RARE EARTH ELEMENTS AND YTTRIUM IN WYOMING

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by

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INTRODUCTION

Rare earth elements (REE) are also known as the lanthanides. Because these 15 elements and the element yttrium usually occur together in nature they are discussed as a unit. These elements are listed in Table 1 along with their crustal abundances and prices. As shown in Table 1, the rare earth elements can be divided into two groups: the cerium group or light rare earth elements (LREE), and the yttrium group or heavy rare earth elements (HREE). The light rare earth elements, and the heavy rare earth elements yttrium, dysprosium, erbium and terbium have commercial applications. The exception to this generalization is the element promethium, which is almost nonexistent in nature. Commercial applications of heavy rare earth elements were not common until the latter half of the 1980s (after Hedrick and Templeton, 1990; Hedrick, 1985). Chemically, REE behave like thorium, and are therefore often abundant in rocks and minerals that are thorium rich (see Felsche and Herrman, 1978).

Minerals that contain rare earth elements and are reported in Wyoming are listed in Table 2. The composition of these minerals is variable and radioactive elements (U, Th) in the minerals often destroy the physical structure of the minerals creating metamict minerals. This means the exact mineralogy of the rare earth-bearing minerals is often uncertain.

Rare earth elements and minerals that contain rare earth elements are present in greater abundances in alkaline igneous rocks, carbonatites, pegmatites, veins and breccias of uncertain origin, and in both fossil and Quaternary placers. Major production of rare earth-bearing minerals has come from: 1) Quaternary stream placers (Malaysia, Thailand, Idaho); 2) Quaternary beach placers (Western Australia, Queensland, India, Sri Lanka, Brazil, Mozambique, Georgia, Florida); 3) veins and breccias of uncertain origin (South Africa, Australia); 4) carbonatites (USSR, China, Burundi, California); 5) alkaline igneous rocks (USSR, Canada); and 6) Precambrian quartz pebble conglomerates (by-product, Canada) (after Hedrick and Templeton, 1990; Hedrick 1985; Neary and Highley, 1984; Roberts and Hudson, 1983, 1984; Youles, 1984). The principal REE deposits, including by-product recovery, have been summarized in Moller (1989); however this summary was compiled in 1986, so a new list needs to be compiled. For REE mineralization related to carbonatites, a recent review is Notholt and others (1990).

Rare earth elements (REE) and yttrium have a myriad of uses and many of these elements go into "high-tech" components (see Table 3). The manufacture of synthetic zeolites, used as catalysts in petroleum distillation, consumes 53 percent of all rare earths and yttrium. In order of consumption, REE and yttrium are used in automobile catalytic converters (22 %), glass polishing and ceramics (39%), permanent magnets (16%), petroleum refining catalysts (12%), metallurgical additives and alloys (9%), rare earth phosphors for lighting, televisions, computer monitors, radar and X-ray intensifying film (l%), and miscellaneous (1%) (Hedrick, 2002). Because of the increasing use of high technology materials, the demand for rare earth elements and yttrium was increasing from 1999 through 2001 (Hedrick, 2000 and 2002).

Table 1. Chemical symbols for rare earth elements and yttrium.

Element	Chemical symbol	Abundance (ppm)	Price ($US/kg)
cerium group -- light rare earth elements (LREE)			
lanthanum	La	30	440.00
cerium	Ce	64	19.20
praseodymium	Pr	7.1	36.80
neodymium	Nd	26	28.50
promethium	Pm	--	--
samarium	Sm	4.5	360.00
europium	Eu	0.88	990.00
gadolinium	Gd	3.8	130.00
yttrium group -- yttrium and heavy rare earth elements (HREE)			
yttrium	Y	22	88.00
terbium	Tb	0.64	535.00
dysprosium	Dy	3.5	120.00
holmium	Ho	0.80	440.00
erbium	Er	2.3	155.00
thulium	Tm	0.33	2,500.00
ytterbium	Yb	2.2	230.00
lutetium	Lu	0.32	3,500.00

Abundances are averages for the upper continental crust from Taylor and McLennan (1985). Note that promethium isn't even listed due to its scarcity, and their average value for total REE is 146 ppm.

The prices in the above table are from Hedrick (2000). Prices are also listed by the U. S. Geological survey for bastanasite concentrates at 5.51 $US/kg and monazite concentrates at 0.73 $US/kg and these prices had remained constant for three years (Hedrick, 2002)

Table 2. Minerals reported in Wyoming that contain rare earth elements--yttrium.

Minerals is which rare earths and yttrium are basic constituents.

Mineral	Chemical formula	Common occurrence
ancylite	$Sr_3(Ce,La,Dy)_4(CO_3)_7(OH)_4 \cdot 3H_2O$	carbonatites, pegmatites
allanite	$(Ce,Ca,Y,La)_2(Al,Fe)_3(SiO_4)_3OH$	carbonatites, veins
bastnaesite	$(Ce,La)(CO_3)F$	carbonatites
brannerite	$(U,Ca,Y,Ce)(Ti,Fe)_2O_6$	placers, pegmatites, veins
brockite	$(Ca,Th,Ce)PO_4 \cdot H_2O$	carbonatites
burbankite	$(Na,Ca)_3(Sr,Ba,Ce)_3(CO_3)_5$	carbonatites, phosphorite
calkinsite	$(Ce,La)_2(CO_3)_3 \cdot 4H_2O$	carbonatites, phosphorite
carbocerianite	$(Ca,Na)(Sr,Ce,Ba)CO_3$	carbonatites
ewaldite	$Ba(Ca,Y,Na,K)(CO_3)_2$	phosphorite
euxenite	$(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$	pegmatites
fergusonite	$(Y,Er,Ce,Nd,La,Fe)(Nb,Ta,Ti)O_4$	pegmatites
gadolinite	$(Y,Ce,La,Nd)_2FeBe_2Si_2O_{10}$	pegmatites
mckelveyite	$Ba_3Na(Ca,Sr,U)Y(CO_3)_6 \cdot 3H_2O$	phosphorite
monazite	$(Ce,La,Nd)PO_4$	carbonatites, placers
rhabdophane	$(Ce,La,Nd)PO_4 \cdot H_2O$	carbonatites
samarskite	$(Y,Ce,U,Ca,Th,Fe)(Nb,Ta,Ti)_2(O,OH)_6$	pegmatites
synchysite	$(Ce,La,Nd,Y)Ca(CO_3)_2F$	carbonatites, pegmatites
xenotime	YPO_4	placers, veins(?)

Minerals in which rare earths and yttrium are relatively abundant accessory constituents, but are not required to form the mineral.

Mineral	Chemical formula	Common occurrence
apatite	$Ca_5(PO_4)_3(F,OH,Cl)_3$	carbonatites, phosphorite
fluorite	CaF_2	carbonatites, veins
pyrochlore-microlite	$(Na,Ca)_2(Nb,Ta,Ti)O_6(OH,F)$	placers, pegmatites(?)
columbite-tantalite	$(Fe,U,Ca)(Nb,Ta)O_4$	pegmatites
huttonite-thorite	$ThSiO_4$	placers, pegmatites
sphene	$CaTiSiO_5$	various
zircon	$ZrSiO_4$	placers

Chemical formulas from Cesbron (1989), Clark (1984), and Felsche and Herrman (1978); see also Mariano (1989).
Common occurrence from Clark (1984), Hedrick (1985), and Neary and Highley (1984); see also Mariano (1989).

Table 3. Uses of rare earth elements and yttrium
(Hedrick, 1991; Hedrick and Templeton, 1990; Preinfalk and Morteani, 1989; Neary and Highley, 1984); Hedrick, 2000; and Hedrick, 2002.

Metal Alloys -- iron alloys (structural steel), super alloys (corrosion resistant, impact resistant, hydrogen-cracking resistant, heat resistant), non-ferrous alloys, and lighter flints.

Glass and Ceramics -- polishing compounds, decolorizers, colorizers, color stabilizers, light and radiation absorbers, optical fibers, optical storage discs, lasers, high temperature refractories, and metal substitutes.

Electronic Components -- permanent magnets, rechargeable batteries, lights, capacitors, phosphors (color televisions, radar screens, x-ray intensifying screens, data displays), carbon arc lamps, high temperature superconductors, semiconductors, computer memories and substrates, and radar guidance systems.

Catalysts -- petroleum, ammonia, gas sweetening, and auto pollution control.

Other -- nuclear reactor components, gas lantern mantles, synthetic gemstones, and hydrogen fuel storage in heat exchangers and fuel cells.

mixtures of REE. About 70 percent of these high purity separates are used to make phosphors that produce the red coloration in color television. Yttrium, europium and terbium oxides produce this coloration (Spooner and others, 1991). Neodymium, samarium and dysprosium separates are used in high strength permanent magnets (Hedrick, 1987). The REE lanthanum and yttrium are present in superconductive materials that perform at higher temperatures than previously created superconductors (Hedrick and Templeton, 1990). As an additional example of the trend towards using individual REE, the dominant U.S. producer (Molycorp) makes cerium, neodymium and erbium separates, and was scheduled in 1989 to begin producing a dysprosium separate (Hedrick and Templeton, 1990). These new applications should increase the demand for individual rare earth elements, especially the heavy rare earth elements. Only a modest increase in overall demand has been forecast for the 1990s (Hedrick, 1991; Spooner and others, 1991).

The United States and China are the number 1 and 2 producers of rare earths in the world, with most of their production being from bastnaesite ores. Because China's production is estimated, the exact rankings are uncertain. Australia, though producing far less than the U.S. and China, is the third largest producer of rare earths in the world. Most of Australia's ores are monazite sands (after Hedrick, 1991; Hedrick and Templeton, 1990).

Rare earth elements were produced in the United States at three locations in the 1980s. Bastnaesite is mined by Molycorp from a carbonatite at Mountain Pass, California, and accounts for most domestic production. Monazite is recovered with ilmenite and zircon from Quaternary black sand beach deposits at the Green Cove Springs mine in Florida by Associated Minerals. This company is owned by Australians. Rare earths, yttrium, and thorium are co-products from the processing of these monazite sands (Hedrick and Templeton, 1990). The third location in the U.S. was in North Carolina. It was operated by Imperial Mining and closed in mid-1990. This company produced mixed heavy minerals (monazite, xenotime and zircon) as a by-product from a gold, and industrial sand and gravel operation (Hedrick, 1991). This material was probably produced from a small stream placer.

Production of rare earths and yttrium in Wyoming has been almost entirely from the Platt Mine. Ten thousand pounds of a rare earth bearing mineral were reportedly shipped from this pegmatite in Carbon County (Houston, 1961b); the U.S. Bureau of Mines reported this production as about 4,000 pounds of euxenite (Kelly and Mullen, 1958; Kelly and others, 1959). Most of the production from this mine, 13 tons of ore in 1956, was for uranium (Wyoming State Board of Equalization, 1957-58). Allanite-bearing ore was removed from the Ramsbottom property in Johnson County between 1952 and 1955 (after Bromley, 1955a), but the ore was apparently never processed and no production was ever recorded. Marzell (1933) also reported production of 800 pounds of samarskite from Wyoming in 1930. But the source of this mineral has never been determined.

Many occurrences of minerals containing rare earth elements are present in Wyoming (Figures 1 through 4, 6 and 7; Tables 4 through 6, 8 and 9). Additional sites shown on these figures and Figure 5, and these tables and Table 7 contain abundant rare earths, as determined by chemical analyses, though rare earth-bearing minerals have not been reported. A REE locality as defined for this report is a place where a sample contained at least 1/2 percent of a rare earth bearing mineral, and/or assayed at least 150 ppm La, 320 ppm Ce, 35.5 ppm Pr, 130 ppm Nd, 22.5 ppm Sm, 4.4 ppm Eu, 19 ppm Gd, 110 ppm Y, 3.2 ppm Tb, 17.5 ppm Dy, 4 ppm Ho, 11.5 ppm Er, 1.6 ppm Tm, 11 ppm Yb or 1.6 ppm Lu. These elemental concentrations are about 5 times average crustal abundances (see Table 1). The variety of mineral occurrences and sites of rare earth enrichment in the state are summarized in Table 4. Data on these localities is presented in the remainder of this report. Localities have been divided into prospects, significant localities (Figure 1), and other and unverified localities (Figure 2) on the basis of the amounts of rare earths or rare earth-bearing minerals. Significant localities contain enough rare earths to be intermediate between prospects and the other localities. Unverified localities are those where the data presented are suspect or incomplete. Data on several special types of localities is also present in this report.

Prospects, potential economic sources of rare earths, in Wyoming have been presented first. In order of economic importance and presentation, they are: 1) Bear Lodge Mountains (Tertiary veins and disseminations in igneous rocks related to carbonatites); 2) Bald Mountain (Cambrian fluvial placers); and 3) Ramsbottom property (Precambrian metacarbonate rocks of uncertain origin). These prospects contain a high percentage of rare earths and a large amount of rare earth bearing material.

Information on other significant rare earth element localities in Wyoming is present after prospect data. These significant occurrences and sites of rare earth enrichment, in order of presentation and alphabetical order by county, are: 1) Tie Siding (Middle Proterozoic pegmatites and the granitic rocks enclosing them); 2) Laramie Anorthosite Complex (Middle Proterozoic syenitic plutons and iron-titanium bodies); 3) Elmers Rock (veins{?} in Archean gneiss terrains); 4) Big Creek (pegmatites and veins{?} in Early Proterozoic gneiss terrains); 5) Bates Hole (Tertiary and Quaternary stream placers); 6) Onemile Creek (Precambrian quartz pebble conglomerate placers); 7) Warm Springs Creek (Quaternary stream placers); 8) Grass Creek (Mesozoic black sandstone beach placer); and 9) Fremont Butte (veins{?} in Archean granitic terrains).

Data on rare earth element localities in Wyoming that are of lessor importance are presented after the information on the significant localities. Data on other and unverified localities are subdivided on the basis of county location, with alphabetical order of the counties, but no order within a county. These data are followed by data on several special types of localities, in chronological order. These special types of localities include: Precambrian quartz pebble conglomerates, Cambrian placers, the Phosphoria Formation, Mesozoic black sandstone beach placers, and Eocene lacustrine rocks. These special localities are grouped together, because they are widespread and may not, if fact, be restricted to the sites that have been found and sampled to date. Exceptions to this order of presentation are the Bald Mountain prospect, and Onemile Creek and Grass Creek significant localities. The Phosphoria Formation and Eocene lacustrine rock localities are also important because phosphorite and trona are processed in Wyoming. Therefore, Wyoming specific studies might be in order to determine if rare earth elements in the phosphorite and trona might be recovered as by-products during beneficiation.

Table 4. Sites of rare earth bearing minerals and enrichment in Wyoming, by age, host rock, mode of mineralization, and name. Locations are shown in Figures 1 through 7.

Age	Host rock	Mineralization	Name(s)
Early Archean	gneiss	pegmatite disseminated uncertain	Angie and Allie claims, Bald Ridge Beartooth Falls, Long Lake Dubois #1 claim, Wind River Range
Middle Archean	granitoid	pegmatite	Rainbow claims
Archean	supracrustal	uncertain	Ramsbottom property
Late Archean	gneiss	pegmatite vein(?) uncertain	Riley claim Elmers Rock Bruns property
	granitoid	disseminated epidote-bearing fault and shear zone-related uncertain	several in central and western Wyoming several in central Wyoming several in central Wyoming, and the central Laramie Mountains Fremont Buttes, Gros Ventre Range, central Wyoming, Medicine Bow Mtns., and central Laramie Mountains
Late Archean--Early Proterozoic	supracrustal	placer-quartz pebble conglomerate	Sierra Madre, Medicine Bow Mtns.
Early Proterozoic	supracrustal	uncertain	Medicine Bow and Laramie Mtns.
	older granitic	vein(?) disseminated	Gaps Trondhjemite Gaps Trondhjemite
	gneiss	pegmatite	Big Creek, Many Values
	quartz diorite	disseminated	Keystone quartz diorite
	gabbroic	uncertain	Mullen Creek mafic complex
	younger granitic	pegmatite disseminated	Blackhall Mountain Mullen Creek area
Middle Proterozoic	syenite	disseminated	Red Mountain and Sybille plutons
	anorthosite	pegmatite(?) Fe-Ti bodies	southern Laramie Mtns. southern Laramie Mtns.
	Sherman granite	pegmatite disseminated	Tie Siding, Weddle claims, Albany area Tie Siding, Albany area

Phanerozoic Paleozoic Cambrian	conglomerate	placer	Bald Mountain and others
Permian	Phosphoria	phosphorite	Thrust Belt, Gros Ventre Range
Mesozoic	sandstone	beach placer uncertain	Grass Creek and others Big Horn and Natrona Counties
	sandstone and shale	fossil bone	Big Horn and Johnson Counties
	shale	uncertain	Niobrara County
Cenozoic Tertiary	carbonatites and alkaline igneous	veins and disseminated	Bear Lodge Mountains
	alkaline igneous	uncertain	Mineral Hill
	lacustrine	uncertain	Green Rvr. Fm., Beaver D., Lysite Mtn.
	sandstone	placer placer(?)	Bates Hole Hurda claims
	shale and sandstone	uncertain	Fremont and Sweetwater Counties
	limestone	uncertain	Sage Hen
Quaternary	sands & gravels	placer	Bates Hole, Bald Mtn., Warm Spring Ck.
	gravels	uncertain	Natrona County
	geyser deposits	hydrothermal(?)	Yellowstone National Park

Figure 1. Index map and list of rare earth element and yttrium prospects and significant localities in Wyoming. Numbers by each locality indicate the corresponding numbered description of that locality in the text.

Prospects

1. Bear Lodge Mountains
2. Bald Mountain
3. Ramsbottom

Significant occurrences

1. Tie Siding
2. Laramie Anorthosite
3. Elmers Rock
4. Big Creek
5. Bates Hole
6. Onemile Creek
7. Warm Springs Creek
8. Grass Creek
9. Fremont Butte

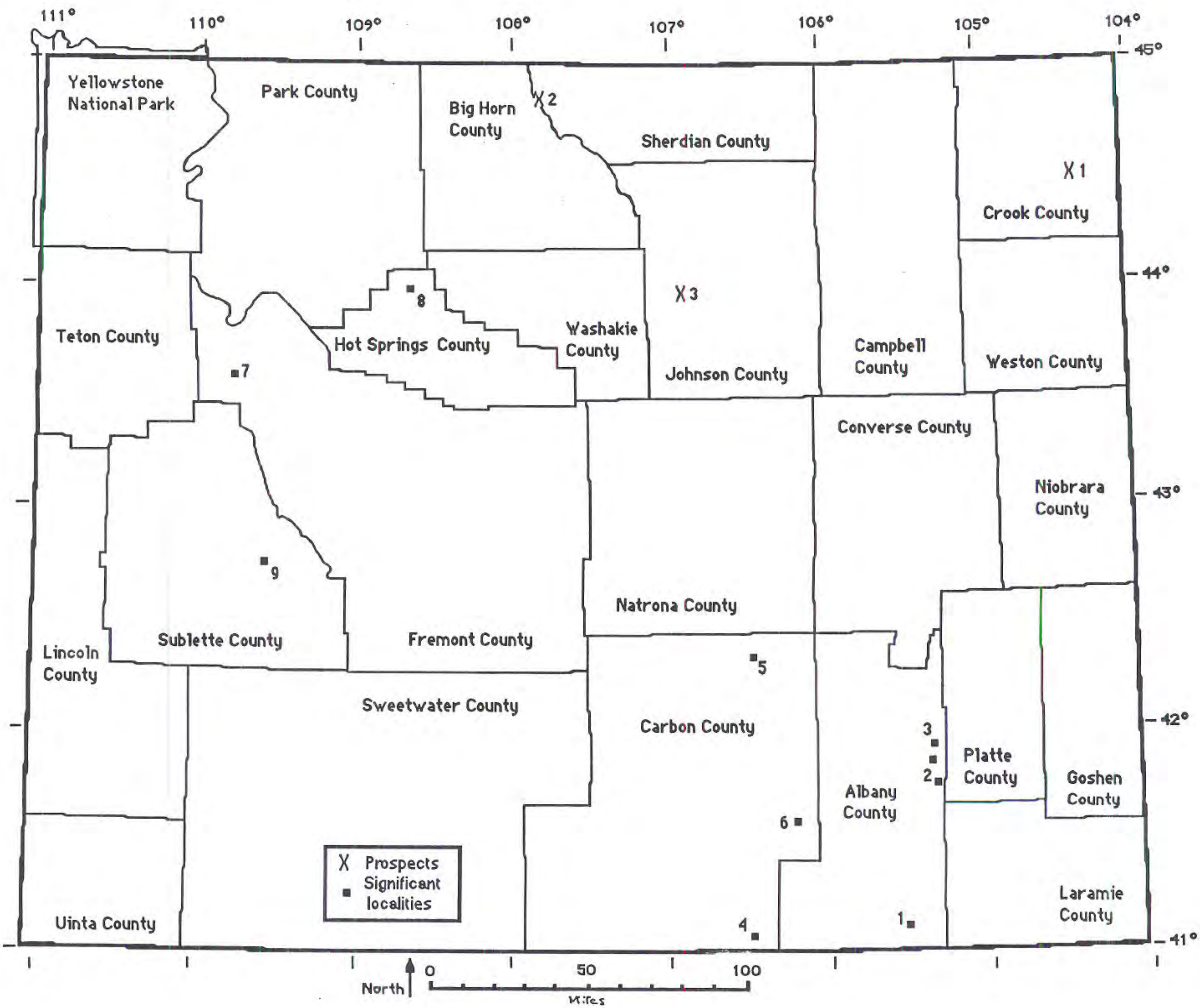
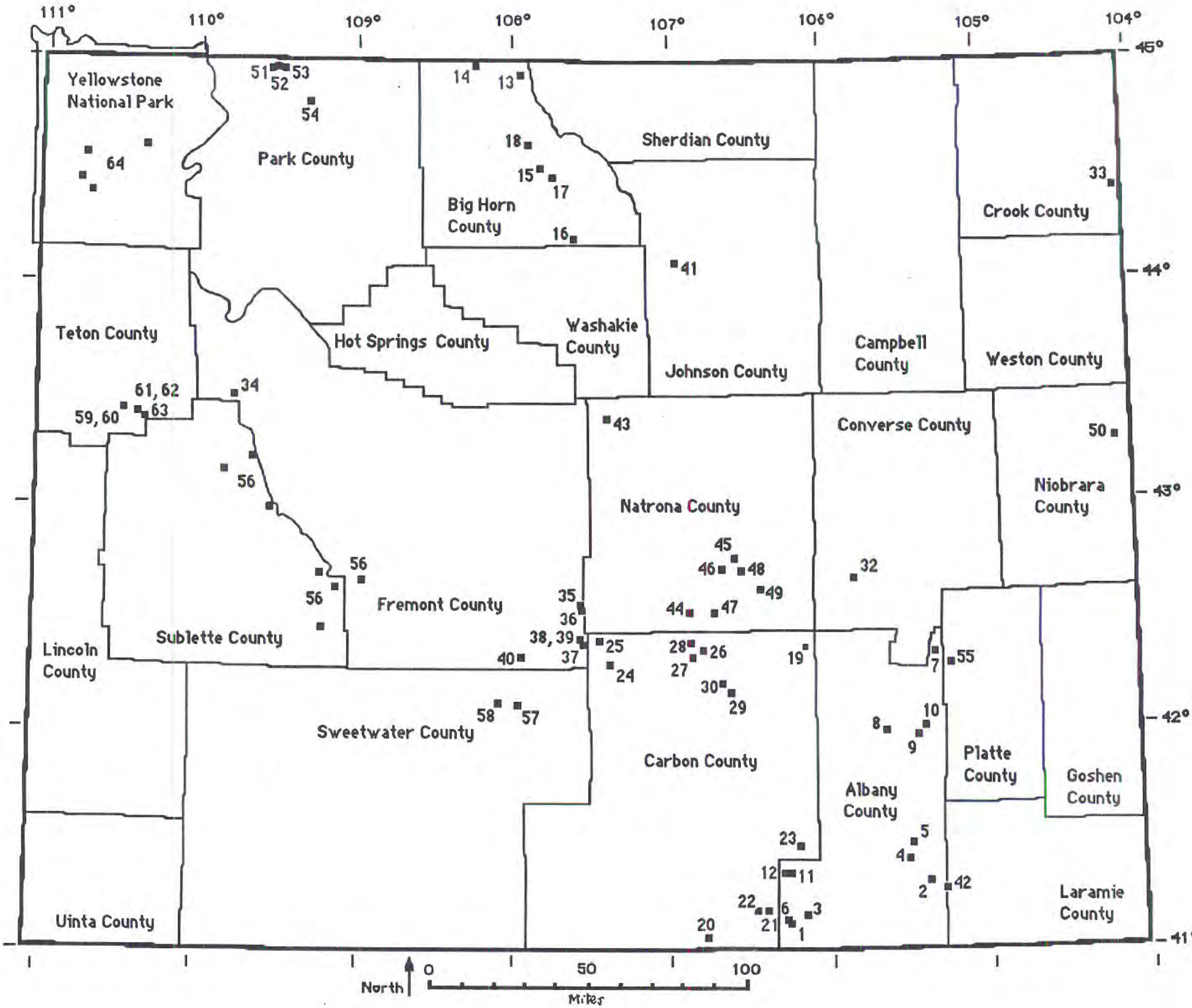

111°
110°
109°
108°
107°
106°
105°
104°
45°
44°
43°
42°
41°
Yellowstone National Park
Park County
Big Horn County
X 2
Sherdian County
X 1
Crook County
Teton County
Hot Springs County
8
Washakie County
X 3
Johnson County
Campbell County
Weston County
7
Converse County
Niobrara County
9
Natrona County
Lincoln County
Sublette County
Fremont County
5
Sweetwater County
Carbon County
3
2
Platte County
Goshen County
Albany County
6
X Prospects
Significant localities
4
1
Laramie County
Uinta County
North
0
50
100
Miles

Fig 1

Figure 2. Index map and list of other and unverified rare earth element and yttrium localities in Wyoming; exclusive of Precambrian quartz-pebble conglomerate, Cambrian placer, Mesozoic black sandstone, Phosphoria Formation and Eocene lacustrine rocks. Numbers by each locality indicate the corresponding numbered description of that locality in the text.

