3			10.4				33.0
230W	230W	25.88%	27.2		2.69		3.4		13.8		13.5			8.0				27.6
230X	230X	94.41%	52.4		1.99		4.3		24.9		24.3			12.8				17.2

Sample ID	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellerium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
120A								6.1		5						6.8												
120B								11.1		2						12.3												
120C	0.71	4.9	740	1.5	0.16	4.40	38	5.5	13.6	2	2.7	0.04	27.4	5950	81	0.8	14.1	71	146	1.14	<0.10	8.9	1.6	3130	1.5	3.9	52	97.6
120D								5.5		6						4.3												
120E								4.3		1						22.4												
120F								3.0		1						8.9												
120G								3.6		27						20.9												
144At																												
144Ab	6.00		1220	3.1		1.24	51		15.5	10	3.8		13.2	3270		10.0	9.2		319	0.38				1550	4.6	9.0	95	252
144B1t																												
144B1b																												
144(pod)				3.4			103		26.3	724	6.0			6650		85.8	41.4							3320		12.4	326	794
144T				3.3			21		9.5	4	1.4			2570		22.6	2.5							402		12.9	59	90.1
144U				2.1			58		11.8	9	3.1			5900		12.7	11.4							1670		4.6	146	236
144V				8.4			21		10.2	13	1.9			3930		12.1	5.3							987		7.9	66	118
144W				2.6			89		19.4	13	4.1			7700		6.0	13.9							3640		5.2	174	254
144(whi)	0.41	3.9	402	0.6	<0.1	0.91	25	7.1	6.0	1	0.7	<0.02	9.2	4530	6290	0.3	3.4	22	167	0.23	<0.1	2.5	0.6	1350	5.9	1.6	34	23.4
144X				3.2			91		19.6	5	4.2			9570		5.5	13.4							3920		5.3	164	206
144Y				3.2			68		17.3	5	3.5			6110		4.1	13.1							3900		5.3	113	158
144Z				2.1			92		20.5	5	3.4			8840		3.7	11.6							4110		3.8	161	125
144B2t																												
144B2b	5.60		105	6.7		0.25	30		9.1	50	3.8		11.3	6520		18.6	9.1		457	0.28				794	1.9	11.3	68	436
144C																												
144D																												
144E	6.79	22.4	21600	6.3	0.52	4.39	91	33.3	27.6	19	7.5	0.09	32.0	6720	24	40.2	17.2	45	310	0.80	0.11	14.5	2.1	2860	4.0	20.1	153	574
205A				2.1		0.31			16.2	675			7.5	2650				4				1.8		1200		5.3		
205B				3.1		3.44			20.3	7			38.2	5000				31				9		4410		3.1		
205(nod)				2.1		1.24	17		4.0	1				7140	14800	0.2	2.1							694		1.2	22	18.7
230(bnt)A	1.28	8.9	753	2.1	0.25	5.67	80	15.5	21.4	2	3.7	0.06	37.3	10200	209	2.1	13.1	83	150	1.05	<0.1	13.2	2.2	3860	1.7	3.8	120	116
230(bnt)B	1.53	8.6	758	1.4	0.25	7.15	92	34.4	22.6	2	3.4	0.06	25.2	6300	85	1.4	12.3	79	114	0.89	<0.1	9.5	1.9	4450	2.2	3.5	146	114
230(bnt)C	1.71	22.0	569	1.5	0.28	7.14	89	21.8	22.6	1	3.5	0.06	27.4	6560	86	1.3	11.6	72	104	0.85	<0.1	9.4	1.9	4230	1.7	2.8	149	118
230(nod)A	0.50	2.8	511	1.4	<0.1	0.99	16	5.6	3.5	1	0.4	<0.02	7.4	3000	13400	0.4	2.0	13	190	0.13	<0.1	1.5	0.4	558	0.6	1.7	25	15.1
230(nod)B	0.54	9.1	1410	1.6	<0.1	1.83	21	3.5	5.0	1	0.7	<0.02	9.0	3710	22000	<0.2	2.8	17	168	0.21	<0.1	2.3	0.5	938	0.1	1.4	25	24.1
230L			521				88		25.3	15			33.7	9370		3.7	14.0							3880		5.1	146	190
230M			692				34		13.5	11			24.0	12900		13.4	6.3							1450		5.7	78	191
230N			282				42		12.1	12			15.3	4160		10.0	10.9							1360		6.5	118	344
230O			214				63		10.4	11			9.9	1500		12.1	14.2							825		7.4	152	236
230P			616				87		20.2	5			33.5	6760		6.8	12.1							3370		5.6	164	186
230Q			653				94		20.2	2			41.6	8940		1.6	11.1							3920		3.0	138	136
230R			1630				43		20.5	16			51.9	2950		16.9	17.4							4140		11.1	87	228
230S			924				91		19.6	12			21.8	6350		12.7	11.8							3040		11.8	233	302
230T			1120				117		23.4	5			44.2	12700		3.2	12.6							4320		5.4	233	238
230U			754				56		15.5	3			25.2	6310		3.0	9.8							3160		5.5	90	133
230V			1040				30		14.4	9			17.9	2720		14.8	14.8							982		12.6	70	118
230W			1330				21		12.2	10			13.0	2570		23.3	4.9							975		14.1	80	69.9
230X			623				80		20.9	2			25.5	10400		2.1	12.0							3610		4.1	112	125

Sample ID	NDGS Field ID	Ash (wt%)	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellerium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
230Y	230Y	69.01%	41.1		1.87		3.3		20.9		18.6			12.1				17.0			932				57		24.6	360			17.3	7490		9.3	43.4							2810		4.4	146	438
230Z	230Z	31.19%	78.0	12.0	7.99	2.49	10.7	2.62	36.1	1.23	39.4	9.4	8.9	21.0	1.87	1.16	7.65	71.8			1070				63		20.6	41			12.1	1760		51.2	13.0							1230		11.0	135	293