1. Many Values
2. Weddle claims
3. Albany area
4. Spring Creek
5. Laramie Range
6. Keystone area
7. Mahoney claim
8. Potato Creek
9. upper Sturgeon Creek
10. lower Sturgeon Creek
11. Medicine Peak
12. Gaps Trondhjemite
13. Rainbow claims
14. Crooked Creek
15. Shell Creek
16. Bobcat Gulch
17. North Sheldon Gulch
18. Davis Draw
19. Hurda claims
20. Blackhall Mountain
21. Mullen Creek
22. Hubbell Ditch
23. Vagner Formation
24. Ferris Mountains
25. Emigrant Trail thrust
26. Omega claims
27. Poe Mountain
28. Pyramid Peak
29. A #1 and Beaver claims
30. WL claims
31. Jem area
32. Bruns claim
33. Mineral Hill
34. Dubois claim
35. Sage Hen
36. unnamed
37. Gap claims
38. Mohawk claims
39. unnamed
40. unnamed
41. Poison Creek
42. unnamed
43. Allie claims
44. Wood claims
45. Dyper Bar Mac
46. Deacons Prayer
47. UMSINC
48. Clarkson Hill area
49. unnamed
50. unnamed
51. Beartooth Falls
52. Long Lake
53. Bald Ridge
54. Angie claims
55. Richard Riley
56. Wind River Range
57. unnamed
58. unnamed
59. unnamed
60. unnamed
61. unnamed
62. unnamed
63. unnamed
64. Yellowstone N.P.


111°
110°
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108°
107°
106°
105°
104°
45°
44°
43°
42°
41°
Yellowstone National Park
Park County
Big Horn County
Sherdian County
Crook County
Teton County
Hot Springs County
Washakie County
Johnson County
Campbell County
Weston County
Converse County
Niobrara County
Natrona County
Fremont County
Sublette County
Lincoln County
Sweetwater County
Carbon County
Albany County
Platte County
Goshen County
Laramie County
Uinta County
North
0
50
100
Miles

Fig 2

Unlike trona and phosphorite, coal does not appear to be a promising source of rare earth elements. Individual rare earth contents of up to about 200 ppm have been reported in ash from burned Wyoming coal, with almost always less than 15 ppm in unburned coal (Glass, 1975; Glass and Roberts, 1984, 1988). These analytical results indicate that rare earth elements are not abundant in organic sediments. Although no studies have been performed regarding the economics of extracting rare earth elements from coal ash, it appears that such a study is not worthwhile since coal contains lower concentrations of rare earths than an average crustal rock (Felsche and Herrman, 1978).

PROSPECTS

1. Bear Lodge Mountains roughly T.52N., R.63W.

The southern portion of these mountains contain Tertiary trachytes, phonolites, and carbonatites, which intrude lower Paleozoic sedimentary rocks. These igneous rocks are enriched in rare earths, thorium, uranium, fluorine, barium, strontium and niobium, with scattered fluorite mineralization in the adjacent sedimentary rocks (Staatz, 1983; Staatz and others, 1980; Gersic and others, 1990). These igneous rocks are not noticeably enriched in tantalum (Gersic and others, 1990), unlike some alkaline igneous complexes. The igneous rocks are notably enriched in the LREE (Staatz, 1983; Staatz and others, 1980; Gersic and others, 1990).

This area has only been partially evaluated for it's gold, thorium, uranium and rare earth potential. These elements are disseminated in at least two extensive systems of microfractures in igneous rocks; these systems of microfractures are physically similar to those in porphyry copper deposits.

The rare earths, uranium and thorium in the Bear Lodge deposit are concentrated in veins and veinlets that contain manganese and/or iron oxides. Minor quartz, cristobalite and sometimes altered trachyte and phonolite, fluorite, barite, and/or strontium-rich calcite are also present in the veins and veinlets. The veins and veinlets vary from soft and porous to hard and highly siliceous. Exploration has been largely confined to these fractured areas (after Jenner, 1984; Staatz, 1983; Wilkinson, 1982; Staatz and others, 1980; Wilmarth and Johnson, 1953; Brown, 1952; Gersic and others, 1990).

Gold mineralization is present in, and gold exploration has been carried out in fractured areas in the igneous complex (Jenner, 1984; Wilmarth and Johnson, 1953; Brown, 1952; Jamison, 1912; Jenny and Newton, 1880; Hall, 1910; Gersic and others, 1990). However, relatively more abundant gold mineralization seems to be geologically and temporally distinct from the radioactive and rare-earth microfracture system. The low-grade gold mineralization at Smith Ridge in sec. 21 is areally separate from abundant rare earth, radioactive and fluorite mineralization. This gold mineralization reportedly occurs in a 120 x 2000 foot area, with a tenor of 0.01 to 0.05 oz/ton (see Gersic and others, 1990).

The igneous complex and surrounding sedimentary rocks have not been completely explored. To date, most of the exploration has been concentrated on geologic features that occur with rare earths, rather than on features that have been demonstrated to correlate to rare earth concentrations. These geologic features were listed in previous paragraphs. Several relevant geologic features were also overlooked in previous examinations, and are presented here. Rare earth concentrations apparently have no correlation with the thorium, uranium, potassium, niobium, manganese, iron, strontium, barium, fluorine, calcium or sodium concentrations. Rare earths are most abundant on the perimeter of areas with the greatest potassium abundances (after Staatz, 1983; Staatz and others, 1980; Gersic and others, 1990; Wilmarth and Johnson, 1953). High rare earth concentrations do <u>not</u> coincide with areas of high total radioactivity, more abundant fracturing or brecciation, any recognizable alteration or color change, or the locations of carbonatites (after Jenner, 1984; Staatz, 1983; Wilkinson, 1982; Staatz and others, 1980; Wilmarth and Johnson, 1953). Though deep purple fluorite is commonly thought to contain abundant radioactive elements, such as those associated with rare earths in the intrusive complex, the color of the fluorite cannot be used as an indirect indicator of rare earth mineralization in the igneous complex. Wilmarth and Johnson (1953) have shown that in the Bear Lodge Mountains purple fluorite contains both high and low amounts of radioactive elements. No analyses are available for lighter colored fluorites in these mountains. This overall lack of correlation means that only REE analyses indicate REE abundances, though the strongest association may be with potassic fenitization. This potassic alteration might be mappable.

Because geochemical sampling has been largely confined to areas within the igneous complex with the previously stated characteristics, an area of rare earth enrichment could have been overlooked. For example, Jenner (1984) described fluorite-bearing igneous and carbonate rocks in the Ogden Creek area, south of the highly prospected area. But, it wasn't until recently that some rare earth enrichment was reported in the Ogden Creek area (see Gersic and others, 1990; and subsection 1E).

Rare earths are often associated with fluorine, so the lack of correlation between fluorine and rare earth contents needs to be carefully examined. The non-correlation in the igneous complex and surrounding rocks is only preliminary for several reasons. Rocks in the igneous complex have not been systematically analyzed for fluorine, only about 30 samples were analyzed for fluorine. The concentrations of rare earths in fluorite-bearing sedimentary rocks around the margins of the igneous complex are even less well defined; only three analyses have been reported. The rare earth concentrations in fluorite in the sedimentary rocks are only in the 10s of ppm (see Wilmarth and Johnson, 1953; Gersic and others, 1990). However, only one sample from a major fluorite prospect (Petersen no. 1 claim; subsection 1G) has been analyzed for rare earths, and the analysis was semiquantitative.

The two other samples of fluorite from sedimentary rocks, that have been analyzed for rare earths, are not considered significant indicators of low rare earth concentrations in this type of mineralization. These two samples were from sec. 16 and are not within the areas of major fluorite prospects. In addition, unlike the major prospects in the Pahasapa Limestone or Minnelusa Formation, these occurrences are in the less chemically reactive Deadwood Formation. The samples contained 18,150 and 1840 ppm F, but only 3 and 6 ppm La, 42 and 37 ppm Y, 24 and 186 ppm Ba, 40 and 37 ppm Sr, 44 and 47 ppm Th, and 4 and 7 ppm U (after Gersic and others, 1990). This means that the usual element suite that accompanies rare earth mineralization in the igneous complex is not present in these fluorite occurrences. It is important to determine if this is true for other fluorite occurrences and prospects. More analyses are needed at various locations around and distance from the igneous complex in order to determine if any pattern of rare earth distribution in fluorite exists.

The preceding information about this district, coupled with the common association of rare earths with alkalic rocks and carbonatites, and poor exposures in the area, means the Bear Lodge Mountains are an incompletely explored, potentially economic source of rare earth elements. A study that evaluates the combined value of thorium, uranium, rare earths, strontium, fluorine, barium, columbium and tantalum in the Bear Lodge igneous complex and surrounding sedimentary units has not been performed and is required to properly evaluate the economic potential of mining.

The information on the following pages covers the characteristics of mineralization within and on the margins of the igneous complex. Mineralized features within the complex include: A) a geochemically demonstrated zone of rare earth enrichment; B) rare earth-bearing veins; C) carbonatites; and D) rare earth-bearing fractures. The Ogden Creek area (E) has characteristics of mineralization within the complex (veinlets in igneous rocks) and mineralization of the margins of the complex (fluorite in carbonate rocks). On the margins of the complex in sedimentary rocks, fluorite abundance might be indicative of rare earth abundance. Therefore major fluorite prospects are described in the following subsections. These sites, counterclockwise from the west, are: F) Royal Purple fluorspar claims; G) Petersen fluorite lode claims; and H) the Lytle Creek area. As noted in these subsections on the richest fluorite occurrences, fluorite-bearing sedimentary rocks are not restricted to these sites.

1A) Zone of rare earth enrichment,
as demonstrated by geochemical sampling
center W1/4 sec, 16, sec. 17, center E1/4 sec. 18, N1/2 sec. 20, T.52N., R.63W.

Rocks within this zone contain more than 5000 ppm (0.5 %) total REE. The boundaries of the zone of enrichment are defined by areally limited geochemical surface sampling (see Staatz and others, 1980; Staatz, 1983; Gersic and others, 1990). This zone is within the disseminated deposits as described by Staatz (1983) and is the largest prospect in the igneous complex. In these disseminated deposits, mineralization is in veinlets and microfractures, though rare earth-bearing minerals are quite scarce. The boundaries of the disseminated deposits can not be defined by visual examination or radiometric measurement (Staatz, 1983). The boundaries of the zone of enrichment are incompletely defined because few samples have been analyzed from the W1/2 sec. 18, and in secs. 19, 22, 27, 28, 29 and 33 (see Staatz, 1983; Staatz and others, 1980), where indicators of rare earth mineralization such as manganese and iron oxide-stained veinlets and veins, and fluorite mineralization are present (after Staatz, 1983; Wilkinson, 1982; Jenner, 1984; Wilmarth and Johnson, 1953; Haff, 1944b; Cox, 1945).

The area within the documented zone of rare earth enrichment is about 1.2 square miles, and data from drill holes indicate that some of the mineralization extends to a depth of about 1200 feet (see Staatz, 1983). A very preliminary resource estimate for the disseminated deposits from surface sampling is 84,000,000 tons of 1.5 percent REO/short ton ore within 200 feet of the surface in an assumed 0.60 square mile area. This estimate includes the veins discussed below that are within the disseminated deposits (Gersic and others, 1990). Note that this estimate is for an area smaller than the documented zone of rare earth enrichment. More sampling and analyses of rocks from outside the known zone of enrichment, and on a more closely spaced surface and subsurface pattern within the documented zone of enrichment are required to better define a potential reserve (see also subsection D, carbonatites).

1B) Rare earth bearing veins
S1/2SE1/4 sec. 7, N1/2NW1/4 sec. 16, sec. 17, E1/2SE1/4 sec. 18, NE1/4SW1/4 sec. 19, N1/2 sec. 20, center sec. 21, NW1/4NW1/4NW1/4 sec. 22, SW1/4NW1/4NW1/4 sec. 27, T.52N., R.63W.

These are the veins of Staatz (1983); by his definition they exceed 2 inches in average width and similar smaller features are veinlets. Staatz (1983) maps and describes 26 veins and presents chemical data for 20. These veins are the most rare earth rich prospect in the igneous complex. These veins are within the zone of rare earth enrichment, except for seven veins (nos. 1, 2, 10, 21, 22, 23 & 24). Vein color is controlled by the kind and abundance of iron and manganese oxides. The veins are sinuous, pinch and swell along strike and dip, and have variable dip along strike. One pattern is apparent in the strike of these veins, a lack of veins that strike N45-75°E (after Staatz, 1983). This orientation is parallel with the short axis of the igneous complex, and in a simplistic structural model, veins with this orientation would be expected to be the most prominent in the igneous complex (JKK). The veins are usually steeply dipping, but dips vary from 25° to vertical, both into and away from the center of the complex. The veins are often only exposed in pits and trenches. Exposed dimensions are from about 1 to 100 inches in width and 1.5 to 400 feet in length (see Staatz, 1983). The extensive cover in the area means the veins could be larger, and more veins are probably present in the igneous complex.

Rare earth bearing minerals are not common in the veins and are fine grained. In order of abundance, these major rare earth-bearing minerals are monazite, brockite and bastnaesite (Staatz, 1983). For comparison, the most abundant rare earth-bearing mineral in surface exposures of carbonatites is bastnaesite, which is the ore mineral at Molycorp's Mountain Pass mine. For more details see subsection C on carbonatites.

The rare earth contents of the veins within the zone of enrichment vary from about 5400 to 98,000 ppm total REE. Veins outside the zone of rare earth enrichment contain less but still abundant rare earths, 2300 to 71,530 ppm total

REE. These veins represent additional high-grade, rare earth resources within the zone of rare earth enrichment, and a potential resource outside the zone of enrichment (after Staatz, 1983; Wilmarth and Johnson, 1953). Staatz (1983) concluded that only two of the veins contain mineable inferred reserves; these total reserves are 3140 tons of rare earth oxides. Staatz (1983) did not state which two veins are mineable or exactly how he arrived at the reserve estimate.

Previous work on these veins has provided additional information. Wilmarth and Johnson (1953) described the northwest-trending vein 22 of Staatz (1983), and named it the Sunrise lode. This vein and vein 21 of Staatz (1983) are the only veins that are in contact with sedimentary rocks. Wilmarth and Johnson (1953) also presented data on the Home Fire no. 43 claims, also known as the Old Clark lode. This claim was probably on vein 24 of Staatz (1983), or is northwest of and adjacent to this vein 24 (see Wilmarth and Johnson, 1953; Staatz, 1983). Veins might be present in igneous rocks in the Ogden Creek area, but only the presence of veinlets has been positively established (after Haff, 1944b; Cox, 1945; Hagner, 1943a; Wilkinson, 1982). Chenoweth (1954) noted fluorite fissure-fillings up to 1-foot wide in igneous rocks in the NW1/4 sec. 8, but he did not mention iron or manganese oxide staining. Wilkinson (1982) mentioned what may be the same fluorite occurrence in a breccia in the same general area (center SE1/4NW1/4 sec. 8), but he also mapped rare earth-bearing fractures in the same general area (SW1/4SW1/4NW1/4 sec. 8).

1C) Carbonatites

surface -- S1/8 sec. 7-8 line; and SW1/4SE1/4 sec. 17 and NW1/4NW1/4NE1/4 sec. 20, T.52N., R.63W.
subsurface -- NW1/4 sec. 17, and NE1/4 sec. 18, T.52N., R.63W.

Carbonatite dikes and stringers in the Bear Lodge igneous complex are prospects because they contain abundant rare earth elements, though slightly less than the veins. Staatz (1983) seems to have lumped them in with the disseminated deposits without close examination in his assessment of the rare earth resources in the complex. Some dikes and stringers are outside the zone of rare earth enrichment. All the carbonatites are notably enriched in strontium, and also contain abundant barium in barite (Wilkinson, 1982; Staatz, 1983; Jenner, 1984; Gersic and others, 1990). Because the carbonatites are only exposed in trenches with no visible float (Wilkinson, 1982; Gersic and others, 1990), the exact extent and size of the carbonatites are not known. The surface exposures are reportedly about 15 by 80 feet (Staatz, 1983), 16 feet wide (Gersic and others, 1990) or 4.5 by 160 feet (Wilkinson, 1982) on the sec. 7-8 line; about 20 by 330 feet in sec. 20 (Wilkinson, 1982); and 4 feet wide in sec. 17 (Gersic and others, 1990). In subsurface, the carbonatites are 10ths of an inch to about 11 feet thick and are steeply dipping (Staatz, 1983). These are apparently actual thicknesses in angled (non-vertical) drill holes because Jenner (1984) reported thicknesses in drill cores of 10ths of an inch to several tens of yards. The color of surface exposures and altered, subsurface carbonatite is controlled by iron oxide staining (red, yellow, orange, brown). In subsurface, fresh carbonatites are usually light gray.

Fresh subsurface carbonatites when compared to weathered and altered carbonatites contain different mineral suites. This difference is probably due to alteration that results from sulfide mineral oxidation and acid production in surface and near surface environments. This alteration has been reported in subsurface cores. The only mineral common to both suites is fluorite. Powdery bastnaesite with minor intergrown powdery synchysite are the rare earth-bearing minerals in surface exposures and altered subsurface cores of carbonatite. In subsurface, the fresh carbonatites contain streaks and lenses of the rare earth-bearing mineral ancylite, with smaller amounts of burbankite, carbocerianite, and two incompletely identified minerals (after Staatz, 1983; Jenner, 1984). Fresh subsurface samples also contain streaks and lenses of strontianite, chalcopyrite, galena, sphalerite, pyrite, and pyrrhotite (Staatz, 1983). These sulfide minerals are also present as fine disseminated grains (Jenner, 1984).

Total rare earth content in the carbonatites varies from about 5800 to 66,000 ppm total REE. Note that the maximum value is less than that for the veins. Ninety-five percent of the rare earths are the light rare earths (Staatz, 1983). The effects of sulfide mineral oxidation on rare earth distribution is not known, because Staatz (1983) did not discriminate between altered surface and subsurface samples, and fresh subsurface samples. The effect of surface oxidation, sulfuric acid production and neutralization by carbonatite on rare earth mobility needs to be determined. Otherwise the complex must be sampled at various depths on a tight spacing by core drilling in order to determine resource potential.

Jenner (1984) maps strontium-poor carbonatites in the Ogden Creek area (E), south of the other carbonatites and the zone of rare earth enrichment. The origin of these Ogden Creek carbonate rocks is uncertain, but they are here considered to be xenoliths of Lower Paleozoic sedimentary, marine, carbonate rocks (see subsection E).

1D) Rare earth bearing fractures

center N1/2 sec. 7-8 line, sec. 17, NW1/4 sec,. 18, SE1/4 sec. 18, N1/2 sec. 20, SE1/4NW1/4 sec. 33, T.52N., R.63W.

Wilkinson (1982) mapped these as extensive fractures in the igneous complex that contained thorium and rare earths. He described them as radioactive, iron and manganese oxide-stained veinlets and veins with secondary silica and features indicative of open-space filling. The presence or absence of rare earths in all of Wilkinson's (1982) fractured areas has not been documented. Wilkinson's (1982) fractured areas are far more widespread than the disseminated deposits of Staatz (1983). A comparison of the locations of Wilkinson's fractured areas with geochemical studies by Staatz and others (1980) indicates that many of these fractured areas have not been analyzed for rare earths or other associated elements, while others apparently do not contain abundant rare earths.

In addition to these fractured areas, White (1980), O'Toole (1981), Wilkinson (1982), Staatz (1983), and Jenner (1984) mapped and described intrusive breccias at various and sometimes contradictory locations in the complex. These intrusive breccias are apparently extensively fractured, iron-oxide stained, altered igneous and metamorphic rocks, where additional new material has been emplaced as a matrix. This new matrix material is mostly altered igneous rocks and siliceous material (Staatz, 1983; Wilkinson, 1982; Jenner, 1984). Fluorite, calcite, gold and pyrite have been reported in the matrix of some of these breccias (Wilkinson, 1982; Jenner, 1984). Locations of these breccias have not been presented because some breccias contain rare earth enrichment while others do not; compare breccia mapping to the zone of rare earth enrichment. The differences between rare-earth bearing and barren breccias need to be determined, as well as the differences and similarities between breccias and fractured areas.

1E) Ogden Creek area (Allen-Wright fluorspar deposits)
SW1/4SW1/4 sec. 27, SE1/4SE1/4 sec. 28, and possibly NW1/4 sec. 34, T.52N., R.63W.

This area merits further examination because of the presence of fluorite and intrusive breccia, and barium, strontium and rare earth enrichment, making it similar to the demonstrated zone of rare earth enrichment to the north. As with most of the Bear Lodge igneous complex, rocks in this area are poorly exposed. The rocks are trachytes and phonolites that surround recrystallized carbonate rocks (Jenner, 1984; Wilkinson, 1982; Staatz, 1983). The carbonate rocks have been variously interpreted as Precambrian limestone xenoliths (Chenoweth, 1955), Paleozoic limestone xenoliths (Haff, 1944b; Staatz, 1983; Wilkinson, 1982), and on the basis of physical, chemical and isotopic analyses, melted Paleozoic limestone (Jenner, 1984). How the limestone was melted remains a problem with this last interpretation. Two samples from this area contained 2430 and 1617 ppm LREE (Gersic and others, 1990). That the Ogden Creek carbonate rocks exhibit the strontium and barium enrichment that is present in the rare earth-bearing carbonatites to the north is in dispute (pro--Gersic and others, 1990; con--Jenner, 1984; Wilkinson, 1982; Staatz, 1983).

The Allen Wright fluorspar claims are on and near the ridge crest between Ogden and Tent Creek, mostly in secs. 27 and 28. Within these claims, the carbonate rocks were the most extensively prospected areas in the igneous complex (Haff, 1944b), prior to exploration for radioactive rocks. Fluorite is relatively abundant in these carbonate rocks, particularly at their margins, but fluorite is also present in the trachytes and phonolites. Limonite-stained, vuggy, siliceous masses that contain fluorite, and fluorite-bearing intrusive breccias are present in the trachyte-phonolite (Haff, 1944b). Intrusive breccias have been mapped in both sec. 28 (Wilkinson, 1982) and sec. 27 (Haff, 1944b). The concentrations of fluorite are greatest in the western carbonate exposure in a trench that straddles the sec. 27-28 line. A zone 100 feet long and tens of feet wide in this exposure contains 5 to 10 percent fluorite, with smaller zones containing even higher percentages (Cox, 1945). The presence or absence of veins has not been resolved (compare Haff, 1944b; Cox, 1945; Hagner, 1943a; Wilkinson, 1982). Samples showing rare earth, barite and strontium enrichment are from the fluorite-bearing, eastern carbonate exposures in sec. 28 (see Gersic and others, 1990).