247L	247L	75.56%	42.3		2.11		3.6		21.6		19.9			15.8				16.3				3.0			74		21.6	26	3.7			13900		6.1	18.3							2830		7.5	165	336
247M	247M	84.26%	83.3		4.10		7.4		40.8		37.2			15.6				36.9				4.5			37		26.6	11	5.2			14800		8.1	19.4							2740		9.9	97	251
247N	247N	92.75%	39.9		3.57		4.2		19.5		17.3			13.1				32.5				6.5			35		9.8	5	2.6			9170		7.2	8.1							1340		8.8	86	162
247O	247O	94.27%	86.8	8.6	5.22	2.25	9.6	1.76	38.3	0.71	42.5	10.1	9.3	12.0	1.50	0.72	4.57	48.7				5.2			33		6.7	7	1.6			4030		3.8	6.3							370		3.3	118	58.7
247P	247P	70.22%	23.2		2.49		3.8		8.5		14.8			10.5				18.2				2.6			27		6.3	5	1.0			5400		9.0	15.2							294		5.8	74	113
247Q	247Q	64.75%	59.3		3.86		5.7		32.2		27.1			16.1				33.7				3.6			67		18.6	6	2.6			7970		12.0	14.3							2440		6.2	165	124
247(bnt)C	247R	44.22%	97.3		3.53		7.7		50.7		42.9			15.2				29.8				1.5			42		26.1	2	8.2			13400		1.6	20.7							3680		7.6	67	243
247S	247S	16.75%	15.5		3.05		2.2		8.6		7.5			8.0				24.0				12.3			30		8.5	27	1.1			5330		9.6	14.9							1130		4.2	59	73.0
247T	247T	26.38%	73.2		3.15		5.1		40.7		28.3			10.4				26.1				3.4			46		19.9	27	3.7			11400		12.4	51.7							2120		16.4	138	196
247(bnt)A	247U	57.30%	66.9		1.97		3.3		42.4		22.0			4.9				19.9				1.0			15		17.2	1	3.1			13800		1.8	13.2							1760		7.8	30	84.5
247(ash)	247V	26.72%	49.5		2.73		3.2		40.8		16.6			1.8				32.1	0.59	1.5	355	0.6	0.13	0.32	7	1.7	8.1	1	1.2	<0.02	10.9	8560	2780	0.5	5.6	7	179	0.64	<0.1	7.9	0.9	944	0.5	4.4	14	32.2
247(bnt)B	247W	78.20%	72.6		1.82		3.7		42.0		24.7			6.2				17.5				0.8			18		21.7	1	4.0			17400		1.0	14.1							2610		9.0	36	99.1
247X	247X	56.53%	119	10.7	5.86	3.28	12.9	2.01	49.4	0.94	63.3	15.1	14.3	20.7	1.91	0.84	5.72	42.9				4.3			73		17.9	7	3.0			7070		31.1	13.7							2310		18.0	265	129
247Y	247Y	65.87%	40.0		1.64		3.3		20.4		19.0			10.7				13.8				1.4			54		14.3	2	2.3			5720		22.2	8.6							2700		6.0	150	77.3
247Z	247Z	21.71%	52.8	8.3	5.27	1.62	7.9	1.78	23.4	0.70	27.4	6.6	6.3	11.6	1.33	0.72	4.55	49.2				8.8			22		6.1	3	1.6			1880		5.6	8.6							546		4.4	62	76.0
248K	248K	95.37%	129	13.0	7.14	3.59	15.7	2.51	56.9	0.88	66.9	15.9	14.8	14.1	2.35	0.94	5.74	61.7				5.8			41		15.9	16	4.9			6850		9.9	17.6							2320		6.7	91	205
248L	248L	95.18%	40.3		3.99		4.4		22.6		17.8			17.8				36.0				6.6			82		23.7	4	4.4			16900		5.8	20.3							4510		11.3	116	312
248M	248M	95.85%	273	26.7	14.6	6.83	30.3	5.20	128	1.83	129	31.9	27.8	23.2	4.66	1.92	12.00	129				7.3			61		20.2	7	3.0			5230		17.7	7.6							831		16.3	72	103
248N	248N	95.75%	91.1	12.5	7.95	2.97	13.1	2.65	42.7	1.14	50.6	12.0	11.6	19.5	2.06	1.10	7.06	68.1				4.6			104		15.9	15	3.6			9070		15.2	19.2							1310		10.6	196	387
248O	248O	96.84%	49.2		1.91		4.1		26.2		23.3			12.3				15.5				1.7			74		15.4	2	2.1			12600		0.6	7.6							3100		2.2	101	75.0
248P	248P	40.87%	84.1	9.2	6.11	2.33	9.7	2.02	50.9	0.82	40.2	9.9	7.9	15.1	1.48	0.84	5.31	62.1				10.5			56		21.8	17	3.6			12200		8.1	12.5							2400		9.2	100	164
248Q	248Q	77.19%	19.3		1.91		2.9		9.4		10.4			8.7				17.2				2.8			21		7.5	1	3.5			8060		5.6	6.8							1620		3.4	44	109
248R	248R	28.59%	31.9		4.83		4.5		17.8		14.6			11.5				47.8				12.2			39		10.0	6	1.9			9450		7.0	13.1							2880		5.9	66	87.1
248S	248S	39.09%	59.3		2.24		4.8		32.3		26.7			12.0				19.6				2.2			92		17.7	4	2.2			7530		2.1	6.9							3260		3.2	150	142
248(bnt)A	248U	93.84%	79.9		1.85		3.6		49.1		25.9			5.2				16.5	1.45	4.6	624	2.1	0.35	0.80	14	12.0	20.7	1	3.6	0.02	37.2	20200	296	1.2	15.9	19	272	1.63	<0.1	28.8	2.1	2170	0.6	7.5	29	101
248(ash)t	248VA	61.32%	77.8		1.72		3.6		46.4		25.9			5.5				14.9	0.75	2.1	682	2.0	0.35	1.44	16	4.3	19.6	2	3.5	0.02	55.3	19000	150	0.6	16.3	28	268	1.61	<0.1	27.7	2.1	2290	1.0	7.7	32	102
248(ash)m	248VB	43.09%	67.1		1.50		3.0		38.9		21.1			4.6				12.9	1.02	5.5	858	2.0	0.31	2.98	13	3.6	16.6	2	3.1	0.02	29.2	10600	237	3.1	13.9	61	252	1.38	<0.1	24.0	1.8	1950	1.9	8.0	27	90.4
248(ash)b	248VC	42.25%	69.3		1.47		3.2		40.7		22.6			5.1				12.9	0.91	4.0	835	1.9	0.35	2.15	12	4.0	17.6	1	3.3	0.02	48.9	15000	182	1.6	14.1	45	294	1.51	<0.1	26.3	1.9	1980	1.0	8.2	28	96.9
248(bnt)B	248W	93.27%	81.3		1.95		4.1		49.3		28.0			7.0				17.1	1.39	9.7	1710	2.0	0.28	1.21	33	7.9	18.0	2	2.8	0.03	34.5	14300	138	6.4	14.4	29	439	1.18	<0.1	19.5	1.8	2510	13.4	10.2	46	89.5
249A	249A	72.82%	54.0		2.67		3.6		29.2		21.8			12.2				20.4				5.5			63		19.3	6	2.8			10000		17.3	15.7							2680		9.1	148	109
249(bnt)	249AR	72.19%	84.4		1.81		4.0		49.2		27.7			6.1				16.2				1.2			19		22.3	1	4.5			18700		1.6	15.2							2350		10.2	39	111
249B	249B	84.53%	56.4		2.86		5.2		30.1		25.9			15.0				25.2				3.2			80		19.9	5	3.4			8880		6.0	14.4							3440		5.0	148	151
249(nod)	249NOD	93.08%	20.5		2.02		2.9		11.1		10.3			6.1				18.6	63.5	657	268	0.9	<0.1	0.80	51	11.5	2.5	1	0.2	<0.02	5.4	1970	3500	10.4	1.9	8	59	0.14	<0.1	2.5	0.9	499	46.1	1.0	36	15.5
249(sil)	249SIL	77.90%	2.9		0.73		0.4		1.9		1.1			0.8				6.9	1.32	9.4	249	4.8	<0.1	0.04	12	1.0	<1	2	0.2	<0.02	3.1	525	90	3.6	5.2	1	75	0.04	<0.1	0.6	0.5	68	2.0	3.6	15	33.3
250Qt	250QA	95.19%	12.2		2.70		2.4		5.8		6.6			7.6				25.1				5.1			23		5.6	15	1.6			8610		12.5	4.6							493		5.8	69	70.5
250Qb	250QB	94.26%	55.7		4.21		7.0		24.9		28.7			7.0				38.0				3.4			26		8.3	7	1.4			4320		18.8	5.7							775		7.5	72	49.1
250R	250R	95.04%	9.9		3.80		3.6		4.8		6.9			7.2				42.3				8.5			12		3.3	8	0.7			14200		5.9	5.4							453		7.3	27	54.0
250(bnt)	250U	95.02%	78.8		1.77		3.7		46.8		25.7			5.8				16.5				2.0			16		18.4	1	3.5			18200		0.9	14.6							2100		7.7	35	99.3
250(ash)t	250VA	38.58%	67.0		1.56		3.3		37.7		22.5			5.0				12.8	0.82	4.6	628	2.0	0.30	1.62	15	5.5	16.6	2	3.2	0.02	45.7	17100	239	1.5	13.7	32	249	1.47	<0.1	25.8	2.0	2080	1.3	6.6	36	96.6
250(ash)m	250VB	36.91%	63.0		1.51		3.0		38.0		20.7			4.7				13.2	2.53	16.5	1300	1.8	0.36	4.13	12	4.2	15.7	2	2.9	0.02	15.5	5890	327	3.2	13.2	93	244	1.35	<0.1	22.4	1.8	1790	4.5	8.7	28	83.4
250(ash)b	250VC	24.60%	52.9		1.25		2.4		30.8		17.2			5.0				10.5	1.61	6.3	1140	1.9	0.34	2.77	15	15.4	16.2	1	3.2	0.02	39.3	12800	290	1.8	13.0	58	257	1.48	<0.1	21.5	1.8	1890	1.3	6.9	33	90.9
250X	250X	92.51%	38.8		1.63		2.8		21.1		16.9			11.2				14.6				1.8			62		14.2	10	2.0			9310		3.5	8.8							2770		3.4	113	78.4
251At	251A	29.31%	8.5		2.00		2.0		4.5		6.2			5.4				20.1				4.9			30		13.4	25	3.0			28400		21.9	11.3							680		7.9	91	372
251Ab	251B	40.35%	49.1		4.68		6.1		27.1		23.6			12.8				44.3				7.3			29		11.0	7	3.8			20400		2.8	15.0							1110		5.1	49	256
251C	251C	85.82%	37.3		1.70		2.9		17.5		16.6			12.3				13.9				3.4			77		17.2	2	3.0			12800		1.1	12.1							3740		10.5	117	149
251D	251D	85.82%	43.8		2.48		3.7		22.5		19.1			11.6				21.9				4.8			48		17.6	5	3.3			9140		2.5	12.0							2610		13.0	84	182
251E	251E	87.02%	55.3		2.45		4.5		27.8		25.2			13.1				21.6				2.7			72		19.1	4	3.5			10000		2.9	13.0							3860		5.2	109	154
251F	251F	87.27%	45.5		2.50		4.2		22.8		21.2			13.3				21.2				3.2			71		19.2	6	3.3			9630		3.0	12.5							3660		4.9	113	144
251S	251S	92.41%	49.8		2.29		4.6		26.9		23.4			12.0				20.0				1.7			67		16.6	6	2.5			9520		0.8	8.0							2980		3.4	118	118
252T	252T	94.44%	44.4		2.59		4.1		23.0		20.6			11.7				23.2				5.0			58		19.9	24	3.8			4860		5.9	14.4							2610		6.9	107	269
252U	252U	94.86%	83.1		3.24		7.7		45.4		40.2			14.8				29.1				2.8			66		23.6	22	3.6			6990		13.2	16.5							2590		13.9	163	215
252V	252V	53.25%	18.9		1.82		2.2		10.3		9.2			7.9				16.5				5.3			26		10.0	12	1.4			4950		10.3	4.4							1220		6.6	69	54.5
252W	252W	68.68%	46.1		2.16		3.9		24.3		20.2			12.3				19.2				4.1			57		17.8	4	3.4			8600		1.6	11.4							3050		7.0	104	176

Sample ID	NDGS Field ID	Ash (wt%)	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellerium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
252X	252X	32.36%	52.6		2.87		4.6		28.7		23.5			15.6				25.1				3.8			80		21.2	7	3.7			9200		1.9	13.3							3980		6.0	126	170
252Y	252Y	89.60%	59.1		2.74		5.2		30.7		28.0			19.0				24.1				2.3			100		23.1	5	3.6			5670		5.2	12.7							4700		5.8	169	137
252(bnt)A	252YR	89.11%	56.4		2.39		4.8		29.7		25.6			16.4				20.9				1.8			89		21.0	2	3.3			6280		2.1	12.7							4390		3.9	149	113