The non-weathered fluorite in all the Ogden Creek occurrences is lavender to deep purple, and is irregularly distributed. When weathered, the fluorite is greenish-white (Haff, 1944b; Hagner, 1943a). Fluorite is present as fine grains in veinlets and disseminations throughout the trachyte-phonolite and intrusive breccia, and as more coarsely crystalline disseminations, aggregates and masses in carbonate rocks (Haff, 1944b). Chenoweth's (1955) observations of larger fluorite crystals contradict statements by Haff (1944b). Chenoweth (1955) also reported that insoluble residues of the carbonate rocks only contain fluorite. This does not preclude rare earth mineralization because surface samples that contain rare earth-bearing minerals are uncommon in the igneous complex. The report of apatite and alteration at Ogden Creek (Hagner, 1943) was not verified by later investigations.

1F) Royal Purple fluorspar claims
roughly W1/2 sec. 30, T.52N., R.63W., and E1/2 sec. 25, T.52N., R.64W.

The location given for these claims is inferred from the description of Cox (1945), using Darton (1905) and Staatz (1983). Brown (1952) does not depict or mention these claims. The geology and topography at the claim location given by Haff (1944c)(sec. 32, T.52N., R.63W.) do not match the geology and topography described by Cox (1945) or by Haff (1944c) himself.

The Royal Purple claims are on roughly northwest-trending ridges on both the north and south banks of Bear Den Canyon (middle fork of Houston Creek). The fluorite mineralization is in pockets and lenses, and disseminations in the Minnelusa Formation. The mineralization is near a northwest-southeast elongate exposure of phonolite-trachyte, with an undetermined intrusive form (after Haff, 1944c; Staatz, 1983).

On the south bank of Bear Den Canyon, deep purple and black fluorite are present in sandstone as disseminated grains and crystal aggregates up to 3 inches across. Ten to 15 percent fluorite was reported in some prospect pits (Haff, 1944c).

On the north bank of Bear Den Canyon, fluorite is more abundant and is apparently restricted to the west margin of the phonolite-trachyte intrusion. Prospect pits in the host Minnelusa sandstone and limestone reportedly contain 20 to 30 percent fluorite, with rich pockets containing as much as 50 to 90 percent fluorite. In the prospect pits, dark purple to almost black fluorite is present in veinlets and blebs that form 5 to 6 vuggy lenses. The lenses are from 1 to 3 feet wide and are at least 8 to 10 feet long. The prospect pits did not completely expose the length of these lenses, but they are elongate northwest-southeast. The fluorite is associated with brown calcite, quartz and siderite(?). Disseminated fluorite and scattered veinlets of fluorite are also present north of Bear Den Canyon in limestone and well-indurated sandstone (after Haff, 1944c; Cox, 1945). Cox (1945) also reported fluorite mineralization in a fault contact between the phonolite-trachyte intrusion and a limestone in the Minnelusa Formation.

Fluorite mineralization of the west side of the intrusive complex is probably more widespread than just the Royal Purple claims. Fluorite has been reported at other sites near Bear Den Canyon, and disseminated fluorite could be easily overlooked in the heavily vegetated terrain which has few exposures. In Bear Den Canyon, Cox (1945) described fluorite-calcite veinlets and low-grade fluorite boulders in the Pahasapa Limestone east of the Royal Purple claims, but the exact location is not known. Fluorite has also been reported north of the Royal Purple claims, probably along strike in sec. 24 (T.52N., R.64W.) (Hilton reference #235 in Osterwald and others, 1966). However, Staatz (1983) does not show any claims in this area. Staatz (1983) does show claims in the Pahasapa Limestone north of Bear Den Canyon in sec. 30 (T.52N., R.63W.), and north and east of Jim Wayne Spring in both the Pahasapa Limestone and Minnelusa Formation in the W1/4 sec. 19, (T.52N., R.63W.).

1G) Petersen fluorite lode claims (Bear Lodge fluorite property) roughly center S1/4 sec. 15, and center E1/2 sec. 22, T.52N., R.63W.

Fluorite is present in the Mississippian Pahasapa Limestone on these claims. Pits and trenches revealed altered, porphyritic igneous rocks on the claims, but only Hagner (1943) mentions fluorite mineralization in the igneous rocks. Exploration was hampered by a mantle of gravel (Haff, 1944a; Cox, 1945; Dunham, 1946). Jenner (1984) mapped exposures of Cenozoic igneous rocks near these claims. Replacement and vein fluorite mineralization, and gradations in between, are present on the property. The deep or dark purple fluorite is associated with calcite, quartz, chert and feldspar. Samples of material from trenches, shafts, and drifts contained about 20 to 85 percent fluorite (after Haff, 1944a; Cox, 1945; Dunham, 1946). Hagner (1943) reported colorless fluorite. The report of feldspar implies some inclusion of porphyritic igneous rock.

Replacement deposits follow bedding in the limestone. Replacement mineralization varies from widely disseminated fluorite grains to bands as much as 1 foot thick that are mostly fluorite. The full extent of the replacement deposits has not been determined. In workings, replacements have been followed to a depth of 24 feet, are up to 5 feet thick where bands are stacked, and are probably up to 50 feet long (after Haff, 1944a, Cox, 1945).

Large fluorite-bearing veins are actually brecciated zones, while smaller fluorite veins are narrow and appear to be in joints, while . The breccia zones contain clay and limestone clasts, with cherty masses and vuggy masses of fluorite. These breccia zones have irregular shapes, and the entire lengths have not been excavated. In workings, the zones are up to 9 feet thick, two extend to depths of 28 and 44 feet, and most are probably less than 20 feet long. Vein mineralization is both parallel to and crosscuts bedding in the limestone. The breccia zones are often elongate parallel to the strike and dip of bedding, but apparently dip at steeper angles (25 to 60°) than bedding (after Haff, 1944a; Cox, 1945). Bedding in this area has a northwest strike and dips about 25°NE (Staatz, 1983).

Wilmarth and Johnson (1953) looked at fluorite mineralization in the Pahasapa Limestone on these claims was well as those in the Lytle Creek area (H). The information they presented contradicts some preceding information by Haff (1944a) and Cox (1945). This implies, though it does not absolutely mean, that these divergent features are confined to the Lytle Creek area (see 1H). The sizes of fluorite mineralization as reported by Wilmarth and Johnson, 1953) are smaller than those presented in the previous paragraph; Wilmarth and Johnson (1953) report vein-breccia zones up to 1-foot wide and 6 feet long, and disseminated replacement deposits up to 2 feet wide and 10 feet long.

Fluorite mineralization in the Pahasapa Limestone is probably more extensive on the eastern and southern margins of the igneous complex than just the Petersen claims. A few additional prospect pits and trenches are located on these margins, and the northeastern portion of the margin is covered by an extensive gravel (Brown, 1952; Staatz, 1983; see also Gersic and others, 1990, samples 17 and 27). Also Chenoweth (1955) reports finely disseminated fluorite in numerous exposures of Pahasapa Limestone on these margins of the igneous complex.

1H) Lytle Creek area
E1/4 sec, 13, T.52N., R.64W.; and NW1/4 sec. 7, and W1/4 sec. 18, T.52N., R.63W.

Wilmarth and Johnson (1953) visited at least four claims in this area that they stated contained fluorite in the Pahasapa Limestone. These claims are the James Walter, Baker Lode, Nichols lode, and Nichols no. 1 lode (see Wilmarth and Johnson, 1953; Everett, 1951 for exact locations). Brown (1952) depicts two fluorite prospects in this area. Staatz (1983) shows prospect pits in the Permian Minnelusa Formation near Lytle Creek. Mapping by Staatz (1983) shows that the Pahasapa Limestone in this area has been more thoroughly invaded by igneous rocks than on the northeastern margin of the complex near the Petersen fluorite claims (G).

As noted in the subsection on the Petersen fluorite lode claims (G), Wilmarth and Johnson (1953) combined their observations on the Lytle Creek claims with those for the Petersen claims. Comparing Wilmarth and Johnson (1953) to Haff (1944a) and Cox (1945), the characteristics of fluorite mineralization on the Lytle Creek claims are apparently like those for the Petersen claims in that: 1) deep purple fluorite is present; 2) fluorite is associated with calcite and quartz; 3) vein-breccia and replacement deposits are present; and 4) mineralization is usually nearly parallel to bedding in the Pahasapa Limestone. Other than size (see 1G), the differences that Wilmarth and Johnson (1953) reported an that might occur exclusively in the Lytle Creek area are: 1) colorless fluorite is interbanded with deep purple fluorite; 2) iron and manganese oxides are present in fractures in fluorite grains in veins; and 3) chert and feldspar are not associated with the fluorite. Colorless fluorite has only been reported elsewhere in the Bear Lodge Mountains in the Ogden Creek area (1E) and in the igneous complex. Interbanded fluorite coloration has not been reported in the igneous complex by any other investigator. The iron and manganese oxides have only been reported in veins <u>within</u> the igneous complex.. These divergent characteristics might be a function of zoning related to the greater invasion of igneous rocks in the Lytle Creek area.

2. Bald Mountain monazite deposit, Bighorn Mountains
at least S1/2 sec. 21, sec. 22, W1/2 sec. 23, N1/4 secs. 27 and 28; and S1/2 sec. 30, and sec. 31, T.56N., R.91W.

The locations given above encompass two separate sites where samples of the basal Middle Cambrian Flathead Formation (Deadwood conglomerate) contained at least 2 pounds of monazite per ton of rock (after Kline and Winkel, 1952; McKinney and Horst, 1953a, 1953b). The exact extent of these monazite-rich placers in the basal Flathead Formation is not known. Monazite-rich rocks might be present between sample locations, and extend in subsurface under thicker overburden to the east and north of the sample sites. Extensive areas of monazite-rich rock might underlie Bald Mountain and Rooster Knob, and possibly Burnt Mountain. This paleoplacer also contains gold and ilmenite. Because Precambrian tantalum- and niobium-bearing mafic dikes are present in the area (Harris, 1987), the paleoplacer might contain these elements as well. Wilson (1951) mentions that Quaternary monazite placers are present in the area (see following locality, 2 sup.).

The basal Flathead Formation is interpreted as the product of fluvial deposition in a braided stream system during major flooding episodes in Cambrian time (Middleton, 1980). Regionally, the source of the arkosic and conglomeratic material was probably to the east. The basal Flathead Formation was previously interpreted as being beach or nearshore marine deposits (Lochman-Balk, 1971). Preliminary, dip-corrected elevations of the conglomerates and elongation directions of the conglomerates, from data in McKinney and Horst (1953b) and Bald Mountain 7-1/2 minute quadrangle map, imply local transport directions in a stream system that flowed to the southwest and southeast. This is probably a local perturbation in the regional westward transport direction in a multitude of streams.

In the Bald Mountain area, the basal Flathead Formation is a poorly-sorted, arkosic sandstone that contains irregularly-distributed, lenticular conglomerates. Low-angle bedding is quite visible in these rocks. The basal Flathead Formation is heterogeneous. It has: 1) variable textural maturity; 2) varies in color from pale buff to brown and deep red; 3) is poorly to well cemented; and 4) is from 10 to 50 feet thick. The conglomerates contain subrounded, quartz clasts that are usually pebble-sized and that appear to be derived from quartz veins. These clasts are in a matrix of sand-sized, angular to subangular, feldspar grains, with minor, sand-sized, rounded to subangular, quartz grains. The arkosic sandstones enveloping the conglomerates are very similar to the matrix material, except that the grain size in the enveloping sandstones may become coarser higher in the stratigraphic section (after Wilson, 1951; Cardinal, 1958; McKinney and Horst, 1953a; Middleton, 1980).

In detail, zones of monazite enrichment within the basal Flathead Formation are not specifically confined to any lithology or horizon. The monazite-bearing rocks are easily recognized by their high radioactivity. Monazite is usually most abundant in poorly-cemented, iron-stained, irregularly-distributed, lenticular, 2.5 to 10 feet-thick conglomerates that lie on or near the underlying red or gray, Precambrian, granitic rock (Wilson, 1951; McKinney and Horst, 1953a). Preliminary isopach, elevation contour, and monazite-content contour maps of zones of monazite enrichment, based on the data in McKinney and Horst (1953b) and from the Bald Mountain 7-1/2 minute quadrangle map, support the irregular distribution and lenticular nature of the conglomerates as first noted by Wilson (1951). These data also indicate that these conglomerates might be stacked upon each other. Wilson (1951) described the monazite concentrations as being pepper-sized, reddish-brown, monazite grains that are present at various locations within conglomerates that are cemented by limonite. McKinney and Horst (1953a) thought most monazite was restricted to poorly-cemented, deep red or yellowish red conglomerates that were overlain by well-cemented sandstones and finer-grained conglomerates. However, monazite concentrations greater than 5 pounds per ton of rock were shown by Kline and Winkel (1952) to be present in these "barren" overlying sandstones and well-cemented conglomerates. Rapid lateral changes are further demonstrated by samples from adjacent drill holes and test pits in the same horizon that do not contain anywhere near the same amounts of monazite (compare Kline and Winkel, 1952, with McKinney and Horst, 1953a, 1953b).

McKinney and Horst (1953a, 1953b) had apparently assumed a sheet-like configuration for a zone of monazite enrichment, because the basal Flathead Formation was then considered to be a beach deposit. As shown later, recognition of the more complex fluvial nature of the monazite placer precludes any accurate determination of monazite resources from the extensive data in McKinney and Horst (1953b).

The Bald Mountain paleoplacer deposit has been extensively prospected for monazite and gold, but any production figures for monazite or gold have not been recorded. The paleoplacers were first examined for gold near the turn of the 19th Century, but gold concentrations proved to be unprofitable. Gold concentrations of about 0.1 oz/ton were reported (Darton, 1906; Darton and Salisbury, 1906). From six samples, McKinney and Horst (1953b) reported much lower gold concentrations of 0.001 to 0.005 oz/ton. These are probably lower than actual concentrations because they used composited samples from the entire depth of dry, rotary-drilled holes. Dense minerals like gold, monazite and ilmenite are incompletely recovered during air drilling at low pressures, and the holes were not entirely in conglomerate. Because dense minerals such as monazite commonly accumulate at the bottoms of drill holes during air drilling, this may also explain the small monazite grain-size in the cuttings, as reported by McKinney and Horst (1953a), compared to Wilson (1951). In the early 1950s, the deposit was examined for monazite as a source of thorium. At this time numerous pits and trenches were dug, and holes were drilled (about 2,000 feet). Numerous samples of drill cuttings were taken (about 27 tons) and analyzed. The potential resource of by-product ilmenite was also noted at this time (Kline and Winkel, 1952; McKinney and Horst, 1953a, 1953b). Results of these examinations define the extent of the monazite-rich rocks and potential resources as presented in the following paragraphs.

In the Bald Mountain area, monazite abundances, as calculated from the radioactivity of samples concentrated on a Wilfley table (with a correction from Wilfley table losses), vary from less than 2 pounds of monazite per ton up to about 30 pounds of monazite per ton of rock. Zones in which all samples contain greater than 5 pounds of monazite per ton are often 10 feet thick and vary from less than 2.5 feet thick up to 15 feet thick. From microscopic examinations of 114 samples, having a wide range of monazite grades, ilmenite contents of Wilfley concentrates are 4.5 to 5 times greater than monazite contents (McKinney and Horst, 1953b).

Within the Bald Mountain deposit, the potential high-grade (>10 lbs. monazite/ton rock) monazite resources are in a 48.3 acre area in the center E1/2 sec. 22 and center W1/2 sec. 23. A less well defined area of high monazite content is located in sec. 31.

The potential monazite resources in secs. 22 and 23 are in a zone that was estimated to be about 6 feet thick, and overlain by 0 to 30 feet of overburden. This potential resource contains an estimated 4,447 tons of monazite in 674,160 tons of rock, that averages 13.2 pounds of monazite per ton of rock. The rocks also contain about 22,000 tons of ilmenite. Lower grade resources are far more extensive and abundant. For example, the area in sec. 31 at the base of Bald Mountain contains about 7,800 tons of monazite in 3,500,000 tons of rock that averages about 4.45 pounds of monazite per ton of rock (McKinney and Horst, 1953b).

As presented in this report, the extent and potential resources of monazite-rich rocks at Bald Mountain are poorly defined. At present it is not even possible to tell if the resources are overestimated or underestimated, let alone the amount of error. The major problems are: 1) the ill-defined lateral extent under thicker overburden; 2) the need to reexamine the deposit in terms of the rapid lateral and vertical changes in the newer fluvial depositional model; and 3) inaccurate sampling and analyses in previous investigations. A reexamination could proceed in several increasingly costly steps.

The first step would be to determine if drilling and lithologic logs are available for the holes drilled in 1952; these operations were summarized by McKinney and Horst (1953a, 1953b). These might enable an investigator to determine: 1) if the holes were really drilled to Precambrian rocks; 2) if and when well-cemented sandstones and conglomerates were encountered; and 3) if there are any lithologic differences between these well-cemented sandstones and conglomerates, and the poorly-cemented sandstones and conglomerates.

Step two would be a field geologic investigation of the area. This would include taking surface samples, and measuring radioactivity to determine the nature and extent of the paleoplacer, as well as the underlying and overlying rock. It must be determined whether there are any indicators of monazite abundance. For example, which is a more accurate guide to ore, the poorly-cemented conglomerates or some specific radioactivity? The investigation would have to be extensive with the secondary goal being the determination of whether the fluvial paleoplacer had been previously sampled in an effective manner, even though sampling was designed for a beach placer. This would determine if holes were drilled deep enough and/or close enough, and if samples were take often enough.

In step three, if sampling has been done in an effective manner, some new samples must be obtained. Because the holes drilled in the 1950s were drilled with air, which causes homogenization of samples and incomplete recovery of heavy minerals, some new holes must be drilled next to the old ones and sampled with a more effective drilling medium. Core drilling might be necessary to ensure compete sample recovery. It might then be possible to recalibrate the old data by analyzing these new samples. Microscopic point counting is recommended along with radiometric analyses of bulk samples and downhole radiometric analyses. If some holes are cored, the rare earth content of the core can be compared to the radiometrics of the core and in the drill hole, to see if radiometrics alone can be used to determine the concentrations of rare earth elements. Radiometric analyses of crushed drill core after concentrations on a Wilfley table are not recommended, because the monazite can have various thorium concentrations, and a great deal of monazite was lost off the Wilfley Table in previous investigations (25 to 40 % according to McKinney and Horst, 1953b).

Step four would be a complete subsurface resampling of the area, if needed. If earlier steps indicate radioactivity is an ore guide, downhole radiometric analyses could be used.

2 sup. Bald Mountain recent placers secs. 20, 23, T.56N., R.91W.; and sec. 6, T.55N., R.91W. (Hausel per. comm.)

Monazite-bearing Quaternary stream placers in the area were first noted by Wilson (1951). The three locations given were discovered during reconnaissance examinations for gold by W. Dan Hausel.

3. Lyle Ramsbottom property (Beaver Creek allanite prospect) NW1/4 sec. 5, NE1/4 sec. 6, T.46N., R.83W.; and S1/2 sec. 31, T.47N., R.83W.

Allanite is present in metamorphosed calc-silicate rocks at this site in the southern Bighorn Mountains. Allanite is ubiquitous in the calc-silicate rocks, with both a homogeneous distribution and as small decussate masses. Individual allanite crystals are up to 1 or 2 inches long. The calc-silicate rocks occur as lenses, bands, layers and pods that are concordant with the N60°W foliation in the enclosing Precambrian quartzofeldspathic gneiss. These discontinuous calc-silicate bodies apparently form a zone 3750 feet long and a few inches to 6 feet wide. The exact extent of the bodies and zone is not known, because excavation is needed in order to further delimit these non-resistant, calc-silicate rocks. Bodies of calcitic marble are also present in this zone, both adjacent to and isolated from calc-silicate rocks. Allanite is apparently more abundant in calc-silicate rocks adjacent to the marble. In addition to the uranium, thorium and rare earth elements in the allanite, high values of niobium have also been reported from samples of calc-silicate rock. The exact origin for the enrichment of these elements is not known, but it is thought to be related to regional amphibolite-grade metamorphism during Archean time (Sargent, 1960; Armbrustmacher and Sargent, 1982; Hose, 1955; Wilson, 1952; Magleby, 1952; see also Magleby and Collins, 1952 for early misinformation). Alternatively, the marble might be a metamorphosed Precambrian carbonatite.

Prior to 1960, the zone of calc-silicate rocks had been prospected by excavation of pits and trenches. The size of the pits and trenches was from a few feet to 10 feet deep, and a few feet across to 54 feet long and several feet across. The sizes of most of the workings were at the small end of the range. In

1955, 300 tons of allanite-bearing rock was shipped from workings in sec. 31 to Casper, Wyoming. This ore was never processed (after Sargent, 1960). The present location of this radioactive ore is not known. Bromley (1955a) states that 600 tons of material were removed from section 31 and stored in Casper. This implies the material was removed after Magleby's (1952) first report (7-1-52) on the property and prior to Bromley's report (5-17-55). Elevatorski (1976) mislocated the site in sec. 32, T.47N., R.83W.

These allanite-bearing calc-silicate rocks are a potential source for rare-earth elements. Uranium, thorium and niobium might be produced as by-products. From only 4 samples, it was estimated that the calc-silicate rocks average 4.44 percent total REE, 0.04 percent Nb, 0.03 percent U and 0.06 percent Th. It was estimated that the zone of calc-silicate rock contained about 400,000 tons of mineable allanite-bearing material. Concentrations of important elements vary from 30 to 1000 ppm Nb, 0.01 to 0.12 percent Th, 0.004 to 0.090 percent radiometric equivalent uranium (eU), and 1.27 to 7.68 percent LREE. Tantalum was not detected in the samples (Armbrustmacher and Sargent, 1982).

SIGNIFICANT LOCALITIES

ALBANY COUNTY

1. Tie Siding area T.12N., R.71W.; T.12N., R.72W.; and T.13N., R.72W.

Many rare earth-bearing, highly radioactive (up to 900 times background), potash-rich, pod-like pegmatites that contain bull quartz are present in the Middle Proterozoic Sherman Granite near Tie Siding (Smith, 1954). Potassium feldspar was produced from a few of these pegmatites in the 1940s (Osterwald and others, 1966). The mineralogy of the rare earth-bearing minerals or materials in these pegmatites is obscure. Pockets in these pegmatites contain yellow-brown iron oxides, at least one highly radioactive, unknown mineral, crytolite (impure zircon) and pyrochlore. The crytolite and pyrochlore in these pegmatites contain minor yttrium (Smith, 1954). Rare earth-bearing minerals were noted in only one pegmatite during 1978 examinations, and high radioactivity was associated with biotite. Given the association of rare earth and radioactive elements (Griffin and Warner, 1982), rare earths might be present in fine-grained minerals that are obscured by the dark biotite. Two other pegmatites (sec. 9, T.12N., R.72W.; sec. 23, T.13N., R.71W.), than the six listed below, are at least 20 times more radioactive than background. Therefore, rare earth mineralization is probably more widespread than just the sites reported here.

This mineralization in the Sherman Granite is similar to that in the Pikes Peak Batholith in the Front Range of Colorado. These two granites are similar in age, and physical and chemical characteristics. Both contain rare earth enrichment and rare earth bearing pegmatites. The Pike Peak Granite seems, however, to contain greater rare earth enrichment than the Sherman Granite in both pegmatites and the granite in general (see Hills and others, 1982; Simmons and Heinrich, 1980).

1A) Holiday Place pegmatite SW1/4SE1/4 sec. 32, T.13N., R.71W. (Smith, 1954; Griffin and Warner, 1982)

During a 1978 examination, a trace of allanite was noted in this pegmatite on Dale Creek. A sample of this pegmatite contained >500 ppm (possibly 1,000 ppm) La, >200 ppm Y, 50 ppm Nb, and 198 ppm cU3O8. No analyses for thorium were reported (Griffin and Warner, 1982).

1B) Pegmatite #1 sec. 35, T.13N., R.72W. (Smith, 1953c)

Pyrochlore was identified in a sample from this pegmatite. Another sample contained 4.1 percent ThO2 and 0.35 percent cU3O8 (1.23 % eU3O8) (Smith, 1954). In addition, radioactivity up to 900 times background was reported and a vitreous radioactive mineral was seen (Smith, 1953c). Griffin and Warner (1982) were unable to locate this pegmatite.