252Z	252Z	93.60%	47.2		2.28		4.1		25.0		21.7			17.6				18.9				1.8			92		21.6	12	3.5			6560		10.8	11.5							4100		5.7	173	148
252(bnt)B	252ZR	89.82%	45.2		2.34		4.4		22.5		22.0			18.7				19.0				2.0			104		22.4	2	3.3			11100		2.3	12.2							4780		4.1	171	107
260P	253POD	86.58%	35.9		2.07		3.0		19.4		16.4			11.5				15.4	6.49	58.2	606	4.5	0.22	4.73	101	34.8	20.9	43	3.5	0.04	20.5	9160	467	4.8	22.9	62	258	0.60	<0.1	7.2	1.3	2440	3.0	5.6	227	298
253S	253S	62.66%	52.3		2.24		4.8		25.7		28.4			18.2				14.3									37.0	71	5.7			8960		35.4	17.0							2920		12.2	299	445
253T	253T	36.90%	72.9		4.34		7.9		35.5		37.7			14.2				35.6									21.5	30	3.6			7710		46.6	11.3							1780		27.6	197	324
253U	253U	49.84%	22.5		4.28		3.7		11.8		12.8			13.2				31.6									21.3	51	3.8			4020		19.0	11.9							999		24.0	141	469
253V	253V	53.67%	67.2		4.56		7.8		32.5		35.0			11.1				37.3									20.1	11	3.8			5410		53.3	21.2							1540		20.4	173	345
254U1	254U1	70.31%	76.6		4.65		9.1		36.1		39.2			14.2				39.3									16.8	24	3.2			3530		55.8	7.5							1100		28.2	124	269
254U2	254U2	52.60%	56.1		3.14		6.2		25.9		29.9			18.4				25.7									15.8	35	3.9			5410		31.4	11.1							2230		13.1	165	294
254V	254V	78.06%	57.1		2.98		5.5		28.7		26.0			13.3				27.3									13.8	18	2.8			4800		23.4	11.7							2170		10.6	120	185
255(nod)A	255CONC	88.83%	18.7		1.30		2.2		11.9		9.1			3.8				16.6	0.29	3.9	527	1.2	<0.1	1.21	21	3.9	4.0	1	0.4	<0.02	11.0	3430	11500	0.2	2.3	16	129	0.14	<0.1	1.5	0.6	647	1.1	0.9	24	16.8
255J	255J	80.35%	55.9		3.13		5.6		29.0		26.0			17.9				29.7									18.7	2	3.2			9980		10.3	10.0							3430		6.5	216	161
255K	255K	39.33%	31.6		3.95		4.0		15.7		14.7			17.3				35.6									16.9	11	3.8			7960		18.4	9.6							1650		11.0	95	249
255L	255L	75.72%	38.6		2.92		3.3		21.3		16.5			17.7				25.4									29.3	5	3.4			13400		6.2	20.0							5780		5.6	132	140
255M2	255M	25.71%	69.4	10.8	7.95	2.53	10.5	2.78	33.0	1.05	37.9	8.9	11.0	22.1	1.58	1.09	7.00	76.7									8.6	8	3.9			6260		9.5	15.1							2850		19.9	204	337
255O	255N	28.63%	32.3		2.05		3.6		15.4		16.8			10.4				16.1									12.7	13	3.2			5950		18.5	12.0							1370		5.2	109	223
255(nod)B	255NOD	29.92%	29.4		4.41		4.3		26.7		13.8			9.7				65.9	0.25	4.1	1230	4.2	0.22	1.94	28	6.2	5.8	1	1.2	0.02	14.3	5330	3990	1.0	4.1	26	676	0.28	<0.1	2.3	0.8	1270	1.0	5.6	41	48.8
255N	255O	62.75%	10.7		2.99		2.5		5.8		6.3			14.1				26.7									13.4	15	4.3			11900		9.1	10.1							887		6.7	90	377
255P	255P	85.75%	61.2		2.75		5.3		31.4		28.7			17.5				22.7									21.1	3	3.7			10500		5.8	12.6							3600		9.1	136	149
255Q2	255Q	70.74%	24.4		3.18		3.3		12.8		11.8			12.6				29.2									15.5	3	4.2			13100		10.1	8.7							2170		11.1	72	209
255R	255R	57.87%	58.5		3.39		5.1		30.4		26.3			15.4				33.0									15.6	2	3.2			12700		3.8	14.6							3480		5.2	82	133
255S	255S	77.36%	46.7		4.51		5.4		47.4		27.0			22.5				46.2									26.4	4	5.1			16200		1.8	18.4							4660		35.2	191	202
255T3t	255TA	81.62%	110	11.0	6.73	2.90	12.0	2.35	56.4	0.89	53.3	13.5	12.6	20.5	1.80	0.93	5.96	65.4									10.8	5	2.9			5740		23.3	6.7							1600		8.9	157	134
255T3b	255TB	52.45%	160	16.5	10.0	4.43	18.2	3.51	73.0	1.31	82.0	20.1	19.3	29.4	2.70	1.37	8.76	91.8									17.8	7	8.0			6130		17.6	17.4							3030		12.0	120	470
255U2	255U	50.14%	81.6		2.93		6.4		40.7		36.6			15.5				25.1									22.1	5	3.8			18500		14.2	13.1							3220		11.0	159	142
257U	257U	53.28%	212	18.3	9.90	5.24	21.5	3.48	102	1.30	102	26.0	22.9	22.6	3.18	1.36	8.67	101	2.68					3.37			23.0	8	5.3		41.4	6010		7.2	10.1			1.10				3130	1.6	11.9	110	231
257V	257V	54.94%	61.7		3.74		5.9		33.4		29.3			19.9				31.6	4.03					7.40			26.5	18	4.7		36.9	10600		2.8	17.7			0.69				2950	2.0	23.3	158	349
257W	257W	86.42%	56.0		2.08		4.4		29.1		25.0			15.8				18.5	1.58					8.91			21.0	3	3.0		54.8	11300		2.0	12.9			0.94				4480	1.6	4.7	142	107
257X	257X	90.67%	27.3		2.21		2.8		14.5		12.5			10.5				20.2	3.74					1.22			10.8	9	2.9		17.6	3670		9.4	11.5			0.48				1950	2.9	6.4	111	226
257Y	257Y	61.70%	15.7		2.91		2.6		8.4		8.0			9.9				25.7	4.92					0.74			11.0	11	1.8		9.0	6570		11.9	11.8			0.28				1140	4.5	9.8	57	151
257Z	257Z	74.96%	13.7		2.51		2.4		6.6		7.5			11.1				23.1	5.56					0.56			8.7	11	2.3		8.1	2430		11.1	13.7			0.22				832	3.0	6.2	76	240
258Q	258Q	88.36%	77.5		3.40		6.6		42.3		35.7			16.3				30.3	7.07					8.44			31.7	60	4.4		49.3	17400		8.1	17.4			0.95				3570	3.2	9.3	154	307
258R	258R	46.35%	44.0		5.62		5.4		24.2		19.8			19.8				49.7	11.4					4.21			29.8	50	3.4		27.2	21000		15.7	15.4			0.58				2310	8.3	12.9	132	284
258S1	258S	27.66%	119		4.96		10.3		56.0		51.5			13.2				46.2	3.01					4.91			23.0	6	5.6		90.5	13800		9.0	12.0			1.53				3110	1.5	13.2	74	226
258S2	258T	28.87%	83.4		3.55		7.5		41.2		39.6			11.9				32.2	3.14					3.90			21.5	7	5.5		67.5	10600		9.3	13.6			1.45				3000	1.7	11.2	74	231
258U	258U	91.46%	38.3		6.80		6.6		20.2		19.3			22.9				62.5	8.94					1.64			25.3	34	5.9		53.1	27000		7.6	16.8			0.94				2520	2.7	6.9	129	411
258Vt	258VA	89.60%	65.2		3.40		6.6		33.2		30.9			12.6				29.5	3.65					4.12			13.2	8	2.8		17.2	12800		6.3	10.9			0.64				2840	1.2	8.6	99	152
258Vb	258VB	65.53%	49.1		3.13		5.1		28.4		20.5			15.2				33.1	5.75					3.87			14.1	4	2.4		37.2	6930		35.1	9.9			0.51				1870	3.5	11.1	121	81.0
258W	258W	87.89%	57.7		2.27		4.9		32.2		27.3			17.4				21.4	1.12					5.78			18.4	2	3.4		23.5	13000		1.6	10.6			0.73				3850	1.6	5.1	153	122
258(wood)	258Wood	84.51%	63.6		2.74		5.5		32.5		29.7			10.0				23.8	2.07	13.4	1010	2.1	0.11	4.05	56	17.8	19.5	16	3.2	0.05	27.9	5190	307	2.6	12.5	67	192	0.77	<0.1	7.5	1.4	2810	5.5	4.6	92	136
258X	258X	60.78%	50.4		2.58		5.1		26.4		25.7			11.9				23.1	1.77					2.76			15.7	12	2.9		23.1	13300		2.2	10.0			0.64				3230	0.9	3.3	103	141
258Y	258Y	36.04%	51.1		2.94		4.6		26.8		22.6			16.2				26.2	2.49					5.11			20.8	4	4.5		50.0	7400		3.9	15.5			1.11				4200	1.7	8.0	118	192
258Z	258Z	60.63%	49.2		3.43		4.5		27.6		22.1			15.4				31.5	4.26					8.95			23.3	8	3.5		35.7	5460		5.6	15.9			1.04				4730	2.3	6.7	131	142
259P	259P	94.35%	75.3		4.77		9.2		31.3		43.2			18.9				36.3									15.0	28	4.7			5270		22.9	18.8							1540		22.4	129	400
259Q	259Q	91.20%	52.5		4.43		7.2		25.7		26.8			14.1				47.2									6.2	3	2.9			4590		5.2	9.5							968		6.4	72	157
259S	259S	83.69%	104		7.48		13.3		49.3		52.3			12.7				72.7									10.3	5	1.1			4760		33.8	2.1							378		10.2	53	50.8
259T	259T	86.48%	25.1		2.41		2.9		13.7		11.7			10.2				22.1									13.1	15	2.4			5060		14.3	8.7							1840		8.9	99	166
261V	261V	43.44%	64.8		4.05		6.4		30.2		32.3			21.2				37.8									33.2	12	4.2			5960		6.3	24.6							8880		7.3	204	217
261W	261W	27.72%	71.2		3.43		6.8		35.7		34.1			18.1				30.7									22.2	9	3.5			7620		3.5	13.2							4430		5.4	167	134
261X	261X	21.85%	85.6		3.99		8.9		42.6		43.7			17.1				32.6									25.1	6	3.4			6230		2.7	12.6							4350		6.3	163	134
261Y	261Y	51.22%	32.1		2.65		3.9		17.1		15.5			15.3				23.8									25.0	3	3.4			3180		2.4	17.2							5350		5.8	141	138
261Y2t	261Y2A	67.26%	140.0		6.70		14.4		68.1		66.3			19.2				62.8									34.7	3	6.8			3110		4.4	25.0							4900		10.7	110	237

Sample ID	NDGS Field ID	Ash (wt%)	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellerium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
261Y2m	261Y2B	84.77%	78.8		4.74		7.6		42.2		35.9			10.5				45.4									25.8	24	3.9			2680		41.3	8.0							1430		17.0	90	188
261Y2b	261Y2C	92.55%	38.1		3.06		4.0		21.4		17.7			13.4				28.5									23.7	25	3.0			3190		4.3	12.3							3430		4.9	135	105
261Z	261Z	91.71%	23.6		2.28		2.9		14.1		11.9			7.5				23.0									10.7	2	1.3			5600		0.2	5.4							1690		1.7	42	48.1
262V	262V	88.80%	89.8		4.09		6.9		54.5		36.2			15.0				38.3									32.6	60	4.1			8590		4.1	25.6							5000		8.1	191	260
262Wt	262WA	61.16%	74.2		4.28		7.6		38.1		35.2			15.5				39.8									27.5	3	3.2			7100		9.4	14.0							4330		7.0	178	111
262Wb	262WB	46.44%	163.0		11.20		19.0		80.0		77.3			16.9				104.0									18.4	10	3.3			3560		11.3	17.6							1280		17.1	104	318
262X	262X	76.09%	28.6		3.15		2.9		17.4		11.5			10.3				30.0									15.2	7	2.9			9890		6.9	22.8							3700		8.0	84	109
262Y	262Y	90.65%	64.5		2.08		4.4		33.6		28.5			13.8				17.2									20.0	2	3.0			5040		1.0	14.3							4360		4.4	128	119