1C) Pegmatite #2 NE1/4 sec. 1, T.12N., R.72W. (Smith, 1953b); or NE1/4SE1/4 sec. 36, T.13N., R.72W. (Griffin and Warner, 1982)

Crytolite was identified in this pegmatite. Another sample contained 1.1 percent ThO2 and 0.09 percent cU3O8 (0.32 % eU3O8) (Smith, 1954). In addition, radioactivity up to 35 times background was reported and a vitreous radioactive mineral was seen (Smith, 1953b). Griffin and Warner (1982) reported that the high radioactivity was associated with biotite and that a rock sample contained 200 ppm La, 50 ppm Y, <10 ppm Nb, 500 ppm Zr, and 20 ppm cU3O8, with no analyses for thorium. Elevatorski (1976) calls this location West Dale Creek.

1D) Pegmatite #3 SW1/4NE1/4 sec. 6, T.12N., R.71W. (Smith, 1953a; Griffin and Warner, 1982)

Radioactivity up to 35 times background was reported and a vitreous radioactive mineral was seen in the pegmatite (Smith, 1953a). Griffin and Warner (1982) report high radioactivity is associated with biotite books, and that a rock sample contained 1,000 ppm Nb and >200 ppm Y, only 50 ppm La, and 127 ppm cU3O8, with no analyses for thorium.

1E) Pegmatite #4 SE1/4SW1/4 sec. 2, T.12N., R.72W. (Smith, 1954; Griffin and Warner, 1982)

High radioactivity is apparently associated with biotite; a select sample containing biotite assayed 500 ppm La, 200 ppm Nb, 150 ppm Y, and 57 ppm cU3O8.

A sample of altered granite just southwest of this pegmatite contained a trace of allanite, 230 ppm La, 100 ppm Nb, 36 ppm Y, and 38 ppm cU3O8. A scintillometer reading on this granite gave 534 ppm eTh and 30 ppm eU. No analyses for thorium were performed on samples from either site (Griffin and Warner, 1982). Elevatorski (1976) calls this location West Dale Creek, and places it in section 3 of this township.

1F) unnamed SE1/4SE1/4NW1/4 sec. 16, T.12N., R.72W. (Griffin and Warner, 1982)

A sample of Sherman Granite(?) from this site contained 1000 ppm La, 50 ppm Nb, 200 ppm Y, and 15.7 ppm cU3O8, with no thorium data reported (Griffin and Warner, 1982). This is probably another pegmatite in the Tie Siding area or an indication of rare earth mineralization in the enclosing Sherman Granite.

2. Laramie Anorthosite Complex T.20, 21, 22N., R.70, 71W.

Samples of syenitic rocks and phosphatic, magnetite-ilmenite bodies in the Middle Proterozoic Laramie Anorthosite Complex (LAC) contain elevated levels of rare earth elements. This was expected because alkaline igneous rocks are often enriched in REE and REE are often enriched in phosphatic rocks and minerals (see Table 1 and section on the Phosphoria Formation). Chemical analyses for REE have only been reported from 11 samples of the LAC, so the extent, degree and any pattern of enrichment in the complex is not known. These localities are important because of the size of the syenites that accompany the anorthosite in the complex, and the widespread occurrence of the magnetite-ilmenite bodies in the complex. Phases of the syenites are potentially large, at least low-grade, potential resources. The syenites (Red Mountain and Sybille plutons) need to be examined in more detail, particularly for apatite and allanite concentrations, to determine the actual potential. The documented enrichment in the magnetite-ilmenite bodies in the LAC indicate that they also warrant further exploration, particularly the more apatite-rich bodies.

2A) Red Mountain pluton (mineral point counts)
roughly E1/2 T.22N., R.71W.

Carl Anderson (personal communication, 1987), a doctoral candidate in the Department of Geology and Geophysics at the University of Wyoming reported that one minor phase of the Red Mountain Syenite (pluton) contains more than 1 percent allanite. The syenite is part of the Laramie Anorthosite Complex. From his preliminary mapping and point counting, Anderson determined that an olivine-absent but clinopyroxene-bearing phase of the syenite contains between 1.5 and 3.6 percent allanite. The allanite is both pristine and metamict. This clinopyroxene phase makes up less than 5 percent of the syenite, and at present this phase has not been completely mapped. To date allanite is most abundant in the N1/2 of the center of sec. 36 (Anderson, personal communication, 1987). A chemical analysis from the pluton seems to indicate that REE enrichment is not restricted to an olivine-absent, clinopyroxene-bearing phase of the pluton (see sample MPK 60A in 2B below).

2B) Red Mountain pluton (chemical analyses)

sample MPK 60A	E1/2E1/2NE1/4 sec. 7, T.22N., R.70W.
sample MPK 83	center N1/2N1/2 sec. 13, T.22N., R.71W.
sample SQ (SR) 22	NE1/4NE1/4NE1/4 sec 16, T.22N., R.70W. (Platte County)

Sample MPK 60 was of a fayalite (olivine) monzonite, and contained 156 ppm Nd and 30 ppm Sm. These REE concentrations in this sample indicate that REE enrichment in the Red Mountain pluton (syenite) are not restricted to an olivine-absent phase as noted by Anderson (see 2A). Sample MPK 83 was of a ferro-hedenbergite (clinopyroxene) monzonite, and contained 731 ppm Nd and 119 ppm Sm (Geist and others, 1990); this seems to indicate greater REE enrichment in the clinopyroxene-bearing portion of the pluton as shown by Anderson (see 2A). Sample SQ (SR) 22 was of a granite and contained 248 ppm Nd and 55 ppm Sm (Geist and others, 1989, 1990). With the work of Anderson (see 2A), these analyses indicate widespread REE enrichment in the Red Mountain pluton.

2C) Sybille pluton chemical analyses
uncertain-possibly along the T.21-22N., R.71W. line

Three samples of hornblende monzonite that were apparently from the syenitic Sybille pluton (see Geist and others, 1990, figure 1; Fountain and others, 1981, figure 1) contained elevated levels of rare earths. The analyses shown in the small table below are from Fountain and others (1981) and are in ppm.

	rare earth element						
sample no.	Ce	Nd	Sm	Eu	Dy	Er	Yb
240-2	754	290	55		24	11	13
240-5	412	150	38		29	16	17
33	312	182	37	10	23	9	10

2D) Magnetite-ilmenite bodies analyses

Taylor (LRA-17, 18)	SE1/4 sec. 35, T.21N., R.71W.
unnamed (LRA-6)	roughly sec. 10-11 line, T.20N., R.71W.
unnamed (LRC-1)	roughly sec. 34-35 line, T.20N., R.71W.
Deposit no. 1 (LAC 8751)	S1/2SW1/4NW1/4 sec. 22, T.21N., R.71W.

The LRA samples are from magnetite-ilmenite bodies that definitely contain apatite; the body where sample LRA-6 was taken contained apatite crystals that were up to 5 centimeters long. Little is known about the body where sample LRC-1 was taken, except that it is called iron ore (see Goldberg, 1983, 1984). Sample LAC 8751 is of an apatite- and Fe-rich troctolite in the anorthosite, but the latitude and longitude location of the sample site (Geist and others, 1990) places it in close proximity to [border of] the Deposit no. 1

magnetite-ilmenite open-cut. It has been assumed that the REE enrichment is due to the formation of the magnetite-ilmenite body rather than enrichment in the anorthosite. Data in the table below are in ppm; LR sample analyses are from Goldberg (1983, 1984), while LAC sample analysis is from Geist and others (1990).

	rare earth element							
sample no.	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu
LRA-6	72	170	98	24	6	3	4	1
LRA-17	172	396	235	61	14	9	9	1
LRA-18	200	479		70	15	9	12	1
LRC-1	99	233	136	34	8	4	6	1
LAC 8751			180	38				

3. Elmers Rock area roughly center SE1/4 sec. 19, T.23N., R.71W.

Graff and others (1981) report that a rock sample from this site contained 1600 ppm La, 1200 ppm Ce, 280 ppm Zr, but only 16 ppm Y. Other results of the sample analysis (#105238) included 33 ppm U and 350 ppm Th. From the location given in Graff and others (1981), the rock sample is probably from either of two Archean quartz veins in an Archean granite (Snyder, 1984; Bull Camp Peak 7-1/2 minute quadrangle) or granite gneiss (Graff and others, 1981). These quartz veins and others mapped by Snyder (1984) in the central Laramie Mountains warrant further sampling given this rare earth enrichment.

CARBON COUNTY

4. Big Creek pegmatite area T.13N., R.80W.; and T.13N., R.81W.

Six pegmatites in this area contain documented rare earth enrichment, and the Platt pegmatite in particular produced at least 2 tons of a rare-earth bearing mineral. All these pegmatites are present within an Early Proterozoic hornblende and quartzofeldspathic gneiss terrain south of the Cheyenne Belt shear zone. Other pegmatites in this terrain south of the shear zone, as mapped by Houston and others (1968), seldom contain documented rare earth enrichment. The Many Values pegmatite {11} is an exception. However, most of these pegmatites have not been examined for rare earths, so more exploration is in order.

Houston (1961b) states that four pegmatites in these two townships, in addition to the Platt pegmatites, contain one or more of the following minerals: euxenite, columbite, and monazite. Houston (personal communication, 1987) stated more rare earth bearing pegmatites are probably present in the area since all the pegmatites were not examined. A sketch map by Houston (1961b) showed niobium-bearing pegmatites in sec. 19 (T.13N., R.80W.) and near sec. 22 (T.13N., R.81W.). Houston (personal communication, 1987) could not remember the exact locations of the pegmatites in sec. 19, but confirmed the presence of a niobium-bearing pegmatite in the section. He marked the three remaining pegmatites on his map published in 1961. The largest pegmatite is a north-south, elongate body in the center S1/2 sec. 13 (T.13N., R.81W.). Two small pegmatites are located along a road in the center E1/2 sec. 14 (T.13N., R.81W.). In an additional comment, he noted that the niobium-bearing mineral in these four pegmatites was metamict, and might be euxenite (samarskite) or fergusonite.

In addition to the pegmatites listed above and the two Platt pegmatites, at least 2 other pegmatites and/or veins (Big Creek mine; Uranium King #2) in the Big Creek area contain elevated levels of uranium and might also contain elevated levels of rare earths.

4A) Platt pegmatite (Platte, Uranium King mine)
SW1/4SE1/4SW1/4 sec. 3, T.13N., R.81W.

This zoned pegmatite in the Big Creek pegmatite area cross-cuts the foliation of the Precambrian gneissic country rock. The pegmatite is 70 feet wide, 160 feet long, and was mined to a depth of 75 feet (Houston, 1961a). Rare earth-bearing minerals, "euxenite" and monazite, are most abundant in the center of the pegmatite and in gash veins. In order of abundance, accessory minerals present in the pegmatite are "euxenite", monazite and columbite. The "euxenite" is metamict so the X-ray identification is suspect. The "euxenite" is most probably samarskite or a niobium-rich, yttrium-bearing tantalite, based on it's chemical composition and x-ray pattern. X-ray fluorescence showed that the only rare earth element that was present in major amounts in the "euxenite" was yttrium. The same kind of analysis on monazite indicated the presence of the following rare earth elements and yttrium, in order of decreasing abundance, cerium, neodymium, yttrium and lanthanum. Some crystals of "euxenite" and monazite reportedly exceeded three inches in length (after Houston, 1961a, 1961b; Platt, 1986). In contrast with the earlier examinations, workers for the U.S. Department of Energy identified the accessory minerals as euxenite and allanite (Adams and others, 1980), and columbite-tantalite (Dribus and Nanna, 1982). The location of the pegmatite was given as 41°07' N. latitude and 106°30' W. longitude by Olson and Adams (1962). At present, the mine has been sealed with a concrete cap, in which small metal grates may permit access.

Ten thousand pounds of "euxenite" were reportedly produced from this mine (after Houston, 1961a, 1961b; Platt, 1986). The U.S. Bureau of Mines only record 3115 and 1,000 pounds of euxenite for 1957 and 1958, respectively (Kelly and Mullen, 1958; Kelly and others, 1959). Most of the production from this mine, 13 tons of ore in 1956, was for uranium (Wyoming State Board of Equalization, 1957-58).

Samarskite is reported from a granite on the King claims in sec. 32 in this same township (Gruner and Knox, 1957). This occurrence probably refers to the Platt pegmatite because: 1) there are no granites in sec. 32; 2) the claim names are similar; 3) the localities are in the same township; 4) only one digit in the section number is different; and 5) the reported minerals are similar. Gruner's sample books do not resolve this problem.

4B) Platte [Platt] garnet pegmatite N1/2NE1/4 sec. 8, T.13N., R.81W. (Roseboom and King, 1953; Geslin, 1954; Dribus and Nanna, 1982)

At this location, Dribus and Nanna (1982) reported that radioactivity up to about 17 times background was associated with black, metallic-looking minerals. Their samples were not assayed, but contained euxenite and allanite as identified by SEM/EDS. This is a radioactive 1 to 3 foot-wide, N30°W trending, garnet-bearing pegmatite in Precambrian biotite schist, a sample of which contained 0.1 percent eU (Roseboom and King, 1953). This is probably the garnet pegmatite that King (1953) noted in the eastern part of the Encampment district that contained 0.12 percent eU and 0.10 percent U. However, Geslin (1954) reported radioactivity of only 2 times background on the pegmatite.

5. Bates Hole area
T.27N. and T.28N., R.78W., R.79W., R.80W. and R.81W.

Harshman (1972) states that several areas of high radioactivity were detected during aerial surveys within this area on the south rim of Bates Hole. From surface examinations, these radioactive zones are attributable to monazite in sandy and conglomeratic beds in the Wind River and White River Formations, and monazite in Quaternary alluvium derived from these formations. The monazite content in these coarse-grained beds is quite variable. Reported concentrations of monazite vary from a few hundredths to 1.43 pounds of monazite per ton of sand, with most samples containing less than 1 pound of monazite per ton of sand (Harshman, 1972). Roehler (1958) states that John Schulte discovered that most of the radioactivity in the area was from thorium in monazite, but Vine and Denson (1954) were the first to note the radioactive contribution of monazite. These occurrences are probably fluvial placers. Within this large area, several specific sites have been noted below, and at least five other sites of high radioactivity are known (see AEC Preliminary Reconnaissance Reports, Carbon County microfiche for airborne radioactivity anomalies 1-3, 7 & 8), where monazite might be present.

5A) Gafco placer claims and Shirley #22 lode claims of Jenkins and Hand (airborne anomaly #9) sec. 3, T.27N., R.81W. (Whalen, 1954b; Vine and Denson, 1954; Schulte, 1956)

Vine and Denson (1954) reported monazite in heavy mineral concentrates that were obtained from coarse-grained, arkosic sandstone and conglomerate in the basal White River Formation (Oligocene) on this property. A channel sample contained 0.12 percent Th and 0.003 percent U (Vine and Denson, 1954). Whalen (1954b) noted that the conglomerate armors a pediment and is rich in igneous rock clasts. A concentrate, 1/50th of the original sample, reportedly contained 25 percent REE, 6 percent ThO2 and 0.25 percent U3O8 (Whalen, 1954b). A sample from the center of sec. 3, of a gravel from the soil horizon resting on or developed on the Wind River Formation contained 9.7 percent heavy minerals; 23 percent of the heavy minerals were monazite, with a trace of zircon. Monazite with possible thorite inclusions were identified by SEM/EDS. A spectrometer reading on the gravels on the Wind River Formation in sec. 3 were 830 ppm eTh and 29 ppm eU, with 470 ppm eTh and 23 ppm cU3O8 (14 ppm eU) in the sample (Griffin and Milton, 1982). Olson and Adams (1962) gave the location as 42°20' N. latitude and 106°32' W. longitude.

5B) unnamed NE1/4 sec. 5, T.27N., R.81W. (Griffin and Milton, 1982)

Two samples (42,43) of gravels from the Wind River Formation or recent gravels were not analyzed for thorium, but contained 700 and 1000 ppm La, 70 and 200 ppm Y, 10 and 50 ppm Nb, 2000 and 5000 ppm Ti, and 500 ppm Zr, with 16.5 and 43 ppm cU3O8. A sample (37) of Wind River Formation sandstone from the same area contained only 150 ppm La, 1500 ppm Ti, 20 ppm Y and 300 ppm Zr. Fourteen spectrometer readings in the area varied between 20 and 1119 ppm eTh, with 0 to 42 ppm eU (Griffin and Milton, 1982). This is probably a fluvial placer like that about 2 miles to the east on the Gafco claims.

5C) unnamed sec. 9, T.27N., R.80W. (Love, 1954a)

A zone of radioactivity is associated with an arkosic sandstone of the Wind River Formation (Love, 1954a; see also Love and Murphy, 1954a). Monazite has been tentatively identified in the samples (Love personal communication in Wilson, 1960), so this is an unverified occurrence.

5D) unnamed sec. 29, T.27N., R.80W. (Love, 1954a)

A 180-foot-long radioactive zone occurs in the Wind River Formation (Love, 1954a; see also Love and Murphy, 1954b). Monazite has been tentatively identified in the samples (Love personal communication in Wilson, 1960), so this is an unverified occurrence.

5E) unnamed (samples AAE 342-347) roughly common corner sec.. 17, 18, 19 and 20, T.28N., R.78W. (Ellis, 1977)

Six samples of 1/6 foot intervals to a depth of 1 foot in residuum from and/or from the White River Formation contained 50 and 100 ppm cTh, with less than 10 ppm eU and cU. No discernable enrichment of elements that are in heavy minerals was noted, but no rare earth analyses were reported (after Ellis, 1977). Monazite-bearing paleoplacers are reported in the White River Formation in this area, so this might another such occurrence. It is presently an unverified locality.

5F) unnamed (samples AAE 320-325) SW1/4 sec. 32, T.28N., R.79W. (Ellis, 1977)

Six samples of 1/6 foot intervals to a depth of 1 foot in residuum from and/or from the Wind River Formation contained 200 to 1900 ppm cTh (148 to 1611 ppm eTh), with 5 to 24 ppm cU (4 to 40 ppm eU). The most thorium-rich sample was at the surface. No discernable enrichment of elements that are in heavy minerals was noted, but no rare earth analyses were reported (after Ellis, 1977). This might be another example of the monazite-bearing paleoplacers in the Wind River Formation in this area, but at present is an unverified locality.

5G) unnamed (sample AAE 319) roughly center south line sec. 31, T.28N., R.79W. (Ellis, 1977)

A sample of a 1/6 foot interval at a depth of 2/3 foot in residuum from or from the Wind River Formation contained 120 ppm eTh, with less than 10 ppm cU and eU. No discernable enrichment of elements that are in heavy minerals was noted, but no chemical thorium or rare-earth analyses were reported (after Ellis, 1977). This might be another example of the monazite-bearing paleoplacers in the Wind River Formation in this area, but at present is an unverified locality.

5H) unnamed (samples 233 and 234) N1/2 sec. 12, T.27N., R.78W.

Samples of an altered (yellow orange), fine-grained, arkosic sandstone (234) and carbonaceous shale (233) in the White River Formation [?] contained 7 and 59 ppm cU3O8, respectively. The sandstone also contained 150 ppm La, 50 ppm Y and 100 ppm Zr (Griffin and Milton, 1982). This appears to be another low-grade indication of a fossil placer in the Shirley Basin. As located, the site is in the White River Formation (Harshman, 1968).

6. Onemile Creek area sec. 6 and N1/2 sec. 7, T.18N., R.78W. (Karlstrom and others, 1981b)

These conglomerates in the Early Proterozoic Magnolia Formation are the most economically promising of the Precambrian radioactive conglomerates in Wyoming (see Figure 3 and Table 5). At an average grade of about 300 ppm each U3O8 and ThO2, about 1801 tons of U3O8 and 1106 tons ThO2 are present in the area. The Onemile Creek area was not evaluated for rare earth potential. Radioactive minerals identified include coffinite, uranothorite, thorogummite and possibly brannerite (Houston and Karlstrom, 1981), with pyrite being the most abundant heavy mineral (Karlstrom and others, 1981a,b). The uranothorite and brannerite (?) probably contain rare earth elements, so radioactivity is indicative of rare earth mineralization. In section 7, units 1, 2 and 3 (oldest to youngest) are exposed in an overturned limb of the Magnolia Formation. These units are also exposed in the same limb in the W1/2 of section 6. Units 4 and 5 are exposed in the NE1/4 of section 6, in the other limb of the same syncline, and in a fault repeated section (Houston and Karlstrom, 1981; Karlstrom and others, 1981b).

The 143 surface samples from the Magnolia Formation in the Onemile Creek area had a mean content of 159 ppm Ce, 163 ppm La, 23 ppm Nb, and 12 ppm Y, with 25 ppm U and 99 ppm Th. Of the six units in the Formation (counting 5a and 5b separately), units 1, 2, 4, 5a and 5b contained significant radioactive rocks (Karlstrom and others, 1981b; see also Graff and Houston, 1977; Houston and others, 1978, 1979).

In section 7, a 1.2 foot thick conglomerate in unit 2 contained 177 ppm U, 371 ppm Th, with the maximum rare earth contents for a surface sample in this section of 657 ppm La, 457 ppm Ce and 41 ppm Y. The only other abnormally radioactive horizons in section 7 that were more than 1 foot thick was a 1.2 foot thick paraconglomerate in unit 1 that contained 164 ppm La, 116 ppm Ce and 9 ppm Y, with 229 ppm Th and 26 ppm U; and a 2.7 foot thick paraconglomerate that contained 131 ppm Th, 15 ppm U, 195 ppm Ce, 261 ppm La and 9 ppm Y (Karlstrom and others, 1981b; see also Graff and Houston, 1977; Houston and others, 1978, 1979).

In the W1/2 sec. 6, a 6.7 foot thick coarse-grained quartzite in unit 2 was the most rare earth rich, yet only contained 248 ppm Ce, no data for La, 13 ppm Y, with 71 ppm U and 270 ppm Th. So no surface samples from the W1/2 of sec. 6 met REE occurrence criteria (150 ppm La, 320 ppm Ce, 110 ppm Y, etc.) (Karlstrom and others, 1981b; see also Graff and Houston, 1977; Houston and others, 1978, 1979).

In the NE1/4 of sec. 6, several abnormally radioactive horizons at least 1 foot thick were encountered in units 4 and 5. In unit 4, two 3-foot thick quartz pebble conglomerates contained 104 and 370 ppm U, 214 and 365 ppm Th, 781 and 381 ppm Ce, no data and 454 ppm La, and no data and 28 ppm Y. A 1-foot thick quartz pebble conglomerate in unit 4 contained 422 ppm Th, 52 ppm U, 566 ppm Ce, 685 ppm La and 27 ppm Y. A 4-foot-thick quartzite in unit 4 contained 650 ppm Th and 37 pm U, with 667 ppm Ce, no data for La and 31 ppm Y. A 1.2 foot thick arkosic granule conglomerate in unit 5a contained 146 ppm Th, 15 ppm U, 269 ppm Ce, 333 ppm La, and 14 ppm Y. In unit 5b, an 8 foot thick quartz pebble conglomerate contained 533 ppm Ce, no data for La, 38 ppm Y, with 64 ppm U and 315 ppm Th. A 12 foot thick quartz pebble conglomerate in unit 5a contained 3952 ppm Ce, no data for La, 757 ppm Nb, 137 ppm Y and 923 ppm Zr, with 102 ppm U and 915 ppm Th. This is the most rare earth and niobium rich sample of all the Precambrian quartz pebble conglomerates in Wyoming. The maximum lanthanum content in this quarter section was from a 0.6 foot thick quartz pebble conglomerate in unit 4 that contained 975 ppm La, 825 ppm Ce and 27 ppm Y, with 43 ppm U and 657 ppm Th (Karlstrom and others, 1981b; see also Graff and Houston, 1977; Houston and others, 1978, 1979).

The 335 subsurface samples from the Magnolia Formation in the Onemile Creek area had a mean uranium contained of 118 ppm U, with 112 ppm Th, 102 ppm Ce, 101 ppm La, 21 ppm Nb and 17 ppm Y (Karlstrom and others, 1981b). These are much lower than surface samples. The origin of this difference is not known.