262Z	262Z	79.55%	55.7		1.93		4.1		29.4		24.1			15.2				17.1									21.0	2	3.4			6170		1.4	14.4							4030		3.6	157	124
264Y	264Y	29.86%	60.8		2.89		5.9		32.7		30.1			13.2				26.0									20.9	7	3.0			7270		4.0	11.4							3500		3.3	122	117
264Z	264Z	78.75%	97.3	7.8	4.45	2.11	8.8	1.54	48.7	0.61	45.2	11.8	9.1	20.1	1.34	0.62	4.00	40.9									32.6	6	5.0			4960		5.0	17.2							4520		8.8	164	217
268W	268W	50.96%	45.7		2.8		4.3		24.5		21.0			13.4				23.7	1.46			2.8		5.53	75		18.0	5				4820		1.8	12.7			0.91				4570	2.2	2.5	111	128
268X	268X	94.44%	37.2		3.82		4.4		18.3		17.5			11.7				32.7	1.01			7.3		1.51	53		20.6	2				3750		1.4	12.9			1.05				3680	3.5	2.5	84	108
268Y	268Y	95.06%	32.8		3.32		3.4		18.6		15.0			14.9				25.9	1.79			7.6		4.95	88		16.7	8				6120		2.8	12.7			0.81				3650	2.0	7.5	126	131
268Z	268Z	95.60%	46.9		2.11		3.5		25.2		19.9			14.7				16.5	1.15			3.2		6.67	84		22.2	2				6280		1.4	13.1			0.99				4420	2.2	3.1	151	113
269Ab	269Ab	82.52%	187		9.71		18.8		99.2		85.2			16.9				98.1									13.9	9				3990		12.5	18.0									19.4	153	188
269At	269At	77.85%	69.3		3.52		6.5		35.5		33.1			18.7				29.2									25.2	10				10700		8.1	14.7									11.0	196	136
269B	269B	70.25%	147		7.66		15.3		79.5		63.4			16.7				74.0									15.2	15				4970		24.3	7.8									12.2	166	151
269(bur)	269BUR	73.87%	29.5		3.03		3.6		16.6		14.2			7.8				25.2	2.37	41.2	326	2.8	<0.1	1.18	34	24.4	5.2	1	1.1	<0.02	16.5	4120	5180	1.1	3.8	22	189	0.25	<0.1	3.0	0.4	1100	0.2	3.9	101	48.0
269(nod)B	269CONC	90.89%	61.2		4.09		6.7		21.7		25.4			10.3				31.2	0.87	27.3	453	3.8	<0.1	1.44	39	17.7	7.5	2	1.3	0.02	8.4	3490	6170	0.2	6.6	35	140	0.77	<0.1	3.2	0.6	1300	2.6	2.1	73	47.0
269F	269F	89.78%	88.5		3.31		6.9		46.3		38.0			14.3				28.8									23.6	3				4260		4.4	17.0									4.5	132	151
269G	269G	77.89%	55.1		1.78		3.9		28.0		24.5			10.3				14.5									18.0	4				4410		1.3	12.3									2.3	91	89.8
269H	269H	91.67%	75.8		2.77		5.8		39.9		32.1			15.7				23.3									21.8	12				6460		3.8	12.9									5.5	169	199
269I	269I	65.16%	53.3		2.86		4.4		29.2		23.3			16.8				22.4									22.2	10				7130		18.1	15.2									7.3	196	268
269J	269J	82.36%	54.6		2.44		4.4		29.1		24.2			13.5				19.5									18.0	3				5280		3.2	13.4									3.3	115	115
269K	269K	42.37%	27.0		1.42		1.9		15.6		11.3			16.2				11.4									17.5	6				5790		1.0	13.1									6.3	224	180
269L	269L	91.93%	51.3		1.84		3.9		27.8		22.6			12.8				14.8									17.8	2				5910		2.1	12.1									4.2	113	112
269M	269M	92.95%	32.5		2.19		2.5		17.8		13.8			14.4				18.5									17.3	9				5440		1.9	15.4									2.5	148	132
269N	269N2	90.85%	38.2		1.61		2.7		18.1		15.5			13.2				12.6									16.0	60				5140		0.8	14.9									3.1	137	127
269(nod)A	269NOD	87.57%	20.8		2.78		3.4		12.0		10.6			5.7				32.8	0.39	1.4	307	2.4	<0.1	1.45	26	4.0	4.0	2	0.7	<0.02	15.3	9130	9860	0.4	2.6	19	115	0.20	<0.1	2.3	0.7	838	0.4	1.0	37	24.6
269O	269O	92.33%	34.7		2.31		3.1		18.6		15.8			10.6				19.6									16.0	9				6600		6.8	10.3									2.7	90	82.0
269O2	269O2	90.85%	8.6		1.18		1.1		4.4		4.1			3.5				9.6	9.65	9.6	211	1.3	<0.1	1.03	21	4.6	10.5	44	0.8	<0.02	6.5	1820	175	13.7	12.0	14	106	0.16	<0.1	1.4	0.3	667	18.5	1.0	59	40.7
269P	269P	94.43%	42.0		2.12		3.4		23.9		18.5			10.5				19.6									17.5	3				7480		2.1	17.2									3.6	102	130
269Q	269Q2	84.53%	17.1		4.03		3.1		10.2		9.0			4.9				40.5									8.7	13				5380		17.8	7.8									5.3	26	42.0
269R	269R	80.86%	44.2		2.14		3.7		23.8		20.2			13.9				18.6									18.8	14				8370		7.9	10.9									4.7	129	90.3
64A	64A	76.35%	52.5	4.0	2.48	1.14	4.3	0.82	26.5	0.38	24.1	6.3	4.7	18.5	0.67	0.37	2.44	20	2.67		892	1.9		7.75	82		20.0	4	3.5		34.7	6570		4.9	12.1		100	0.91				4060	1.3	4.9	142	127
64B	64B	18.55%	52.5	4.0	2.48	1.15	4.4	0.82	26.9	0.38	24.5	6.3	4.8	19.0	0.67	0.36	2.45	21	3.37		661	2.3		7.88	93		21.6	6	3.5		47.1	7340		6.4	12.3		94	0.94				4370	1.3	4.3	169	127
64D	64D	92.50%	15.3	3.6	2.22	0.72	3.1	0.74	5.8	0.36	10.0	2.2	2.8	9.8	0.56	0.33	2.31	15																												
64E	64E	24.55%	6.6	1.1	0.87	0.19	0.7	0.26	4.1	0.16	2.7	0.7	0.6	23.7	0.15	0.14	0.99	6																												
64EE	64EE	92.29%	20.8	1.9	1.32	0.47	1.7	0.42	10.3	0.23	9.3	2.5	1.9	19.0	0.30	0.21	1.41	11																												
64F	64F	91.96%	37.3	2.8	1.83	0.80	2.9	0.59	18.8	0.29	16.7	4.4	3.2	16.7	0.46	0.27	1.89	15	1.67		853	2.5		5.04	77		22.0	2	3.4		65.3	4870		4.8	10.5		116	0.77				4910	1.6	3.8	136	133
64G	64G	90.85%	54.6	4.3	2.67	1.17	4.5	0.88	27.8	0.41	24.1	6.4	4.8	15.0	0.72	0.39	2.59	23																												
64H	64H	17.24%	43.9	3.9	2.31	1.26	4.5	0.78	21.9	0.36	22.8	5.6	4.9	15.3	0.67	0.34	2.30	18																												
64I	64I	85.89%	131	9.5	4.96	3.20	11.6	1.82	60.7	0.60	59.3	15.4	11.6	16.6	1.72	0.67	4.08	46	1.78		14800	5.3		9.21	141		22.2	10	3.4		78.7	14800		2.6	10.6		209	0.84				3810	1.2	9.3	282	184
64I2	64I2	86.21%	78.7	6.5	3.55	2.14	8.1	1.22	34.9	0.5	43.5	10.5	9.6	19.3	1.17	0.51	3.39	27.4	3.44		1140	4.0		10.2	131	11.3	20.0	7	3.4		32.3	9490		8.9	8.4			0.93				3250	1.3	13.8	247	209
64I3	64I3	86.66%	70.5	8.7	5.53	2.04	8.8	1.82	31	0.8	38.7	9.5	8.8	26.4	1.41	0.81	5.42	44.6	2.31		1430	3.2		2.74	157		19.8	43	4.7		23.9	5840		9.0	7.2		249	0.63				2400	4.7	16.8	279	388
64I4	64I4	66.41%	46.4	5.1	3.14	1.49	5.9	1.03	19.8	0.49	29.2	6.7	6.7	18.5	0.87	0.46	3.3	21.8																												
64I5	64I5	60.50%	94.9	9.7	5.22	3.26	11.3	1.85	39.5	0.66	51.5	12.5	11.1	17.0	1.69	0.70	4.41	48.7	3.64	18.8	20100	3.1	0.50	7.30	148	21.7	18.3	8	4.1	0.07	35.6	9360	248	8.8	8.2	68	202	0.66	0.11	10.1	2.0	3740	2.1	35.1	407	382
255M1	64I6	90.39%	34	5.2	3.53	1.41	5.1	1.13	16.1	0.55	20.3	4.7	4.9	13	0.81	0.51	3.54	29.8																												
64I6	64I7	80.74%	45	2.8	1.79	1.31	3.3	0.57	25.1	0.3	20.5	5.3	4	14.8	0.46	0.27	1.91	13.3																												
64J	64J	59.82%	63.6	6.9	4.21	1.85	7.0	1.40	27.1	0.64	32.3	8.1	7.2	13.1	1.14	0.62	4.14	35																												
64K	64K	42.95%	52.0	4.9	3.21	1.21	4.9	1.06	25.3	0.47	24.1	6.3	5.0	20.0	0.79	0.45	2.99	30																												
64L	64L	72.74%	34.8	3.0	1.92	0.86	3.2	0.64	15.5	0.31	16.7	4.2	3.4	17.2	0.50	0.29	1.97	14	3.26		766	2.2		7.44	97		20.9	5	3.8		41.7	5630		7.2	12.2		118	0.93				4510	1.3	5.7	174	140
64M	64M	89.40%	53.4	4.0	2.42	1.15	4.4	0.81	26.8	0.37	24.4	6.4	4.8	17.8	0.66	0.36	2.39	21																												
64N	64N	52.40%	51.0	3.7	2.11	1.20	4.3	0.71	25.0	0.32	25.0	6.4	5.0	18.7	0.64	0.31	2.06	17																												

Sample ID	NDGS Field ID	Ash (wt%)	Cerium	Dysprosium	Erbium	Europium	Gadolinium	Holmium	Lanthanum	Lutetium	Neodymium	Praseodymium	Samarium	Scandium	Terbium	Thulium	Ytterbium	Yttrium
64O	64O	81.92%	41.6	7.0	4.71	1.40	5.9	1.56	18.1	0.70	21.8	5.4	5.2	15.8	1.05	0.68	4.54	43
64P	64P	85.86%	5.7	1.9	1.62	0.32	1.3	0.49	2.8	0.28	3.3	0.8	0.9	9.3	0.26	0.25	1.72	13
64Q	64Q	93.53%	83.1	9.5	6.20	2.52	9.8	2.07	38.7	0.95	43.6	10.5	9.4	19.6	1.53	0.91	5.99	52
255Q1	64Q6	92.87%	39.6	3.6	2.54	0.99	3.6	0.78	21.2	0.43	18.5	4.7	3.8	16.3	0.55	0.39	2.75	19.9
64R	64R	51.92%	56.1	4.8	3.29	1.13	4.8	1.08	28.9	0.50	25.1	6.7	4.9	13.9	0.77	0.48	3.23	31
64S	64S	22.61%	94.6	6.7	4.02	1.67	7.4	1.39	47.5	0.56	41.5	11.2	8.0	11.1	1.14	0.58	3.74	40
64S5	64S7	54.18%	48.9	3	2.09	0.83	3.2	0.65	28.2	0.34	20	5.5	3.7	16.4	0.48	0.33	2.25	17.7
64T	64T	80.47%	129	13.5	7.86	3.08	13.6	2.79	65.1	1.02	58.4	15.2	12.0	20.8	2.22	1.08	6.82	79
64T2	64T2	87.57%	206	22.8	12.3	6.50	25.1	4.36	83.9	1.64	114	27.4	25.8	30.7	3.87	1.69	10.8	101
64T3	64T3	88.28%	83.3	8.7	5.46	2.28	9.3	1.81	42.9	0.8	41.5	10.1	9.1	20	1.44	0.78	5.26	48.6
64T4	64T4	46.54%	127	13.1	7.57	3.71	15.1	2.59	62.9	1.04	65.9	16.1	14.8	20.3	2.24	1.03	6.83	63.3
255T1	64T5	42.91%	125	12.8	7.67	3.45	13.9	2.58	61.2	1.07	62.6	15.6	14.1	23.5	2.13	1.07	7.08	67.5
255T2	64T6	40.48%	148	14.4	8.41	4.27	16.5	2.86	67.9	1.15	78.4	19	17.5	26.3	2.52	1.16	7.77	72.2
64T5	64T7	44.59%	82.9	8.6	5.43	2.18	8.9	1.78	39.4	0.8	40.4	10	8.9	19.6	1.4	0.78	5.24	44.3
64U2	64U	27.93%	139	15.4	9.19	3.50	15.6	3.22	62.7	1.19	63.6	15.7	13.6	27.0	2.57	1.26	7.98	91
64U1t	64U2	42.46%	120	11.9	6.23	3.42	14.3	2.24	43.9	0.80	69.6	16.7	15.2	20.2	2.08	0.84	5.34	50.2