Several radioactive horizons were encountered in section 7 in drill hole MB-16. In unit 1, four 1-foot samples of arkosic paraconglomerate between depths of 121 and 125 feet contained 45 to 236 ppm U, 54 to 104 ppm Th, 72 to 196 ppm La, 57 to 147 ppm Ce and 8 to 23 ppm Y. Also in unit 1, a 1-foot sample of quartz granule conglomerate at a depth of 142 feet contained 84 ppm U, 212 ppm Th, 286 ppm La, 226 ppm Ce and 19 ppm Y. Two other samples in unit 1 at depths of 170 and 181 feet contained 36 and 63 ppm U, 8 and 53 ppm Th, 484 and 179 ppm La, 440 and 133 ppm Ce, and 29 and 12 ppm Y, respectively. The sample from 170 feet is the most rare earth rich from subsurface in this section. In unit 2 at a depth of 272 feet a 1-foot sample of pebbly quartzite contained 273 ppm U, 212 ppm Th, 245 ppm Ce, 347 ppm La and 28 ppm Y. Two samples of pebbly quartzite taken around 390 feet deep contained 940 and 1620 ppm U, 79 and 110 ppm Th, 133 and 189 ppm La, 88 and 124 ppm Ce, and 56 and 40 ppm Y (Karlstrom and others, 1981b). Houston and Karlstrom (1981) state the thickness of this 390 foot deep radioactive zone was about 5 centimeters.

In the W1/2 sec. 6, a significant radioactive zone was encountered in a medium-grained quartzite in drill hole EMB-1 at depths between 393 and 403 feet. A sample through the unit contained 217 ppm U and 257 ppm Th, with no data for La, only 90 ppm Ce and 30 ppm Y. At depths of 453 to 475 feet in unit 3 in drill hole EMB-1, 3 samples covering the entire radioactive interval contained 80 to 129 ppm U, 62 to 272 ppm Th, 104 to 244 ppm Ce, no data to 242 ppm La and 11 to 25 ppm Y. This is the most lanthanum rich interval in subsurface from this half section. Drill hole EMB-4 also intersected radioactive mineralization at a depth of 34 feet. A 1/2-foot-thick sample contained 402 ppm Th, 29 ppm U, 436 ppm Ce, no data for La and 19 ppm Y, making it the most cerium rich interval in subsurface in this half section (Karlstrom and others, 1981b).

In the NE1/4 sec. 6, highly radioactive zones in units 4 and 5 were encountered in several drill holes. In drill hole EMB-2, these zones weren't sampled; they were located in quartz pebble conglomerate near the base of unit 5, at about depths of 169 to 183 feet, and in unit 4 at depths of 326 to 334 feet. In unit 5 in drill hole EMB-2 just above radioactive zone at 169 feet, an eight foot sample of quartzite contained 96 ppm U, 142 ppm Th, 286 ppm Ce, 409 ppm La, and 42 ppm Y. In drill hole EMB-6, unit 5 contained highly radioactive quartz pebble conglomerates at depths of about 131 to 144 feet, 240 to 242 feet and 293 to 305 feet. Rare earth rich samples were from depths of about 93, 141, 225, 236 to 245, and 295 to 305 feet. These samples contained 29 to 792 ppm U, 47 to 725 ppm Th, 41 to 466 ppm Ce, no data to 495 ppm La and 8 to 75 ppm Y. The rare earth rich zones in drill holes EMB-7 and EMB-8 are difficult to determine because sampling was not comprehensive. Assays commonly exceeded 150 ppm Ce in 37 of 72 samples in EMB-7 ($\geq$200 ppm U in 18 of 72 samples) and 18 of 45 samples in EMB-8 ($\geq$200 ppm U in 14 of 45 samples), with up to 965 ppm Th. Up to 719 ppm Ce, 535 ppm La (with many samples not analyzed for La), and 97 ppm Y are reported in samples from EMB-7, and up to 462 ppm Ce, 645 ppm La and 97 ppm Y are reported in samples from EMB-8. A very thorium rich quartz pebble conglomerate was encountered at a depth of about 284 to 285 feet in drill hole EMB-9. The zone was at least 1-foot thick and contained up to 921 ppm Ce, no data for La, 142 ppm Y, 1143 ppm Th and 545 ppm U. Drill hole EMB-10 also intersected radioactive mineralization, but no rare earth enrichment (Karlstrom and others, 1981b).

In drill holes EMB-6 and EMB-7, average values in unit 5a were 298 and 220 ppm U (271 and 304 ppm Th) over thicknesses of 49 and 88 feet, respectively, while average values in unit 5b were 289 and 171 ppm U (144 and 231 ppm Th) over thicknesses of 132 and 101 feet. No averages for REE were calculated, but these are the data that need to be used to calculate rare earth contents for the Onemile Creek uranium and thorium potential resource defined by Borgman and others (1981). From core descriptions, these must be composite thicknesses of enriched zones rather than a single zone (see Karlstrom and others, 1981b).

FREMONT COUNTY

7. Warm Spring Creek placers
secs. 31, 32, 33 and 34, T.42N., R.108W.

Monazite- and gold-bearing black sands are reported in alluvial material in Warm Spring Creek (Love, personal communication, 1987; Dunnewald, 1958), and possibly in terrace material along this creek (S1/2 secs. 28, 29) and alluvial material in the South Fork of Warm Spring Creek as far upstream as the junction of the South Fork of Cow Creek (secs. 1 and 11, T.41N., R.109W.)(Robertson in Dunnewald, 1958). Results of more recent sampling (#5 and 6) of Quaternary alluvium in section 31 (N1/2NW1/4SW1/4) indicates an even greater extent, with assays of 424 and 1270 ppm eTh, and 1270 and 1951 ppm Zr, with no REE analyses (Hesse, 1982). The locations given were derived from these sources, and the alluvial and terrace deposits as mapped by Keefer (1957). Love (personal communication, 1987) believes the monazite placers are also present downstream along the Wind River. Warm Spring Creek (Dunnewald, 1958).

The alluvial deposits on Warm Springs Creek are from 1/4 to 5/8 of a mile in width and are about 1-2/3 mile long. The highest known terraces are more than 100 feet above above the Creek. In the summer of 1957, the placers were tested by the Little Jim Mining Company using a portable sluice. A small amount of gold was recovered along with monazite-bearing black sands (Dunnewald, 1958). Radiometric assays of six samples from this operation were 1.3 to 2.33 percent $eThO_2$ (WGS files in Wilson, 1960).

HOT SPRINGS COUNTY

8. Grass Creek area
north segment--secs. 8, 9, and 16, T.46N., R.98W.
southern segment--secs. 33, and 34, T.46N., R.98W.
(Houston and Murphy, 1962)

These radioactive black sandstones occur at the top of the lowermost sandstone of the Mesaverde Formation (Cretaceous). They are the largest, high-grade, paleo-beach placer deposits in Wyoming. The heavy mineral fraction contained one and 18 percent monazite and zircon, respectively. A niobium-bearing, radioactive, heavy opaque mineral was also identified. The northern segment of the black sandstone is at least 5,600 feet long and 680 feet wide, and it is up to 16 feet thick with an average thickness of 11 feet. The southern segment is exposed for 1,600 feet and is at least 5 feet thick. This exposure is probably the width of the black sandstone. In 25 samples, the titanium content averaged 16.0 percent TiO_2, with 0.37 to 33.36 percent TiO_2 in the northern segment and 1.40 to 30.52 percent TiO_2 in the southern segment. Uranium content averaged 0.015 percent eU and 0.002 percent cU. The concentrations varied from 0.001 to 0.056 percent eU and less than 0.001 to 0.009 percent cU (Houston and Murphy, 1962). Early reconnaissance analyses of the black sandstones were 0.16 to 0.25 percent vanadium, 0.01 to 0.03 percent cU_3O_8 (0.03 percent eU_3O_8) from 4 samples (Klostermann and Knaak, 1952; Barrett, 1953). Dow and Batty (1961) reported 0.06 to 0.12 percent eTh from six samples.

Four more recent reported analyses (4, 101-103) from the northern segment were 39 to 252 ppm U, 282 to 781 ppm Th and 10,343 to 14,131 ppm Zr, with no REE data. An analysis (108) from the southern segment was 138 ppm U (158 ppm U_3O_8), 1670 ppm Th and 15,229 ppm Zr, with no REE data (Hesse, 1982). Other samples from the northern and southern segments reportedly contained 1374 and 1020 ppm La, respectively (Madsen, 1978). This northern segment sample of Madsen (1978) is the second most lanthanum-rich sample reported for Mesozoic black sandstones in Wyoming (see Table 8).

Drilling on the northern segment reportedly delimited a 3 million ton potential resource that averaged 21.0 percent TiO_2 and 4.8 percent zircon (W.A. Graves personal communication in Hausel, 1990).

SUBLETTE COUNTY

9. Fremont Butte claims
NW1/4 sec. 21, T.32N., R.107W. (Love, 1954b, 1954c)

Iron-stained fractures along the contact of an Archean mica schist and foliated granite contain a radioactive greenish-yellow, non-fluorescent mineral, and a radioactive colorless but greenish-yellow fluorescent mineral. The contact trends about N60°E with a dip of 80°NW. Radioactivity up to about 50 times background occurs along the contact. A sample of mica schist from the most radioactive protion of the contact (Love, 1954c) contained 0.002 percent uranium (0.030% eU) with >0.1 percent (>1000 ppm) <u>each</u> Ce, La and Nd (>3000 ppm total REE). Yet, no rare-earth bearing minerals were reported (Love, 1954b). If confirmed, these rocks contain more neodymium than any other rocks in the State, and might be an economic source of rare earths.

Three other nearby sites are also highly radioactive, but neither one has been analyzed for REE.

A vertical, 1-2 foot wide, N50°W trending, fine-grained granite dike in the Archean granite was located 200 yards southeast of the site sampled on the Fremont Butte claims. This dike was about 30 times more radioactive than background (Love, 1954c). The dike was later mislocated, though radioactivity was reported as 15 times background and a dike sample contained 0.04 percent eU3O8 (Meehan-Papulak, 1954a).

On the John Paul #5 claim in the N1/2SE1/4 sec. 17, T.32N., R.107W. (Love, 1954b, 1954d), an Archean, coarse-grained, brown granite contained an abundant black crystalline mineral. Radioactivity was up to about 30 times background over some 10 foot [square ?] areas (Love, 1954d). A highly radioactive granite sample contained 0.002 percent uranium (0.015 % eU) (Love, 1954b). Two months later on the claim, though mislocated in section 16, a probe hole had been drilled. Maximum radioactivity was less than the maximum surface radioactivity (7 vs. 10 times background) in the hole (Meehan-Papulak, 1954b). Olson and Adams (1962) list a rare earth bearing mineral occurrence with the location of 42°44' N. latitude and 109°36' W. longitude. This is probably a mix-up with the Fremont Butte claims.

Gebhardt and others (1982) report that a sample (# 64) of Precambrian granite from the center of section 17 contained 366 ppm eTh with only 13 ppm cU3O8 (4 ppm eU) and no analyses for REE.

OTHER AND UNVERIFIED LOCALITIES

(exclusive of Precambrian quartz pebble conglomerate, Cambrian placer, Phosphoria Formation, Mesozoic beach placer, and Eocene lacustrine rock localities)

UNKNOWN LOCATION

Eight hundred pounds of samarskite were reportedly shipped to California from an undisclosed location in Wyoming in 1930 (Marzell, 1933). It is possible that this material is misnamed, and could have come from any of several pegmatites that were known at this time. The potential sources include the Platt mine, Richard Riley claims and Many Values prospect. It is also possible that the source of the material was from outside of Wyoming, possibly the Black Hills of South Dakota or from northern Colorado, and that Wyoming was only the shipping point along the railroad.

ALBANY COUNTY

1) Many Values prospect (George-Funk Mica, Muscovite)
W1/2NE1/4SE1/4 sec. 32, T.13N., R.78W.

This tantalum prospect was developed in a poorly-exposed pegmatite in Early Proterozoic schists and gneisses. Mica, beryl and tantalite were produced from the pegmatite; production figures are given in Hanley and others (1950) The location is from Beckwith (1937). Beckwith (1937) estimated that the pegmatite is 600 feet long with a maximum width of 70 feet and an average width of 40 feet. The pegmatite was exposed in shafts and pits for a length of 140 feet, a width of 15 feet, and a depth of 20 feet in 1942. It intruded Precambrian tourmalized mica schist and gneiss, on a N50°E trend with a 85°NW dip (Hanley and others, 1950). Minor tantalite and possibly fergusonite were identified in the pegmatite in 1942 (Hanley, and others, 1950; Beckwith, 1937; see also Hagner, 1942). Because the fergusonite was not positively identified, this is an unverified occurrence.

2) Weddle claims--Middle Lodgepole Creek area
sec. 2, T.15N., R.71W.

On these claims, a euxenite(?)- and beryl-bearing pegmatite cuts the Middle Proterozoic Sherman Granite. The pegmatite is on average 75 feet wide, contains a black radioactive mineral and is as much as 35 times more radioactive than background. Some feldspar and mica were mined intermittently from the pegmatite prior to 1954 (Whalen and Shepard, 1954). In 1978, euxenite was not seen, but a sample of the pegmatite contained 700 ppm La, 50 ppm Nb, 367 ppm cU3O8, but only 70 ppm Y. High radioactivity is reportedly associated with biotite in this pegmatite (Griffin and Warner, 1982). This means this pegmatite is like those near Tie Siding (1.).

3) Sherman granite--Albany area N1/2 T.14N., R.78W.,
SW1/4 T.15N., R.78W. (Dribus and Nanna, 1982; Mussard, 1982; Sanford and Stone, 1914)

Allanite is disseminated in the Middle Proterozoic Sherman Granite and occurs in pegmatites in the granite at many locations in these two townships (Dribus and Nanna, 1982; Mussard, 1982; Sanford and Stone, 1914). The allanite is usually present in trace amounts up to about 0.6 percent by volume (Dribus and Nanna, 1982; Mussard, 1982). One sample of Sherman granite contained 2.8 percent allanite (by volume). Although this sample location was not reported (Mussard, 1982), it was probably from the north half of T.14N., R.78W. from his sample numbering scheme. REE analyses were performed on 17 samples of Sherman Granite. REE concentrations varied from 175 to 328 ppm Ce, 48 to 198 ppm La, <15 to 22 ppm Nb, 4 to 72 ppm Y, 219 to 1117 ppm Zr. The most lanthanum rich sample contained 0.60 percent allanite and was from a site about 5/8 of a mile west of Albany (roughly center N1/2 sec. 15, T.14N., R.78W.). Limited chemical analyses of five other samples from the Sherman Granite in this area indicates low uranium contents (3 to 13 ppm cU3O8) and 22 to 106 ppm eTh (Dribus and Nanna, 1982).

Sanford and Stone (1914) first reported allanite in a pegmatite near Albany Station on the sec. 3-10 line (T.14N., R.78W.). See Elevatorski (1976) for some misinformation.

4) unnamed (sample 6)--Spring Creek area
roughly W1/2SE1/4 T.17N., R.72W.

Geist and others (1989) reported that a sample of granite or supracrustal rock that is older than the Sherman Granite contained 237 ppm La, 280 ppm Nd and 26 ppm Sm, exceeding the locality criteria of this report. The sample was not analyzed for other REE. This sample would seem to indicate that the basement terrain for the Sherman Granite and Laramie Anorthosite Complex (LAC) is enriched in REE and might have contributed to the REE enrichments in the Granite and LAC. Alternatively, sample 6 might really be of a rock related to these large, younger intrusions.

5) unnamed--Laramie Range sec. 2, T.18N., R.72W.

A 4-inch allanite crystal was reported in Precambrian pegmatite at this site, and was described as highly radioactive (Osterwald reference #17 in Wilson, 1960). As located, this site is in the Middle Proterozoic Laramie Anorthosite Complex (Love and Christiansen, 1985), so the location may be in error or the crystal may not have been from a pegmatite. The fact that the site is in the anorthosite complex and the report of allanite in the Red Mountain pluton (2.) means the locality warrants further examination. In addition, the mineral was never positively identified as allanite and therefore might not contain rare earths. Therefore, this is an unverified occurrence.

6) unnamed roughly S1/2 sec. 35, T.14N., R.79W. (Mussard, 1982)

Mussard (1982) reported two samples of the Middle Proterozoic Keystone quartz diorite, taken 1 to 2 miles northwest of the Lake Resort area, contained 0.33 and 0.63 percent allanite (by volume).

7) Mahoney #1 claim center sec. 15, T.27N., R.71W.
(after Seeland, 1982; Segerstrom and Weisner, 1977; Lindlof, 1954)

High radioactivity (up to 25 times background) was found in a 25-foot adit and samples from the adit. The drift apparently follows a fault contact between Precambrian granite and schist. No visible radioactive minerals were noted (Lindlof, 1954; Seeland, 1982). The adit is actually in a shear zone in an Archean granite (Segerstrom and Weisner, 1977). Samples (145-147) of the schist, granite, and fault contact taken in 1979 contained <20, 110 and 250 ppm La, <100, 150 and 360 ppm Ce and 27, 21 and 38 ppm Y, with 1, 9, and 5 ppm U, and <2.5, 294, and 140 ppm Th, respectively (Seeland, 1982).

8) unnamed--Potato Creek area SE corner sec. 12, T.25N., R.73W.
(Houston, written communication, 1989);

This is an unverified occurrence. The border zone of a batholithic (?) Precambrian red granite, possibly the Archean Laramie Batholith, on the north side of the North Laramie River is very radioactive (20 to 50 time background). Two samples contained 75 and 96 ppm U3O8 and 535 to 250 ppm thorium (±25 ppm), while a sample of altered red granite from this border zone contained only 18 ppm U3O8 and 41 ppm thorium. No REE analyses were performed. However, the high phosphate contents on the unaltered samples, 1.52 and 3.55 percent P2O5, implies the uranium and thorium bearing mineral is a phosphate (Houston, written communication, 1989; Karlstrom and others, 1981a,b), and might be brockite or xenotime. As located, the site is just on the north side of and might be related to the shear zone that separates the northern Laramie Mountains Laramie Batholith from the central Laramie Mountains Archean gneiss terrain.

9) unnamed--Upper Sturgeon Creek area
NE1/4SE1/4 sec. 24, T.25N., R.72W. (Graff and others, 1981)

High radioactivity is reported near this creek in sheared granite in an Archean granite-gneiss complex. Three samples taken in the area (105336-8) contained 73 to 110 ppm Ce, 100 to 150 ppm La and 3 to 4 ppm Y, with 67 to 140 ppm thorium and 4.3 to 7.1 ppm uranium (after Graff and others, 1981); this demonstrates minor REE enrichment.

10) unnamed--Lower Sturgeon Creek area
center NE1/4 sec. 7, T.25N., R.71W. (Graff and others, 1981)

High radioactivity is reported near this creek in sheared granite in an Archean granite-gneiss complex. The three samples taken in the area (105339, 105341-2) contained 44 to 290 ppm Ce, 44 to 310 ppm La and 10 to 57 ppm Y, with 63 to 130 ppm Th and 7.6 to 35 ppm U (after Graff and others, 1981); this demonstrates some REE enrichment.

11) unnamed (sample 160287)
center E1/2SW1/4 sec. 8, T.16N., R.79W.

A sample of conglomerate in the Early Proterozoic Medicine Peak Quartzite contained 2000 ppm Y, 1000 ppm V and 500 ppm Zr, with no data for Ce and La, and only 28 ppm U and 46 ppm Th (Karlstrom and others, 1981b). Even a typographical error (200 not 2000) would still make this an occurrence. The sample probably contained 1.0 percent Ti rather than the 1.0 ppm listed. Still, the very high yttrium content is not explicable as a placer unless the amount is 200 ppm Y.

12) Gaps Trondhjemite roughly center S1/2 sec. 8, and NE1/4NW1/4 sec. 17, T.16N., R.79W. (Karlstrom and others, 1981b)

A sample from the Early Proterozoic Gaps Trondhjemite at this site reportedly contained 114 ppm Th and 1 ppm U, with no rare earth enrichment. Uraninite was noted in fractures in the Gaps Trondhjemite and assays of 1000 ppm uranium came from fractured rock. Yttrium enrichment is present in two samples of Gaps granite, one from each section, and a sample of quartz vein in granite in sec. 17; no data are available for Ce and La. One granite sample (sec. 17) was not analyzed for uranium and thorium, but contained 200 ppm Y, 500 ppm Mn, 200 ppm Mo, 700 ppm Pb and 150 ppm V. The other granite sample (sec. 8) contained 150 ppm Y, 300 ppm V, 70 ppm Zr, 8 ppm U and 49 ppm Th. The quartz vein contained 1500 ppm Y, 1500 ppm Cu, 1500 ppm Mn and 500 ppm Pb, with 1 ppm U and 56 ppm Th (Karlstrom and others, 1981a,b) A sheared granite in sec. 8 was 10 times more radioactive than background (Houston and others, 1978). Granite yttrium contents in sec. 17 appear to be related to metals, while that in sec. 8 seems to be the natural Gaps Trondhjemite abundance. The vein analysis is probably explicable as sulfide mineralization, but the very high yttrium content is unusual. It might be a typographical error (150 not 1500). See Lanthier (1978) for geologic details.

BIG HORN COUNTY

13) Rainbow claims
uncertain location, estimated as T.58N., R.92W. unsurveyed

This occurrence has not been verified. Parker (1963) reports euxenite in a pegmatite on these claims in the northern Bighorn Mountains. His location (44°58' N. latitude, 107°53' W. longitude) is just east of Cookstove Basin in sedimentary rocks, so the location and/or occurrence information could be in error. Parker (1963) also mislocated the Many Values property and Platt pegmatite. Therefore, the location given above is that for the Cookstove Basin where Archean granites are exposed. Monazite is reported by Ray E. Harris in pegmatites in Precambrian granitic rocks in the basin, but this has not been verified and Taucher (1953) did not mention or map any pegmatites in the Cookstove Basin.

14) Crooked Creek group claims
secs. 27 and 28, T.58N., R.95W. (Hart, 1955b)

This locality is a peculiar one in that the radioactive mineralization is at least predominantly uranium roll-front mineralization along the Morrison Formation-Cloverly Formation contact (after Hart, 1955b) or in limonite-stained, channel sandstones in the Morrison or Cloverly Formation. Three samples (671-673) of mineralization contained 115, 490 and 105 ppm eU3O8 (140, 530 and 1,200 ppm eU3O8). The sample with the highest chemical uranium also contained 500 ppm Y but only 100 ppm La. All the samples had 40 to 100 ppm

La, 100 ppm Zr, 3000 to 4000 ppm Ti and at least 100 ppm Y. The sample with the highest radiometric uranium was not enriched in rare earths, and no thorium analyses were done (Garrand and others, 1982). The origin of the yttrium enrichment isn't known since roll fronts seldom contain abundant rare earths. The reported value might be just a typographical error (50 not 500). The high titanium values might indicate a local heavy mineral accumulation in addition to the roll front.

15) Shell Creek prospect (Reeves Ranch) sec. 11, T.52N., R.92W. (Reyner, 1950; Osterwald, 1950)

On the Shell Creek prospect, black, silicified bones in the Morrison Formation are highly radioactive (up to 25 to 30 times background). Some of these bones are pyrite bearing. Silicified wood and carbonaceous trash in the area are not radioactive (Reyner, 1950). In this area, a sample (151) of mudstone containing carbonaceous material only assayed 26 ppm cU3O8 (22 ppm eU and 9 ppm eTh), with no REE enrichment. While a sample (152) of pyritic dinosaur bone contained 230 ppm La, 298 ppm Nb, 96,200 ppm P, 1050 ppm Sr, 645 ppm Ti, 307 ppm W, 384 ppm Y and 229 ppm Zr, with 2,660 ppm cU3O8 (2,026 ppm eU) and 1 ppm eTh (Damp and Jennings, 1982). This suite of elements and REE enrichment is probably due to the phosphate content of the bone. Most of the radioactive dinosaur bones are found at the base of a 12-foot-thick lens of gray, medium-grained sandstone. The bones are composed of a black medium-grained, crystalline material. Very little of the internal structure of the bones remains (Osterwald, 1950).

16) Bobcat Gulch--Hyattville area sec. 31, T.49N., R.89W.

Dinosaur bones in alluvium on the property assayed 1,020 ppm cU3O8 (749 ppm U and 2 ppm eTh), with 110 ppm La, 628 ppm Nb, >100,000 ppm P, 5350 ppm Sr, 126 ppm Y and 619 ppm Zr (Damp and Jennings, 1982). The rare earth enrichment is probably due to the phosphatic nature of the bones.