64U3	64U3	57.29%	134	11.6	6.33	3.21	13.7	2.24	55.6	0.8	68.8	17.1	14.5	17.7	2.04	0.87	5.56	55.3
64U4	64U4	37.50%	165	14.7	7.8	4.03	17.9	2.81	56.2	0.96	87.7	21.4	18.5	17.5	2.58	1.05	6.61	69
255U1	64U5	60.11%	79.2	6.3	3.64	1.74	7.5	1.25	37	0.49	39.8	10.1	8.3	8.4	1.1	0.51	3.38	31.4
64U5	64U7	54.02%	182	13.9	7.1	4.45	17.4	2.56	67.5	0.93	91.8	22.4	20.6	24.1	2.55	0.99	6.55	54.9
64V2	64V	48.74%	163	19.4	11.0	4.80	20.7	3.86	68.0	1.47	86.3	20.8	19.4	26.3	3.22	1.50	9.46	99.0
64U1b	64W	38.97%	201	20.0	10.3	5.54	22.6	3.67	64.2	1.29	111	27.0	24.9	23.8	3.45	1.42	8.86	83.8
65A	65A	84.49%	52.8	9.4	6.60	1.56	7.6	2.21	25.6	0.90	25.5	6.5	5.8	21.6	1.38	0.93	5.7	87
65B	65B	91.79%	48.3	3.2	1.98	0.89	3.4	0.67	24.2	0.28	20.4	5.5	3.8	14.3	0.53	0.29	1.87	20
276(ash)	Breien	94.86%	50.6		1.46		2.8		28.3		19.1			4.4				12.8
277(ash)2b	03-2a	93.00%	49.8		1.48		2.8		28.1		18.5			4.3				12.6
277(ash)3m	03-3frsh	94.44%	48.1		1.32		2.6		27.3		17.9			3.5				11.4
277(ash)5b	03-5bot	94.59%	50.2		1.39		2.7		28.9		18.5			3.7				12.1
277(ash)5t	03-5top	94.43%	50.8		1.49		2.8		28.6		19.1			4.2				12.5
277(ash)7b	03-7base	94.35%	47.5		1.27		2.5		26.9		17.3			3.6				11.1
277(ash)7t	03-7frsh	94.51%	47.9		1.22		2.5		26.9		17.3			3.3				11

Sample ID	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cesium	Chromium	Cobalt	Gallium	Germanium	Hafnium	Indium	Lithium	Magnesium	Manganese	Molybdenum	Niobium	Rubidium	Strontium	Tantalum	Tellerium	Thorium	Tin	Titanium	Tungsten	Uranium	Vanadium	Zirconium
64O																												
64P																												
64Q																												
255Q1	5.03		1170	2.8		7.47	108		19.7	10	4.9		28.1	9360		12.3	13.2		247	0.66				3400	1.3	6.8	272	323
64R	1.78		409	6.1		7.77	51		17.0	2	3.0		44.2	12600		3.7	15.1		416	1.30				3690	2.4	6.0	80	117
64S																												
64S5	2.11		814	2.5		12.0	101		25.4	3	3.9		43.4	11700		2.5	13.6		130	0.97				4340	2.0	8.0	189	145
64T																												
64T2	8.29	36.0	2230	6.9	0.39	2.53	68	32.2	30.9	10	10.0	0.07	17.3	5550	65	34.9	16.6	23	537	0.56	0.16	8.2	1.3	2010	11.7	18.4	145	768
64T3																												
64T4	9.58		1430	4.9		2.89	61		17.5	7	7.6		14.8	4550		36.5	16.9		594	0.56				1900	4.2	11.2	151	529
255T1																												
255T2	6.39		2930	4.5		2.12	84	17.2	19.3	7	11.0		20.0	5460		19.9	23.6			1.01				2720	4.5	12.0	152	678
64T5	4.04		529	4.6		1.67	45		12.6	5	4.3		9.7	3870		19.0	7.4		286	0.30				984	4.9	11.4	60	259
64U2																												
64U1t																												
64U3																												
64U4	6.28		2110	4.9		3.50	58		15.5	21	7.1		37.8	6910		43.0	24.3		126	0.68				1840	4.9	50.4	134	434
255U1	3.49		438	2.8		4.03	49		12.2	7	3.9		31.5	5300		12.5	13.0		120	0.96				2830	2.1	9.1	70	174
64U5	8.37		545	4.1		3.98	64	6.2	14.4	14	5.6		23.6	3500		57.9	14.0			0.69				1970	4.2	53.9	181	356
64V2	6.08		551	7.0		1.87	46	30.5	12.8	8	3.7		7.2	4990		26.3	8.5			0.30				908	4.6	10.2	123	172
64U1b	8.11	102	528	6.4	0.56	2.11	71	11.4	10.7	8	3.6	0.06	19.9	7990	74	33.3	9.3	22	179	0.55	0.15	16.3	1.3	1860	3.5	24.8	87	186
65A																												
65B																												
276(ash)	2.15	15.0	989	1.9	0.25	3.77	13	4.2	17.3	2	2.6	0.02	14.0	5920	324	2.5	12.1	99	215	1.17	<0.1	15.4	1.6	1760	2.1	5.6	28	71.1
277(ash)2b	2.04	17.6	1040	1.8	0.29	4.41	15	3.9	17.2	2	2.7	0.02	25.4	6560	408	3	11.6	112	175	1.24	<0.1	16.1	1.7	1700	2.2	5.9	31	72.8
277(ash)3m	2.21	22.2	1010	1.8	0.26	4.36	8	2.5	16.7	2	2.7	0.02	19.7	4760	344	3.1	11.0	118	173	1.23	<0.1	16.2	1.7	1440	2	5.8	21	70.9
277(ash)5b	2.19	18.0	988	1.8	0.29	4.46	10	3.7	17.2	2	2.7	0.02	17.7	6000	517	3.2	11.4	118	166	1.25	<0.1	16.8	1.7	1470	2	5.8	23	70.7
277(ash)5t	2.15	20.1	997	1.9	0.28	4.58	13	4.1	17.4	2	2.8	0.02	19.5	6030	386	3.1	11.7	119	167	1.25	<0.1	16.2	1.8	1640	2	5.9	28	73.7
277(ash)7b	2.07	16.6	949	1.8	0.26	4.20	10	3.5	16.9	2	2.7	0.02	22.2	6640	519	3.2	10.6	110	167	1.25	<0.1	17.0	1.7	1480	1.9	6.2	24	72.7
277(ash)7t	2.03	18.0	987	1.8	0.27	4.29	8	2.4	16.5	2	2.7	0.02	17.6	5360	352	3.1	10.6	116	167	1.25	<0.1	16.7	1.7	1370	1.9	6.4	19	69.7

Results initially reported in Kruger and others (2017)