17) North Sheldon Gulch--Shell area sec. 33, T.52N., R.91W.

Radioactive ironstone concretions are present in a light gray, bentonitic shale in the Jurassic Morrison Formation. The concretions contained an estimated 0.01 to 0.05 percent eU3O8 (Hail, 1954). A later analysis of an ironstone concretion gave 487 ppm cU3O8 (387 ppm eU and 4 ppm eTh), 17 percent P2O5, 94 ppm La, 200 ppm Sr, 167 ppm Y and 76 ppm Zr (Damp and Jennings, 1982). The rare earth enrichment is probably due to the phosphatic nature of the concretion.

18) Davis Draw
SW1/4NW1/4 sec. 12, T.54N., R.92W. (Damp and Jennings, 1982)

A sample of carbonaceous, poorly cemented yellow brown to gray sandstone that is associated with an ironstone ledge in the Cloverly Formation contained 168 ppm cU3O8 (157 ppm eU and 4 ppm eTh), 4.98 percent Fe, 10.8 percent P2O5, 82 ppm La, 110 ppm Nb, 883 ppm Sr, 1460 ppm Ti, 180 ppm Y and 88 ppm Zr (Damp and Jennings, 1982). The sandstone is highly phosphatic, which probably results in the high yttrium concentration.

CARBON COUNTY

19) Hurda claims
sec. 7, T.27N., R.77W.; sec. 12 and 13, T.27N., R.78W. (Whalen, 1954c)

Up to 10 times background radioactivity is reported in a carbonaceous shale in the White River Formation. No uranium minerals were visible and five 200 foot deep drill holes did not penetrate ore (Whalen, 1954c). A sample of altered pink silty arkosic sandstone from the Wind River Formation in the center W1/2 of section 7 contained 300 ppm La, 100 ppm Y and 50 ppm Zr, with 52 ppm cU3O8 (Griffin and Milton, 1982). As located, the site is in the White River Formation (Harshman, 1968). The origin of the rare earth enrichment is not known, but the White River Formation in this area, the Shirley Basin, does contain fossil placers at some sites.

20) Blackhall Mountain secs. 2,3 and 11, T.12N., R.83W.

DeNault (1967) reported that a pegmatite on the ridge crest of Blackhall Mountain contained a metamict, rare earth-bearing mineral in two of the four thin-sections that he examined. The ridge crest is actually three crests, and he maps a pegmatite along each ridge. Therefore, the exact location of his discovery is not certain. As mapped the pegmatites are 200 to 800 feet wide and 0.5 to 1.5 milers long. X-ray fluorescence of the mineral showed 1 percent or less <u>each</u> of cerium , lanthanum, praseodymium, neodymium and thorium, leading DeNault (1967) to conclude the mineral might be allanite. The actual abundance of rare earths in the pegmatites is not known, so the site is an unverified occurrence. As located, the pegmatite is within an Early Proterozoic granitic rock that is similar in age to the granitic rocks that intrude the Mullen Creek mafic complex to the east (after Love and Christiansen, 1985).

21) Mullen Creek area roughly T.14N., R.80W.

McCallum and Kluender (1983) reported that a sample of vein material in the Early Proterozoic mafic complex contained 1000 ppm La. The sample as located (center W1/2NW1/4 sec. 11, T.14N., R.80W.) was from a fault in gabbroic rocks (McCallum and Kluender, 1983).

Because younger Early Proterozoic granitic rocks were intruded into the mafic complex (Hills and Houston, 1979), the high lanthanum values might be related to these granitic rocks rather than to the mafic complex. Mussard (1982) reported 1 percent allanite by volume is present in a sample of this younger granitic rock near this site (W1/2SE1/4 sec. 11). Some other samples of this granitic rock in the mafic complex contained 0 to 0.88 percent allanite. Chemical analyses of this granitic rock showed up to 244 ppm La, 475 ppm Ce, 13 ppm Y, 3 ppm Yb and 685 ppm Zr. The chemically most rare earth rich sample contained 0.53 percent allanite, but samples with more allanite were not analyzed. Outside of sec. 11 in the mafic complex, the three richest samples, containing a mineral occurrence or chemically documented rare earth enrichment, are in the SE1/4SE1/4 sec. 34 (T.15N., R.80W.) and two sites in sec. 36 (T.14N., R.80W.) (Mussard, 1982).

22) Hubbell Ditch area center S1/2 sec. 11, T.14N., R.81W.

A sample of Precambrian chlorite schist taken at this site near Mullen Creek contained 500 ppm La. Stream sediment samples taken both up and down stream from this site (center N1/2 sec. 11 and center S1/2 sec. 14) contained at least 150 ppm La (McCallum and Kluender, 1983). From existing geologic maps (Houston and others, 1968), it is difficult to determine if the high lanthanum concentrations are from an Archean quartzofeldspathic gneiss or from the Early Proterozoic Heart Formation, which is chiefly quartzite. The site is also near and possibly related to the Cheyenne Belt shear zone.

23) unnamed (sample 159979) NE1/4NE1/4 sec. 6, T.17N., R.78W.

A sample of quartzite in the Early Proterozoic Vagner Formation contained 150 ppm Y, with no data for Ce and La, and only 25 ppm U and 24 ppm Th (Karlstrom and others, 1981b). The origin of this yttrium enrichment is not known.

Many dikes, pegmatites, and fault, shear and epidotized zones are present in the Archean granitoid rocks in central Wyoming. These rocks are in the Granite, Green, Ferris, Pedro, Shirley and Seminoe Mountains in Carbon, Fremont and Natrona Counties. Many fractured, dike-like and epidotized zones contain uranium and/or thorium mineralization, but only a few have been analyzed for rare earths. Some of the granitoid rocks themselves contain radioactive and rare earth mineralization. Sites with abundant rare earth elements are reported below in this compilation. Since few rare earth analyses have been performed, other rare earth occurrences might be present in the area. For example, Graveson (1965), and Griffin and Milton (1982) report several sites with uranium and/or thorium enrichment, but only mentioned traces of allanite and didn't report quantitative rare earth abundances.

24) Ferris Mountains roughly T.27N., R.88W.; SW1/4 T.27N., R.87W.; N1/2 T.26N., R.87W.; NW1/4 T.26N., R.86W.

Master (1977) reported up to 3 percent allanite as an accessory mineral in Archean granitic rocks in the Ferris Mountains. The abundance of allanite in Archean pegmatites in the Mountains was not mentioned, but would normally be greater than the granites. However, samples from the pegmatites do not contain more lanthanum and yttrium than the enclosing granitic rocks. The highest values of lanthanum and yttrium that Master (1977) found in samples of granitic rock in this area are 200 and 100 ppm, respectively. It would appear that he did not analyze any of the allanite rich samples, or the report of 3 percent allanite is in error. Concentrations of lanthanum and yttrium reported in another study covering a slightly larger area in the Ferris Mountains (Neubert, 1985) do not even approach those reported by Master (1977).

In a short report on the Cherry Creek prospect in SE1/4 sec. 26, T.27N., R.88W., a property that is called the Babbs mine in Master (1977), Wilson (1955) noted that a mineral in the adit that might be allanite is present with copper-bearing minerals.

The relatively low values of lanthanum and yttrium coupled with the lack of higher concentrations of allanite imply that this area is probably not rich in rare earths. However, an examination directed towards finding rare earths, rather than metals, is needed to prove this tentative evaluation.

25) Emigrant Trail thrust and County Line claims
NE1/4 sec. 32, T.28N., R.89W. (Love, 1970; Griffin and Milton, 1982).

Griffin and Milton (1982) reported that a sample of a vein [?] in an Archean granite at this site contained 700 ppm La, 100 ppm Y, 20 ppm Nb and 100 ppm Zr, with 116 ppm Th, and 33 ppm cU3O8 (40 ppm eU). While a sample of granite contained only 100 ppm La, 50 ppm Y and 70 ppm Zr, with 70 ppm cU3O8 (140 ppm eU) and 29 ppm eTh. This may be the same site as locality 24 of Love (1970), since the location is the same. But Love (1970) reports lead, silver and uranium mineralization in nodules in prospect pits in highly fractured Precambrian granite of the Emigrant Trail thrust block where it overrides Triassic rocks. The maximum measured uranium content in the granite was 0.22 percent U3O8 (Love, 1970). Griffin and Milton (1982) concur with the uranium mineralization, but report lead levels of less than 0.01 percent, and they did not analyze for silver.

Whalen (1954) reported up to about 25 times background radioactivity with lead and ruby silver in a biotite schist in the footwall of the fault in secs. 30 and 31 of this township. So the mineralization is not restricted to one area.

26) unnamed, possibly Omega claims
SW1/4SE1/4SE1/4 sec. 17, T.27N., R.83W.

This site is on shattered, biotite-rich zones in an Archean quartz monzonite. A sample (#4) of biotite quartz monzonite contained 700 ppm La and 606 ppm eTh, but only 30 ppm Y, 20 ppm Nb and 50 ppm Zr. No rare earth-bearing minerals have been reported (Griffin and Milton, 1982). On the Omega claims in this section, Holmquist (1955d) reported up to about 30 times background radioactivity on a biotite and quartz-bearing vein in Precambrian granitic rocks.

27) Poe Mountain no. 2 (Rainer no. 1)
roughly center E1/2 sec. 12, T.26N., R.84W.

This claim is on an Archean, epidote-rich dike in quartz monzonite. A sample from the dike contained 500 ppm La and 490 ppm eTh, but only 20 ppm Y, 40 ppm cU3O8 (31 ppm eU) and 70 ppm Zr. No rare earth-bearing minerals were reported (Griffin and Milton, 1982).

28) Pyramid Peak area roughly center T.27-28N. line, R.84W.

The exact location of this sample site is not given by Griffin and Milton (1982). They show the location on their plate 5, but many of the locations on this plate are not accurate. From petrographic examinations, Griffin and Milton (1982) reported a trace of allanite and <5 percent epidote in a sample of Archean granitic rock from the property. The rock was also described as an Archean quartz monzonite. The allanite is probably the reason for the 700 ppm La and 20 ppm Y in one sample (#10), with only 150 ppm La and 10 ppm Y in the other sample (#11). The samples (10 & 11) assayed 100 ppm Zr, 15 and 13 ppm cU3O8 (13 and 17 ppm eU) with 77 and 89 ppm eTh, respectively (Griffin and Milton, 1982). This site is therefore another of the rare earth enriched epidotized zones in the Pedro Mountains and adjacent areas.

The sample site might be on the Canyon claim #1 of Holmquist (1955c) in sec. 34 (T.28N., R.84W.). On this claim, no radioactive minerals were observed, but a sample taken previously, reportedly, contained 0.142 percent U3O8. Radioactivity was up to 90 times background along a vein of greenish quartz in Precambrian granitic rock (Holmquist, 1955c).

29) A #1 claim and Beaver #1 claim NW corner sec. 3
and NE corner sec. 4, T.25N., R.82W., respectively (Holmquist, 1955a,b)

Up to 20 and 30 times background radioactivity, respectively, but no visible uranium minerals were reported in Precambrian granite on these properties (Holmquist, 1955a,b). Samples (246, 247) of an Archean diorite and quartz monzonite that apparently came from one of these properties contained 200 and 300 ppm La, <10 ppm Nb, 100 and 200 ppm Zr, and 10 ppm each Y, with 3 and 9 ppm cU3O8 (2 and 11 ppm eU) and 714 and 807 ppm eTh, respectively. A trace of allanite and apatite were also detected in a thin section of sample 246. This sample was described as magnetite-bearing and the sample description implied it was a pegmatite. A spectrometer reading on the site where sample 246 was taken was 1737 ppm eTh (Griffin and Milton, 1982). The exact location of these sample sites is not known.

30) WL claims area secs. 29, 31 and 32, T.26N., R.82W.

Small black vitreous crystals are reported in a 20 by 60 feet highly radioactive zone (up to 50 times background) in a 100 foot wide, north trending pegmatite that cuts a Precambrian granite(Whalen, 1955). The mineralogy of the crystals is not known.

Seven samples were taken by Griffin and Milton (1982).in this area, but only one was precisely located, and none were taken of pegmatitic material. They all probably contain epidote in various abundances. Samples (242, 124) of Precambrian quartz monzonite from sections 29 (SW1/4; epidote bearing) and probably section 31 contained 17 and 23 ppm cU3O8 (13 and 29 ppm eU), with 31 and 235 ppm eTh, respectively. Samples of epidote bearing Precambrian quartz diorite that probably came from section 32 (sample 244) and section 29 (SE1/4; no. 267) contained 7 and 5 ppm cU3O8 (7 and 6 ppm eU), with 465 and 192 ppm eTh, respectively. Samples of epidote from Precambrian granitoid rocks, probably from section 29 (SE1/4, no. 266; SW1/4, no. 264; and SW1/4, no. 265), contained 42, 35 and 70 ppm cU3O8 (34, 36, 95 ppm eU), with 1490, 1910 and 5110 ppm eTh, respectively. Little data is available on rare earth contents of the epidosites; sample 244 contained 150 ppm La but less than 10 ppm Y. Examination of epidosites by SEM/EDS revealed traces of urano(?)-thorite in each sample (Griffin and Milton, 1982).

31) Jem claims area (sample 30) center sec. 14, T.25N., R.81W.

This sample is of a Precambrian granitoid rock, and is not related to the uranium deposit in karst on this claim. Sample 30 contained 150 ppm La, 20 ppm Y and 100 ppm Zr, with 58 ppm eTh, and 21 ppm cU3O8 (7 ppm eU). The rock sample was called a quartz monzonite, but the mineral percentages given indicate that is is a granite. In addition to major minerals traces of opaques, apatite and zircon are also reported. The granite is reddish near the unconformable contact with younger rocks, but it is not known if this portion of the granite was samples. In the granite, the feldspars were slightly altered and biotite was almost entirely altered to chlorite, iron oxides and calcite (after Griffin and Milton, 1982).

CONVERSE COUNTY

32) Otto Bruns property sec. 29, T.32N., R.75W. (Seeland, 1982)

Two samples of Archean, iron-oxide stained, granitoid rock from this property contained crytolite (uraniferous zircon). Analyses revealed 0.005 and 0.007 percent cU3O8 (0.021 and 0.035 % eU3O8), and 0.08 and 0.09 percent Th (Smith, 1954). No REE analyses are available for this locality, so this is an unverified occurrence. This site is in an Archean gneiss terrain in the northern Laramie Mountains (after Love and Christiansen, 1985).

CROOK COUNTY

33) Mineral Hill (Tinton, Negro Hill) area, Wyoming and South Dakota
In Wyoming, roughly T.51N., R.60W. and N1/2 T.50N., R.60W.

This area encompasses a Tertiary alkalic intrusive complex, with carbonatitic affinities and possibly carbonatites, which was intruded into Precambrian schists and lower Paleozoic sedimentary rocks. The schists contain Precambrian pegmatites that are elongate roughly parallel to the foliation in the schists. Rare earth-bearing minerals have <u>not</u> been reported in the area (Welch, 1974; Smith and Page, 1941), but elevated levels of REE are present in samples that were not taken for evaluating rare earth potential. Ten samples of Precambrian and Tertiary rocks taken in the area were analyzed for REE and niobium, with nine of them also analyzed for elements associated with REE in the Bear Lodge igneous complex. The samples contained 13 to 124 ppm La, 99 to 473 ppm Ce, 10-74 ppm Y, 350 to 1576 ppm Ba, 318 to 2686 ppm F, 12 to 89 ppm Nb, 384 to 1806 ppm Sr, <10 to 148 ppm Ta, 9 to 42 ppm Th, and 1 to 15 ppm U (Gersic and others, 1990; Welch, 1974). Also, four of twenty stream-sediment samples from the area contained elevated levels of rare earths (see Warren, 1980). These data plus the common association of rare earth elements with carbonatites and pegmatites means the area merits further examination for rare earth bearing minerals.

Gold is present in both the Precambrian schist and Tertiary intrusive complex (Norby, 1984; Welch, 1974). Gold values vary from 0.5 to 10s of ppm (Welch, 1974), though Gersic and others (1990) report much lower values. Considering the possible presence of carbonatite, and a gold, columbite and tantalite bearing Precambrian basement, the intrusive complex could contain resources of columbium, tantalum, and gold in addition to rare earths.

FREMONT COUNTY (SEE ALSO SUBLETTE COUNTY)

34) Dubois claims (Uranium Claim no. 1) center sec. 24, T.41N., R.108W.

Gruner and Knox (1957) report the minerals uraninite, allanite and uranophane at the Uranium Claim no. 1 in a granite [?], and give the location. Granger and others (1971) state that these claims are for pitchblende in a quartz-, hematite- and magnetite-cemented breccia zone that cuts Precambrian biotite gneiss and several pegmatites. They do not mention allanite, therefore the presence of allanite has not been confirmed, and this is an unverified occurrence.

Ullmer (1983) describes the mineralization as being in a brittlely deformed zone in an iron-rich (magnetite) pod in a micaceous schist in an Archean gneiss terrain, and that one sample assayed 2.4 percent U3O8.

35) unnamed (Sage Hen)
E1/2 sec. 24-25 line, T.30N., R.90W. (Love, 1970)

Eight samples from 4 large exposures of a thorium-bearing, algal limestone from the Moonstone Formation (Miocene-Pliocene) contained 0.001 to 0.023 percent uranium (0.006 to 0.033 percent eU) and 0.08 to 0.16 percent Th-232. The exposures vary from 3 to 20 feet thick and 60 to 1000 feet in diameter (Love, 1970). This thorium bearing material apparently contains the rare earth-bearing mineral rhabdophane. A sample[s?] of the material contained less than 0.5 percent total rare earth elements, with <1500 ppm Y, <300 ppm Yb and <10 to <500 ppm other REE (Dooley and Hathaway, 1961). However, the cut-offs are so high that they don't mean that the sample wasn't rich in rare earths. The origin of the thorium enrichment is not known.

36) unnamed (sample 23) SE corner sec. 25, T.30N., R.90W.

A sample of an epidosite vein in quartz monzonite contained 150 ppm La, 100 ppm Y, 133 ppm cU3O8 (153 ppm eU) and 37 ppm eTh (Griffin and Milton, 1982). Unlike most epidosites in the region, this one does not have the characteristic thorium enrichment relative to uranium.

37) Gap claims NW1/4 sec. 25, T.28N., R.90W. (Griffin and Milton, 1982)

Two samples of Archean quartz monzonite from the property contained 63 and 47 ppm U3O8 (100 and 62 ppm eU) with 90 ppm eTh each. Sample 17 contained 300 ppm La, 20 ppm Nb, 70 ppm Y and 100 ppm Zr, while sample 18 contained 150 ppm La, 70 ppm Y and 70 ppm Zr (Griffin and Milton, 1982).

This and the following two localities are other examples of the central Wyoming rare earth enriched Archean granitoid rocks like those described in Carbon and Natrona Counties (see also the Mohawk claims and sample 201 locality below).

38) Mohawk claims 2 and 3
SE1/4 sec. 20, T.28N., R.90W. (Holmquist, 1956)

Autunite(?), as streaks and lenses along fracture planes, was present in a fault zone in Archean granite (Holmquist, 1956). A sample from these claims contained greater than 0.10 percent U3O8 (Bromley, 1957). Griffin and Milton (1982) reported a sheared granite contained 237 ppm U while an unsheared granite contained only 14 ppm U. Their sample 19 contained 150 ppm La, 150 ppm Y, 300 ppm Zn and 70 ppm Zr.

In SE1/4SE1/4 sec. 20, Love (1964) reported an analysis of Cody Shale (Cretaceous) located directly below the thrust sheet of Precambrian granite contained 0.010 percent uranium (0.050 percent eU). So the origin of this REE enrichment is not known.

39) unnamed (sample 201)
SE1/4SW1/4 sec. 18, T.28N., R.90W. (Griffin and Milton, 1982)

A sample of Archean quartz monzonite contained a trace of radioactive phosphates similar to monazite, and assayed 300 ppm La, <10 ppm Nb, 10 ppm Y, 100 ppm Zr, 221 ppm eTh and 5 ppm cU3O8 (2 ppm eU) (Griffin and Milton, 1982).

40) unnamed (sample 44) NE1/4 sec. 30, T.28N., R.92W.

A sample of gray carbonaceous shale in the Battle Spring Formation from this site contained 56 ppm cU3O8. Inexplicably this sample also contained 150 ppm La, but with only 20 ppm Y, 1400 ppm Ti and 200 ppm Zr (Griffin and Milton, 1983). Other Battle Spring Formation samples in Sweetwater County are enriched in rare earth elements.

JOHNSON COUNTY

41) Poison Creek (sample 44)
NE1/4SW1/4SW1/4 sec. 36, T.48N., R.83W.

A sample of dinosaur bones from the Jurassic Morrison Formation contained 1360 ppm cU3O8 (962 ppm eU; 0 ppm eTh), 58 ppm La, >100,000 ppm P, 1190 ppm Sr, 729 ppm W, 123 ppm Y, 217 ppm Zn and 822 ppm Zr (Damp and Jennings, 1982). The yttrium enrichment is probably due to the phosphatic nature of the bones.

LARAMIE COUNTY

42) unnamed feldspar deposit
uncertain T.15 and 16N., R.70 and 71W. (JKK)

Allanite is reportedly associated with a feldspar deposit in Precambrian rocks on the east flank of the Laramie Range (Osterwald reference #16 in Wilson, 1960). Feldspar deposits with this general location are present in the Middle Proterozoic Sherman Granite about 25 miles northwest of Cheyenne, and the source of the allanite could be any of them. These deposits include the: 1) Bear pegmatite which contains fluorite (NW1/4 sec. 5, T.15N., R.70W.; Cox, 1944); 2) state lease pegmatite (actually in Albany County; sec. 36, T.16N., R.71W.; Hagner, 1943c); 3) Beaver pegmatite (sec. 26, T.16N., R.70W.; Hagner, 1943b; Clabaugh and others, 1946); 4) unnamed allanite-bearing pegmatite (actually in Albany County in the Laramie Anorthosite Complex; sec. 2, T.18N., R.72W.; Osterwald reference #17 in Wilson, 1960); and most likely 5) the Weddle claims pegmatite {2} that might contain euxenite (sec. 2, T.15N., R.71W.; Whalen and Shepard, 1954). In addition to these specific sites, many pegmatites are located within a few miles of the Bear deposit (Cox, 1944). The setting is similar to the Tie Siding pegmatites in the Sherman Granite in Albany County, so many more pegmatites in this area might contain rare earth mineralization.

NATRONA COUNTY

43) Allie claims (Parlett-Adams)
secs. 12, 13, T.39N., R.88W.; and secs. 7, 18, T.39N., R.87W.

Russell and Devore (1948) reported allanite in and at the margins of pegmatites at the southern end of the Bighorn Mountains. These lenses of granitic pegmatites are generally parallel to the regional northwest-trending foliation in the enclosing Archean gneiss. Twenty-three claims mostly encompass scattered outcrops of pegmatites and pegmatitic float. Due to the scatter of pegmatitic materials, the number and extent of the pegmatites is not certain. Radioactivity of only 2 to 12 times background was reported over the pegmatites. Allanite was reported on the basis of hand specimen and microscopic examinations. The radioactive allanite grains are from 1/4 to 3 inches in length. No estimates on the percentages of allanite in the area were reported, and only geiger counter surveys of radiation were performed (see Russell and Devore, 1948). A newspaper article reported that a sample from the property, that was analyzed in California, contained 0.15 percent U (Rocky Mountains News, December 22, 1948, p. 28).

The mineralogical characteristic reported by Russell and Devore (1948) for their allanite do not conform with those for allanite in Roberts and others (1974). Therefore the presence of rare earth elements in Russell and Devore's

(1948) dark, radioactive mineral is not certain, and this is an unverified occurrence.

These claims need reexamination because the Ramsbottom rare earth prospect (3.) in the central Bighorn Mountains is surrounded by the same gneiss terrain, and the origin of the Ramsbottom mineralization has not been determined and might be related to that on the Allie claims.

44) Clarence Wood lode claims SW1/4 sec. 5, T.29N., R.85W.

These claims are on a moderately radioactive (13 times background), irregular, dike-shaped epidosite (80 % epidote) body in Archean quartz monzonite or granite. A sample (#8) of the dike contained 700 ppm La, 100 ppm Y and 200 ppm Zr, with 93 ppm cU3O8 (114 ppm eU) and 70 ppm eTh. But, no rare earth-bearing minerals were reported (Griffin and Milton, 1982).

This locality is another of the sites of rare earth enrichment in Archean granitoid rocks in Carbon, Fremont and Natrona Counties in central Wyoming.

The following four localities are enigmatic in that they have chemical characteristics of both roll front uranium deposits and fossil placer rare earth mineralization. Both types of mineralization are common in Natrona County.

45) Dyper-Bar-Mac no. 7 claim roughly SW1/4 sec. 35, T.33N., R.82W.

On this claim on the south flank of Oil Mountain, a highly radioactive (probably 25 to 250 times background), 1/2 to 2 foot-thick, black, carbonaceous mudstone lying just above the basal conglomerate of the Cloverly Formation (Lower Cretaceous) contained no uranium minerals, but two radiometric assays were 0.048 and 0.221 percent eU3O8 (Bromley, 1955b). Sabugalite (?) was reported on the number 7 claim by Gruner and others (1956).

A later examiner of what was probably the claim no. 7 reported yellow uranium minerals in all of the sampled units. Samples (#45, 1 & replicate) of the shale contained 486, 967 and 1,099 ppm cU3O8, while samples (#46 & 60) of an overlying sandstone and the underlying basal conglomerate in the Cloverly Formation contained 82.5 and 290 ppm cU3O8, respectively. These samples contained 50 to 150 ppm La, 10 to 50 ppm Y, 1500 to 3000 ppm Ti and 300 to greater than 1000 ppm Zr (Griffin and Milton, 1982).

46) Deacon's Prayer group NW1/4NE1/4 secs. 19, T.32N., R.82W.

An examination failed to discover any uranium minerals, and radioactivity was at most 3-1/2 times background. However, a sample (#2) of limonitic, calcite-cemented sandstone contained 90 ppm cU3O8, 150 ppm La, 70 ppm Y, 3000 ppm Ti and 300 ppm Zr, with no analysis for thorium. This sample was taken from a coarse-grained to conglomeratic, arkosic sandstone in the Wind River Formation, just above it's contact with the Fort Union Formation (Griffin and Milton, 1982). The original report on this property (NE1/4 sec. 19 & W1/2 sec. 20) noted only 6 times background radioactivity and no uranium minerals in a conglomerate and an iron-stained sandstone (Lindlof and Geslin, 1954).

47) U.M.S.I.N.C. Mining Company claim #8
roughly center sec. 1, T.29N., R.83W.

High radioactivity (12 to 120 times background) but no uranium minerals were reported at the contact between the Cretaceous Cloverly Formation and the underlying Jurassic Morrison Formation. The high radioactivity was apparently localized in a black to blue-gray, partially carbonaceous, clayey shale at the top of the Morrison Formation (Guilinger, 1956). Rock samples were taken later from the center of the section on what is probably this claim. Samples (#7 & 6) of altered (pink to orange), roundstone conglomerate from the basal Cloverly Formation and an adjacent shale in the Morrison Formation contained 57, and 560 or 590 ppm cU3O8, respectively. Sample 6 contained 150 ppm La, 70 ppm Y, 5000 ppm Ti and 300 ppm Zr, while sample 7 only contained 100 ppm La, 10 ppm Y, 500 ppm Ti and 50 ppm Zr (Griffin and Milton, 1982).

48) Clarkson Hill area SE1/4SW1/4 sec. 9, T.31N., R.82W.

Rich (1962) reported that some carbonaceous siltstone, shale and sandstone units within the basal, conglomeratic, arkosic sandstone of the Wind River Formation are radioactive in the Clarkson Hill area.

Two samples (#50-51) were taken in this partial section, where carnotite and a yellow-green mineral coated sand grains. Samples of a white, limonite stained, coarse-grained arkosic sandstone, and the underlying carbonaceous shale contained 40.5 and 360 ppm cU3O8, respectively. Sample 51 contained 300 ppm La, 50 ppm Y, 5000 ppm Ti and 200 ppm Zr, while sample 50 only contained 50 ppm La, 10 ppm Y, 1500 ppm Ti and 200 ppm Zr (Griffin and Milton, 1982).

49) unnamed (sample 168) roughly SW1/4 sec. 8, T.30N., R.81W.

This sample of Pleistocene gravels contained 150 ppm La, but only 20 ppm Y, 1500 ppm Ti and 300 ppm Zr (Griffin and Milton, 1982). If this lanthanum enrichment is real rather than an analytical problem, it might indicate that Pleistocene placers are not restricted to the Bates Hole area (5.). The difficulty is that all the analyses for lanthanum of Griffin and Milton (1982) seem to be slightly elevated relative to other NURE analyses.

NIOBRARA COUNTY

50) unnamed (sample 65) SE1/4 sec. 1, T.38N., R.61W. (Santos, 1982)

A composite sample of a moderately radioactive (11 times background), limonite-stained, paleo-slump structure of shale and siltstone from the Pierre Shale contained 700 ppm La, 500 ppm Ce, 0.56 percent P, 5000 ppm Sr, 20 ppm Y, <40 ppm Zr and 0.14 percent Ti, with 192 ppm Th and 13 ppm U. This site was reportedly an airborne radioactivity anomaly (Santos, 1982). The high concentrations of elements with placer affinities in the sample implies the slump structure contains a radioactive heavy mineral(s), but this is an unusual setting for a heavy mineral accumulation.

PARK COUNTY

As a group the following four localities indicate that the Beartooth Plateau Archean gneiss and granite terrain is at least slightly enriched in rare earth elements and warrants further exploration, particularly for pegmatites.

51) unnamed (sample 89)
roughly NW1/4 sec. 7, T.58N., R.105W. unsurveyed

A sample of Archean granitic gneiss and granite from the Beartooth Plateau near Beartooth Falls just off U.S. Highway 212 (44°56'19" N. latitude and 109°36'21" W. longitude) contained 200 ppm La, with only 10 ppm Y, 200 ppm Zr, 1 ppm cU3O8 and no analyses for thorium (Garrand and others, 1982). The lack of enrichment of other elements usually associated with lanthanum means the occurrence is unverified and might be due to a typographical error (i.e. 20 not 200).

52) unnamed (samples 28 and 66)--Long Lake area
roughly sec. 3, T.57N., R.105W.

These samples contain slightly elevated levels of cerium but not of yttrium. Analyses were not done for the other rare earth elements, and other samples analyzed from along the Beartooth Highway (U.S. Highway 212) did not contain nearly a great as cerium enrichment. Sample 28 of the Archean Long Lake granodiorite phase of the larger Long Lake granitoid intrusion contained 395 ppm Ce but only 43 ppm Y. Sample 66 of a late aplite dike in the Long Lake granitoid intrusion contained 382 ppm Ce and only 44 ppm Y (see Wooden and others, 1982).

53) Bald Ridge sec. 25, T.56N., R.104W.

Radioactive allanite and other rare earth-bearing minerals are present in nodules in feldspar in a pegmatite in Archean granitic gneiss at this site (Hart, 1955a; see also Olson and Adams, 1962). In order to be in Precambrian rocks, the location must be in the NW1/4NW1/4 of the section (after Pierce, 1965).

54) Angie claims--Stockade Lake area NE1/4 T.57N., R.105W.

Fay and Hart (1955) state gadolinite (beryllium- and rare earth-bearing mineral) and possibly other rare earth-bearing minerals are present in pegmatites in Archean granitic gneiss southeast of U.S. Highway 12 toward Stockade Lake. Radioactivity was less than 6 times background (Fay and Hart, 1955). Some beryl-bearing pegmatites have also been reported northeast of the Stockade Lake area (Harris, 1959). A location in this area is reported (44°59' N. latitude; 109°28' W. longitude) by Olson and Adams (1962). This is probably a mislocation of the site reported by Fay and Hart (1955).

PLATTE COUNTY

55) Richard Riley claims
SE1/4SW1/4 sec. 29, T.27N., R.70W. (Smith and Garnick, 1953)

Allanite is present as round inclusions associated with biotite in a pegmatite in Archean rocks 14 miles northwest of Wheatland. The pegmatite exposure is about 350 feet long, trends northeasterly and had radioactivity of up to about 200 times background. Two samples of allanite-bearing material contained 0.06 and 0.19 percent cU_3O_8 (0.70 and 0.61 % eU_3O_8) (Smith, 1954). This is probably the locality reported by Wells (1934) in which the allanite contained 14.63 percent Ce_2O_3, 7.34 percent (La and other REE)$_2O_3$, 1.28 percent ThO_2 and 0.2 percent U_3O_8. Wells (1934) noted that the mineral had originally been identified as gadolinite. The amount of allanite in this pegmatite needs to be determined.

SHERIDAN COUNTY

Palmquist (1990) reported an isolated occurrence of a 1.6 x 2.4 x 4.5 centimeter metamict allanite poikiloblast in Archean gneiss in the glaciated high country of the Bighorn Mountains 88 kilometers north of the Horn [Ramsbottom] allanite (see 3.). The general location would be in T.55N., R.87 or 88W. if the distance from the Horn is correct, but this is not high country, glacial deposits are not extensive in this area, and the host rock has been mapped as granitoid (quartz diorite to quartz monzonite) (see Love and Christiansen, 1985). This occurrence is not numbered because the location is uncertain and the amount of allanite was not stated. If verified, this occurrence could indicate rare earth enrichment like that in the nearby Archean Beartooth Plateau gneiss and granite terrain (see Park County).

SUBLETTE COUNTY

56) Wind River Range

Several Precambrian units in the Wind River Range have elevated levels of light REE. The difficulty is that analyses for REE have been reported without exact locations and sample descriptions, and only simplified geologic maps are available. Therefore, the unit sampled is often uncertain. Eight of 57 samples that are reportedly from the Louis Lake batholith, one of 18 samples reportedly from the Bear Ears pluton (Popo Agie batholith; Middle Mountain batholith), and three of 29 samples reportedly from miscellaneous crystalline rocks meet or exceed the locality criteria of this report. These data support the previous concept that the Louis Lake batholith is at least slightly enriched in REE (Condie and Lo, 1971). The lack of overall enrichment in the Bear Ears pluton does not preclude mineralization in the pluton, because Fremont Butte (see 9.) is mapped as being in the Bear Ears pluton and so are 5 rare-earth rich samples that have been reported as being Louis Lake batholith samples. More analyses are needed before anything definitive can be stated. Most of the samples that met or exceeded the locality criteria used in this report are in Sublette County, but samples 37 and LLB 8 are in Fremont County. The reported host units are from Condie and Lo (1971) for samples 37 and 86, and from Stuckless (1989) for the other samples. The mapped host units are from the combination of Stuckless (1989), Stuckless and others (1985), and Love and Christiansen (1985).

Localities

sample no.	location	reported host	mapped host
37	SW1/4 T.31N., R.101W.	Louis Lake	Louis Lake
86	E1/2 T.30-31N. line, R.103W.	Louis Lake	Louis Lake
LLB 8	NW1/4 T.31N., R.101W.	Louis Lake	Louis Lake
PRM 1	SW1/4 T.30N., R.104W.	Louis Lake	Bear Ears
PRM 6	NE1/4 T.29N., R.104W.	Louis Lake	Bear Ears
BW 3	center E line T.35N., R.106-107W. uns.	Louis Lake	Bear Ears
BW 7	center E line T.35N., R.106-107W. uns.	Louis Lake	Bear Ears
BW 22	SE1/4 T.32N., R.104W. uns.	Louis Lake	Bear Ears
BW 15	SW1/4 T.37N., R.108W.	Bear Ears	Bear Ears
BW 14	SW1/4 T.37N., R.108W.	miscellaneous	Bear Ears
BW 48	NE1/4 T.37N., R.107W. uns.	miscellaneous	migmatite
BW 49	NE1/4 T.37N., R.107W. uns.	miscellaneous	migmatite

The table below presents analyses from these 12 samples that met or exceeded locality criteria. Analyses for samples 37 and 86 are from Condie and Lo (1971), analyses for the rest of the samples and the means are from Stuckless (1989). All values are in ppm.

	rare earth element						
sample no.	La	Ce	Nd	Sm	Eu	Gd	Y
occurrence criteria	150	320	130	23	4	19	110
Louis Lake mean	98	190	77	12	2	8	26
37	156	291		22	3		
86	207	376		27	3		
LLB 8	213	410	155	28	3	18	64
PRM 1	171	315	117	16	2	9	27
PRM 6	242	472	194	29	5	17	45
BW 3	168	328	133	20	3	15	48
BW 7	102	243	116	19	5	13	32
BW 22	166	327	139	21	3	16	30
Bear Ears mean	78	144	52	8	1	6	17
BW 15	158	296	121	18	3	14	37
BW 14	174	333	128	19	4	15	30
BW 48	166	321	128	19	5	12	31
BW 49	168	271	97	12	2	6	17

SWEETWATER COUNTY

Two sites in the Great Divide Basin are enigmatic. They are in the area of Tertiary roll front uranium mineralization but have some of the chemical characteristics of rare earth bearing placer mineralization.

57) unnamed (sample 52) roughly NW1/4 sec. 16, T.24N., R.92W.

A sample of sandstone from the Battle Spring Formation in this area contained 300 ppm, La but only 20 ppm Y, 3000 ppm Ti, and 300 ppm Zr. The sample was not analyzed for thorium, but contained 6 ppm cU3O8 (Griffin and Milton, 1982), so the origin of the lanthanum enrichment is not known.

58) unnamed (sample 55) roughly W1/2 sec. 6-7 line, T.24N., R.93W.

A sample of silty shale from the Battle Spring Formation in this area contained 150 ppm La, but only 10 ppm Y, 2000 ppm Ti and 200 ppm Zr. The sample was not analyzed for thorium, but contained 27 ppm cU3O8. A sandstone sample from the same area contained 525 ppm cU3O8 with no rare earth enrichment or indication of placer mineralization. It was not analyzed for thorium (Griffin and Milton, 1982).

TETON COUNTY

Five sites in an Archean granite terrain in the Gros Ventre Wilderness contain elevated levels of rare earths. The origin(s) of these enrichments is no known; all but one (#3124) are associated with metal oxide or sulfide mineralization.

59) unnamed (USGS sample #3103) roughly common corner secs. 28, 29, 32 and 33, T.40N., R.114W. unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that a sample of a small, magnetite-bearing, fault zone in an Archean granite contained 1000 ppm Y, with 20,000 ppm Pb, 20 ppm Au and 1 ppm Ag.

60) unnamed (USGS sample #3124) roughly center sec. 28-33, T.40N., R.114W. unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that a sample of an unmineralized Archean granite or granite gneiss contained 200 ppm Y and 70 ppm La, with 150 ppm V.

61) unnamed (USGS sample #3169) roughly NE1/4 sec. 34, T.40N., R.113W. unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that a sample of a quartz hematite veinlet in an Archean granite contained 1000 ppm Y and 150 ppm La.

62) unnamed (USGS sample #3181) roughly center E1/2 sec. 2, T.39N., R.113W. unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that a sample of a sulfide veinlet in an Archean granite contained 200 ppm La, with 2000 ppm Cr, and 100 ppm Cu and Ni.

63) unnamed (USGS sample #3190) roughly N1/4 sec. 11-12 line, T.39N., R.113W. unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that a sample of a magnetite veinlets in a fault in an Archean granite contained >1000 ppm La, with 500 ppm V.

YELLOWSTONE NATIONAL PARK

64) Yellowstone National Park thermal areas

The only information pertaining to rare earth elements in the Park is from drill cores from holes in the geothermal areas at the Mud Volcano and Upper Firehole River areas, and in the Norris, Upper and Lower Geyser Basins. The mineral bastnaesite was seen lining a few fractures at three depths in core from the Mud Volcano hole. Rare earth-bearing minerals have not been reported in cores from the Upper Firehole River area, and the Norris, Upper and Lower Geyser Basins (Bargar, and Beeson, 1984; Keith and others, 1978a, 1978b; Bargar and Beeson, 1985; Honda and Muffler, 1970; Bargar and Beeson, 1981; Keith and Muffler, 1978; Bargar and Muffler, 1982). Some of the samples from the cores drilled in all these geothermal areas contain high concentrations of rare earth elements. Reported values are up to 1800 ppm Ce, 450 ppm La, 420 ppm Nd and 140 ppm Y. High concentrations of one rare earth element are usually accompanied by high concentrations of others in the same sample. Sample spacings are so wide that it is impossible to tell if there are zones of rare earth enrichment in the cores, or if the high concentrations of rare earths are just local phenomena. (after Beeson and Bargar, 1984; see also Sturchio and others, 1986).

Beeson and Bargar (1984) reported high concentrations of rare earth elements in samples of core from three holes for which in the information on mineralogy and hydrothermal alteration has yet to be published. Examination of core from these three holes might reveal more rare earth minerals and/or a greater abundance of rare earth minerals.

SPECIAL TYPES OF LOCALITIES

PRECAMBRIAN QUARTZ PEBBLE CONGLOMERATES

Rare earth bearing, radioactive, pyritic, quartz-pebble conglomerates are a variety of fluvial paleoplacers that have several special characteristics. These conglomerates are mined for uranium at Blind River, Ontario, with by-product recovery of yttrium, and for gold and uranium on the Witwatersrand, South Africa. They are also special because of the presence of reduced uranium and thorium minerals in these metasedimentary rocks, which is associated with their time bounded nature (Late Archean and Early Proterozoic), the presence of large clasts of what is probably vein quartz, and the anatomizing nature of the fluvial channels. The disposition of the channels is more like that of an alluvial fan than the usual fluvial deposits.

Coffinite, huttonite-thorite, monazite, brannerite and pyrite are present as detrital grains in Archean and Early Proterozoic quartz pebble conglomerates in Canada and Wyoming (Roscoe, 1973; Houston and Karlstrom, 1981). In the present oxidizing atmosphere, pyrite and coffinite quickly oxidize. This suggests that the Precambrian atmosphere was oxygen poor (reducing) during this time. This conjecture is supported by the lack of pyritic and uraniferous placers after about 2.3 billion years ago, when the earth's atmosphere presumably evolved to a more oxidizing medium (Roscoe, 1973).

In Wyoming, two successions of Late Archean and Early Proterozoic metasedimentary rocks have been examined in the the Sierra Madre and Medicine Bow Mountains, north of the Mullen Creek-Nash Fork shear zone (Cheyenne Belt). Two sequences in these successions contain some weakly to strongly radioactive, rare-earth, thorium and uranium bearing, pyritic, quartz-pebble conglomerates. Details of this work are available in Karlstrom and others (1981a,b), and Borgman and others, (1981). See Karlstrom and others (1981a, table 2) for a stratigraphic summary. Figure 3 and Table 5 contain the summaries of the specific localities. Sites of very high thorium concentrations are included on this Figure and Table because rare earth enrichment is usually found with high thorium concentrations in placers.

The lower succession in Wyoming, the Late Archean Phantom Lake Suite, is subdivided into a lower, dominantly metavolcanic sequence and an upper, dominantly micaceous quartzitic sequence. These sequences are separated by an unconformity which is overlain by radioactive, rare earth bearing conglomerates. This conglomerate is the Deep Gulch conglomerate in the Sierra Madre and the Rock Mountain conglomerate in the Medicine Bow Mountains. In the overlying quartzitic sequence, two correlative units also contain radioactive, rare earth bearing conglomerates. They are known as the Jack Creek Quartzite in the Sierra Madre and Bow River Quartzite in the Medicine Bow Mountains. The Jack Creek Quartzite and the Deep Gulch conglomerate, which is the basal portion of the Jack Creek Quartzite, are the most radioactive units in the Sierra Madre, and are thorium-rich. Though of local extent, the most radioactive and continuous beds in the Sierra Madre are in the Deep Gulch conglomerate in the northwestern Sierra Madre (Houston and Karlstrom, 1981).

The upper succession, the Early Proterozoic Deep Lake Group, unconformably overlies the Phantom Lake Metamorphic Suite. The basal formation of the Deep Lake Group is the Magnolia Formation, which contains radioactive, rare earth bearing, arkosic quartz-pebble conglomerates. This Formation is the most radioactive unit in the Medicine Bow Mountains, as well as the Sierra Madre, and is uranium-rich. Most radioactive beds of rare-earth bearing conglomerate in the Phantom Lake Suite are of local extent, the exception being the beds in the Magnolia Formation in the northeastern Medicine Bow Mountains. Within the Deep Lake Group in the Medicine Bow Mountains, the Lindsey quartzite also contains radioactive and rare earth mineralization (Houston and Karlstrom, 1981).

Widely-spaced drilling of the quartz-pebble conglomerates has identified a small aggregate potential resource of uranium and thorium in the Onemile Creek area in the Magnolia Formation in the northeastern Medicine Bow Mountains. However, the limited rare earth data available for this potential resource area have yet to be merged with the assessment of uranium and thorium resources. Approximately 3,860 tons of U3O8 with a cut-off grade of 100 ppm (0.01 percent) U3O8, and 8,350 tons of ThO2 with a cut-off grade of

Figure 3. Index map of rare earth and yttrium bearing Precambrian quartz-pebble conglomerates in Wyoming. Numbers by each locality indicate the corresponding number on Table 5 and the numbered description of that locality in the text.

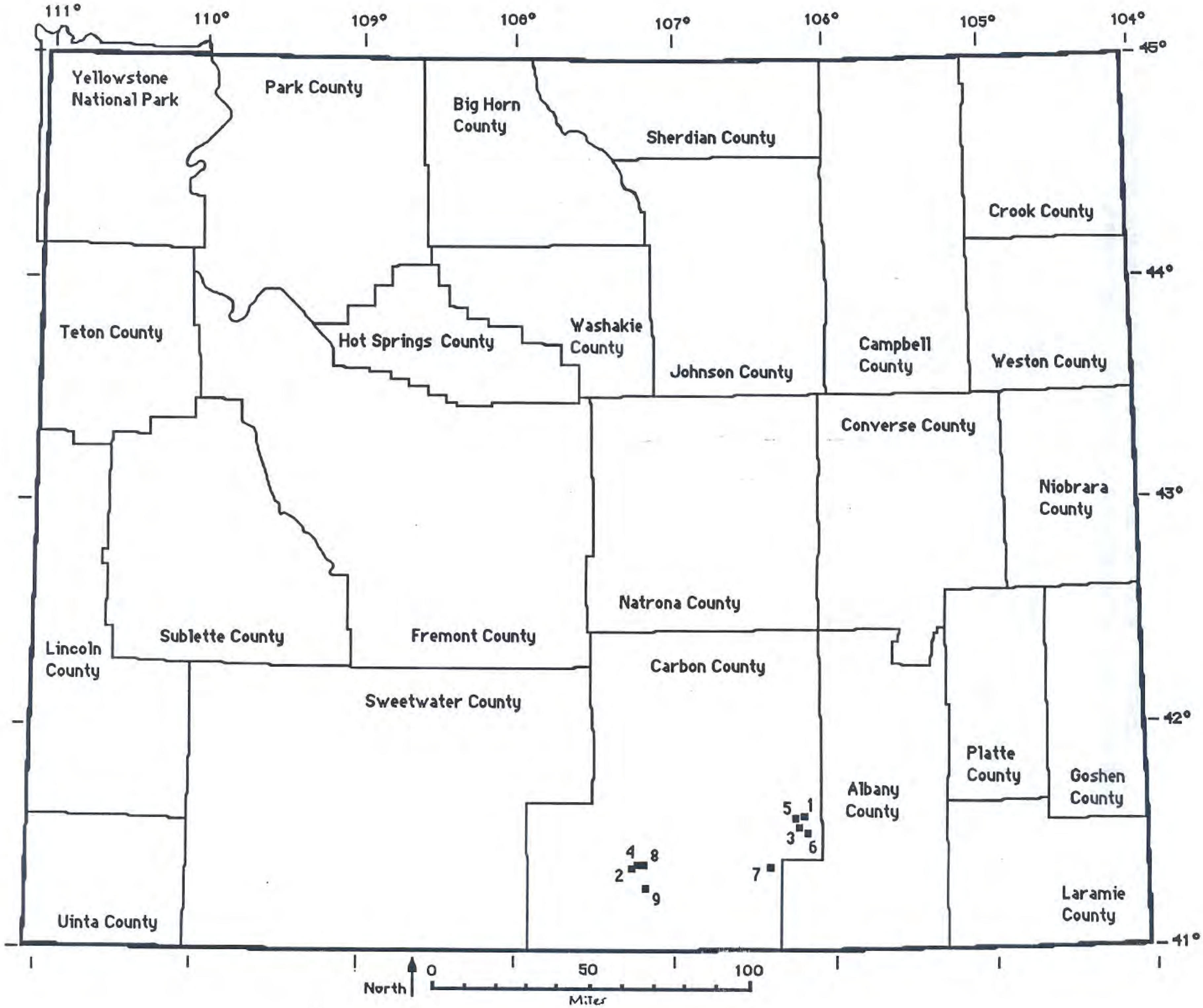

111°
110°
109°
108°
107°
106°
105°
104°
45°
44°
43°
42°
41°
Yellowstone National Park
Park County
Big Horn County
Sherdian County
Crook County
Teton County
Hot Springs County
Washakie County
Johnson County
Campbell County
Weston County
Converse County
Niobrara County
Natrona County
Lincoln County
Sublette County
Fremont County
Carbon County
Sweetwater County
Platte County
Goshen County
Albany County
Laramie County
Uinta County
1
2
3
4
5
6
7
8
9
North
0
50
100
Miles

Fig 3

Table 5. Locations of occurrences of rare earth-bearing minerals and sites of rare earth enrichment in Precambrian quartz-pebble conglomerates.

No.*	Name	Location	Comments
Confirmed mineral occurrences (Karlstrom and others, 1981b)			
1	Onemile Creek	sec. 6,7, T18N, R78W Magnolia Formation	uranothorite and possibly brannerite; up to 685 ppm La, 3952 ppm Ce, 137 ppm Y; 465 ppm Th
2	Carrico Ranch	sec. 12, T15N, R88W Deep Gulch conglomerate	monazite and possibly huttonite; up to 223 ppm La, 185 ppm Ce, 150 ppm Y; 2596 ppm Th
Sites of rare earth enrichment (Karlstrom and others, 1981b)			
3	Rock Creek	sec. 19, T18N, R78W Magnolia Formation	up to 905 ppm La, 610 ppm Ce, 45 ppm Y; 344 ppm Th
4	Deep Gulch	sec. 36, T16N, R88W; sec. 30, T16N, R87W Deep Gulch conglomerate	up to 241 ppm La, 195 ppm Ce, 110 ppm Y; 844 ppm Th
5	Rock Mountain	secs. 2, 11, T18N, R79W Rock Mountain Conglomerate	up to 150 ppm La, 396 ppm Ce 55 ppm Y; 86 ppm Th
6	Cooper Creek	sec. 33, T18N, R78W Magnolia Formation	up to 150 ppm Y; 485 ppm Th
7	unnamed	sec. 15, T16N, R80W Lindsey Quartzite	no data La, Ce, 150 ppm Y; no data Th
Sites of very high thorium concentrations (>30 times crustal abundance) (Karlstrom and others, 1981b)			
8	Manning Ranch	secs. 29, 30, T16N, R87W Deep Gulch conglomerate	up to 653 ppm Th; <required ppm for any REE
9	Dexter Peak	secs. 21, 28, T15N, R87W Jack Creek Quartzite	up to 667 ppm Th; <required ppm for any REE

100 ppm ThO2 have been delimited (see Borgman and others, 1981 for details). A smaller, higher-grade (300 ppm cut-off) potential resource is defined under this significant occurrence at Onemile Creek (see 6.).

Gold concentrations reported in the fossil placers are somewhat encouraging, even though only 77 of the 314 samples analyzed for gold contained detectable gold. These 77 samples assayed on average 0.37 ppm gold and varied from 0.01 ppm to 10.0 ppm gold (Houston and Karlstrom, 1981, p. 180-181).

Rare earth concentrations in samples taken for the uranium and thorium assessment of these placers are not very high except in a few cases. In the Sierra Madre, samples contained up to 241 ppm La and 150 ppm Y, with at least 249 ppm Ce, and possibly as much as 1000 ppm Ce in a sample that was not analyzed for other rare earths, zircon or titanium. In the Medicine Bow Mountains, samples contained up to 905 ppm La, 137 ppm Y, 3952 ppm Ce and 757 ppm Nb, with no lanthanum analysis for the cerium, niobium and yttrium-rich sample (after Karlstrom and others, 1981b). Obviously the available rare earth data needs to be incorporated into potential resource figures for uranium and thorium.

5-1) Onemile Creek area **see significant occurrence 6.**

5-2) Carrico Ranch roughly E1/2 sec. 12, T.15N., R.88W.; and SW1/4 sec. 6 and NW1/4 sec. 7, T.15N., R.87W. (Karlstrom and others, 1981b)

On the Carrico Ranch, radioactive, 1.8 to 3.2 foot thick, quartz-pebble conglomerates in unit 3 of the Archean Deep Gulch conglomerate, in the basal Jack Creek Quartzite, are traceable for about 2 km in. The units are overturned. Radioactive minerals are thorium-rich and include thorian monazite and possibly huttonite, with a minor contribution from zircon. Pyrite is the most abundant heavy mineral. In section 12, surface samples contained as much as 151 ppm Ce with no data for La, 24 ppm Y and 524 ppm Th. Surface samples in secs. 6 and 7 did not meet REE locality criteria (320 ppm Ce, 150 ppm La, 110 ppm Y, etc.) and contained up to only 245 and 224 ppm Th, respectively. None of the samples contained even 50 ppm U. Other samples of other conglomerates in the Deep Gulch conglomerate contained up to 208 ppm La, 181 ppm Ce, 150 ppm Y, with 1129 ppm Th and 72 ppm U. The sample with the most yttrium was not analyzed for other rare earths (Karlstrom and others, 1981b; Houston written communication, 1989).

In drill hole SM-2, the thickest, and most uranium and thorium rich zone in the Sierra Madre was encountered in a quartz pebble conglomerate in unit 3 at a depth of 163 to 180 feet. Samples from this zone contained up to 2596 ppm Th, 718 ppm U, 223 ppm La, 185 ppm Ce, 122 ppm Y, 78 ppm Nb, and 2133 ppm Zr. Two other drill holes (SM-1, SM-1A) encountered zones with up to 167 ppm La, 77 and 65 ppm Y, 133 and 121 ppm Ce, with 546 and 960 ppm Th, and 209 and 269 ppm U, respectively. Drill holes SM-3 and SM-2D also encountered thorium mineralization, but analyses for any single rare earth were less than locality criteria (Karlstrom and others, 1981b).

5-3) Rock Creek (Threemile Creek) area NW1/4 and W1/2SW1/4 sec. 19, T.18N., R.78W. (Karlstrom and others, 1981b)

In this area, a quartz-pebble conglomerate in the upper granular quartzite unit of the Early Proterozoic Magnolia Formation is strongly radioactive (up to 20 times background). Surface samples contained up to 122 ppm U and 130 ppm Th. The most uranium rich sample contained 70 ppm Y and was not analyzed for Ce and La. Other samples contained no rare earth enrichment, but few were analyzed for rare earths other than yttrium. Therefore, no surface samples met REE locality criteria (320 ppm Ce, 150 ppm La, 110 ppm Y, etc.). Drill holes (EMB-5 and EMB-11) encountered the target conglomerates and samples taken contained up to 365 ppm U, 344 ppm Th, 905 ppm La, 610 ppm Ce and 45 ppm Y in EMB-11, with the most thorium and rare earths at depths of greater than 703 feet. The target conglomerates in EMB-5 contained no rare earth enrichment. The conglomerate is apparently continuous down dip from the surface outcrop for at least 300 meters (Karlstrom and others, 1981b).

5-4) Deep Gulch sec. 36, T.16N., R.88W. and SW1/4 sec. 30, T.16N., R.87W. (Karlstrom and others, 1981b)

At Deep Gulch, the radioactive Archean Deep Gulch conglomerate of the basal Jack Creek Quartzite is traceable for about 1.5 km and is overturned. Surface samples in unit 3 contain as much as 206 ppm U and 844 ppm Th, both from a single sample of quartz pebble conglomerate. The most uranium-rich sample with a measurable thickness contained 56 ppm U with 154 ppm Th for a 0.5 foot thick quartz pebble conglomerate. All other surface samples contained less than 50 ppm uranium. No conglomerate that was at least 1 foot thick contained even 100 ppm Th, but 0.2 and 0.3 foot-thick quartz pebble conglomerates contained 214 and 261 ppm Th. None of the surface samples from this area met rare earth locality criteria (150 ppm La, 320 ppm Ce, 110 ppm Y, etc.), but few samples were analyzed for lanthanum (Karlstrom and others, 1981b; see also Houston and others, 1978; Graff and Houston, 1977).

In drill holes (JP-1, JP-2), the richest rock was a 0.4 foot thick quartz pebble conglomerate in unit 3 at a depth of about 411 feet in hole JP-1. It contained 494 ppm U, 483 ppm Th and 2.5 ppm Au, but no REE enrichment. Sporadic radioactive horizons were also encountered in units 1 through 3 in both drill holes; the highest values were from different intervals, and contained up to 107 ppm U, 337 ppm Th, 241 ppm La, at least 192 ppm and possibly 1000 ppm Ce, and up to 110 ppm Y (Karlstrom and others, 1981b).

In this area, in addition to the aforementioned surface samples, an arkosic granule conglomerate in the Phantom Lake Group (undivided) contained 100 ppm Y, with no data for La and Ce, 393 ppm Th and 11 ppm U (Karlstrom and others, 1981b). This does not constitute a rare earth locality, but it might if analyzed for lanthanum and/or cerium. Note that this is one of the few sites of high radioactivity in the Phantom Lake Group undivided in the Sierra Madre.

5-5) Rock Mountain area
surface--S1/2 sec. 2,T.18N., R.79W.
subsurface--NE1/4NE1/4 sec. 11, T.18N., R.79W.
(Karlstrom and others, 1981b)

In this area, two of 18 surface samples of the Archean Rock Mountain Conglomerate contained 91 and 270 ppm U, with 95 and 57 ppm Th, but none met REE locality criteria (150 ppm La, 320 ppm Ce, 110 ppm Y, etc.). Only a single sample of coarse grained quartzite that only contained 14 ppm U and 4 ppm Th did meet REE criteria; it contained 396 ppm Ce, 30 ppm La and 11 ppm Y. The drill hole (MB-10) in the surface area failed to intersect any rocks with above normal radioactivity. A sample of arkosic paraconglomerate in the Rock Mountain Conglomerate at a depth of 523 feet in the subsurface area (drill hole MB-15) contained 190 ppm U, 86 ppm Th, 150 ppm La, 127 ppm Ce, 55 ppm Y, and 327 ppm Zr. These radioactive zones are quite lenticular and thin (Karlstrom and others, 1981b). This subsurface sample was the only subsurface sample in the area with rare earth enrichment.

5-6) Cooper Creek area roughly center S1/2 and SE1/4 sec. 33, T.18N., R.78W. (Karlstrom and others, 1981b)

Surface radioactivity was only about 5 to 6 times background on the Early Proterozoic Magnolia Formation in this area. Three surface samples of quartz pebble conglomerate contained 34, 320 and 485 ppm Th, with at most 13 ppm U. The sample containing the most thorium also contained 150 ppm Y with no data on Ce or La. This is the only documented rare earth enrichment in the area. In drill hole MB-4, at most 14 ppm U and 30 ppm Th were encountered, and these were from the Lindsey Quartzite and Bow River Quartzite, respectively. No rare earth enrichment was encountered in this drill hole (Karlstrom and others, 1981b).

5-7) unnamed (sample 160402) NE1/4NE1/4 sec. 15, T.16N., R.80W.

This sample of quartz pebble conglomerate in the Lindsey Quartzite contained 150 ppm Y with no data for Ce, La and Th, and only 2 ppm U (Karlstrom and others, 1981b).

5-8) Manning Ranch NW1/4 sec. 29 and NE1/4 sec. 30, T.16N., R.87W. (Karlstrom and others, 1981b)

On the Manning Ranch, a radioactive, quartz-pebble conglomerate in unit 3 of the Deep Gulch conglomerate of the basal Jack Creek Quartzite is traceable for about 1.5 km and is overturned. Samples contained as much as 21 ppm U and 406 ppm Th, but always less than the concentrations needed so the site can be called a rare earth locality (150 ppm La, 320 ppm Ce, 110 ppm Y, etc.). The thickest conglomerate that contained >100 ppm Th, is 1 foot thick and contains 293 ppm Th. Drill hole (JP-4) samples containing 14 to 48 ppm U and 223 to 653 ppm Th came from quartz pebble conglomerates in this same unit, at a depth of 284 to 293 feet. Rare earth element contents in samples from this drill hole were always less than locality criteria. A single thorium-rich sample in this interval came from an arkosic granule conglomerate (Karlstrom and others, 1981b). This site is an unverified rare earth locality, because rare earth enrichment is usually found with high thorium concentrations in placers, and sampling for rare earths rather than radioactive elements might reveal rare earth enrichment.

5-9) Dexter Peak roughly SW1/4SE1/4 sec. 21 and center N1/2 sec. 28, T.15N., R.87W. (Karlstrom and others, 1981b)

The upper portion of the Jack Creek Quartzite (Archean) contains outcrops of strongly radioactive, quartz-pebble conglomerate near the top of the Peak. The section is overturned. Samples from these outcrops assayed 3 to 131 ppm U, with 16 to 664 ppm Th. All the analyses for rare earths show REE concentrations of less than locality criteria (150 ppm La, 320 ppm Ce, 110 ppm Y, etc.). However, not all the samples were analyzed for cerium and lanthanum. Despite the high surface uranium and thorium values, two drill holes (SM-4A and B) spotted to the south along strike only yielded samples that contained at most 8 ppm U and 66 ppm Th, with no rare earth enrichment. A surface sample of quartz pebble conglomerate in the Jack Creek Quartzite to the south and east contained 77 ppm U and 377 ppm Th, while most surface samples of conglomerate from the same formation along strike with Dexter Peak contained <10 ppm U, with up to 667 ppm Th. None of these samples met REE locality criteria (Houston and Karlstrom, 1981b; Houston written communication, 1989; Houston and others, 1978; see also Graff and Houston, 1977). This site is an unverified rare earth occurrence because rare earth enrichment is usually found with high thorium concentrations in placers, and sampling for rare earths rather than radioactive elements might reveal rare earth enrichment.

CAMBRIAN PLACERS

Rare earth-, gold- and thorium-bearing fossil placers, that are probably fluvial in origin, have been found in the Cambrian Flathead Formation in the northern Bighorn Mountains (Bald Mountain), central Bighorn Mountains, northwestern Wyoming near Cody, on the northern flank of the Wind River Mountains and in central Wyoming near Pathfinder Reservoir, and in the equivalent Deadwood Formation in the Black Hills (see Figure 4 and Table 6). Sites of very high thorium concentrations are included on this Figure and Table because rare earth enrichment is usually found with high thorium concentrations in placers. Radiometric indications of Cambrian fossil placers have been found as far south as the Rawlins uplift. The existence of the Bald Mountain prospect (2.) indicates that these fossil placers are important potential sources of gold, rare earths and titanium.

The most radioactive of these exposed placers have probably been discovered. But the fact that most of the occurrences listed in Table 6 were not found until the late 1970s, during the last phase of NURE exploration, implies that undiscovered exposed rare earth bearing fossil placers in Cambrian rocks are probably present in Wyoming. Other such placers are probably present in the shallow subsurface.

These fluvial placers formed as accumulations of heavy, chemically resistant minerals in stream channels. If grain sizes are equal, grains of light minerals are more easily transported by stream flow, while the heavy mineral grains can accumulate in the same stream flow. Heavy minerals are often deposited where stream flows decrease slightly, such as on the inner bends of channels. These heavy mineral grains are smaller than the associated stream deposits.

In Wyoming, rare earth bearing minerals in Cambrian fluvial placers include: monazite, zircon, and xenotime. Non-radioactive heavy minerals found in Wyoming include magnetite, ilmenite, garnet, and native gold.

The information in Table 6 and Figure 4 is from Griffin and Milton (1982), Malan (1972), Garrand and others (1982), Damp and Jennings (1982), Gersic and others (1990), Gebhardt and others (1982), and Damp and Brown, 1982).

Figure 4. Index map of rare earth and yttrium bearing Cambrian placers in Wyoming. Numbers by each locality indicate the corresponding number on Table 6 and the numbered description of that locality in the text.

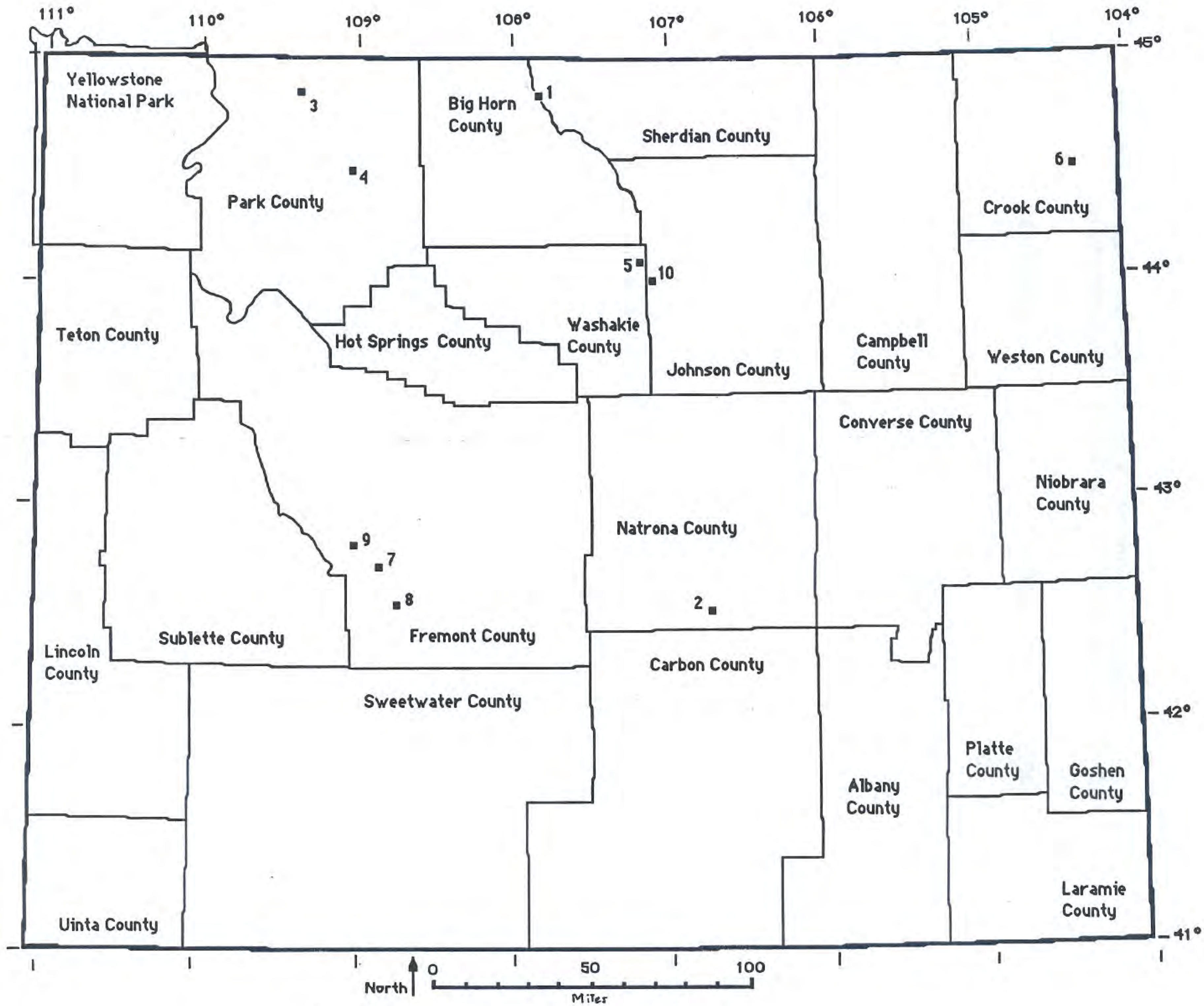

111°
110°
109°
108°
107°
106°
105°
104°
45°
44°
43°
42°
41°
Yellowstone National Park
Park County
Big Horn County
Sherdian County
Crook County
Teton County
Hot Springs County
Washakie County
Johnson County
Campbell County
Weston County
Converse County
Niobrara County
Natrona County
Lincoln County
Sublette County
Fremont County
Carbon County
Sweetwater County
Platte County
Goshen County
Albany County
Laramie County
Uinta County
1
2
3
4
5
6
7
8
9
10
North
0
50
100
Miles

Fig 4

Table 6. Locations of occurrences of rare earth-bearing minerals and sites of rare earth enrichment in Flathead sandstones and conglomerates.

No.*	Name	Location	Comments
PROSPECT			
1	Bald Mountain	secs. 21,22,23,27,28,30,31, T56N, R91W	monazite see prospects
Confirmed mineral occurrence			
2	Little Basin	sec. 21,22,27, T29N, R83W	monazite, xenotime up to 10,300 ppm eTh
Sites of rare earth enrichment			
3	Dilworth Bench	roughly sec. 8, T56N, R104W unsurveyed	1000 ppm La; no data Th
4	Shoshone Canyon	sec. 6, T52N, R102W	150 ppm La,2 ppm Au;no data Th
5	Prospect Creek	sec. 26, T48N, R86W	215 ppm La, 366 ppm eTh
6	Bear Lodge Mountains	sec. 33, T52N, R63W	174 ppm La, 344 ppm Ce, 108 ppm Th
Sites of very high thorium concentration (>30 times crustal abundance)			
7	unnamed	sec. 22,23, T32N, R101W	446 ppm eTh
8	unnamed	sec. 29, T30N, R99W	312 ppm eTh
9	unnamed	sec. 24, T2S, R3W	366 ppm Th
10	unnamed	sec. 18, T47N, R85W	324 ppm eTh; only <100 ppm La, <40 ppm Y

6-1) Bald Mountains area, **see prospect 2.**

6-2) Little Basin area sec. 21, SW1/4SW1/4 sec. 22, NW1/4NW1/4NW1/4 sec. 27, T.29N., R.83W.

In this area, high thorium concentrations (783-10,300 ppm eTh) are reported in samples of sandstone and pebble conglomerates in the Flathead Formation in secs. 22 and 27 (samples 226-228). The thorium was reportedly in a paleo-beach placer, and heavy mineral analyses revealed monazite, zircon and xenotime. A SEM/EDS analysis on the monazite detected possible thorite inclusions. Spectrometer data at four sites were 73 to 6882 ppm eTh (Griffin and Milton, 1982). Lower thorium contents (194 & 273 ppm Th) are reported in sec. 21 (Malan, 1972), and might be indicative of an extension of the mineralization. The amount of rare earths at these sites should be determined because fluvial paleoplacers in the Flathead Formation at Bald Mountain contain abundant rare earths, and they were once considered to be beach paleoplacers.

6-3) Dilworth Bench roughly sec. 8, T.56N., R.104W. unsurveyed

Garrand and others (1982) reported that a sample (#76) of Flathead Sandstone obtained along Barrus Creek on the Dilworth Bench contained 1000 ppm La, 3000 ppm Ti, but only 40 ppm Y, 200 ppm Zr and 4 ppm cU3O8. They did not have the sample analyzed for thorium. This site might be a paleoplacer in the Middle Cambrian basal Flathead Formation. Alternatively, the locality is just a typographical error (100 not 1000).

6-4) Shoshone Canyon roughly center sec. 6, T.52N., R.102W.

A sample (227) of basal Flathead Formation on an area of 3 times background radioactivity along U.S. Highway 14/20 was not analyzed for thorium and only contained 5 ppm cU3O8. The sample is probably from a paleoplacer because it contained 10,000 ppm Ti, 300 ppm W, 150 ppm La, 2 ppm Au, 30 ppm Y and 700 ppm Zr (Garrand and others, 1982). At least four other sites in the basal Flathead Formation north of Shoshone Canyon (secs. 5 and 8, T.55N., R.104W.; sec. 31,T.56N., R.104W.; secs. 6 and 7, T.56N., R.103W.; secs. 16 and 21, T.57N., R.103W.) have above background radioactivity with and without uranium mineralization. These other sites might also be locations of paleoplacers, since none of them were ever assayed for thorium let alone rare earths.

6-5) Prospect Creek area E1/2SW1/4NW1/4 sec. 26, T.48N., R.86W.

Damp and Jennings (1982) report high thorium concentrations in a paleoplacer in a conglomerate in the Flathead Formation at this site. A chemical analysis of the conglomerate (sample 47) revealed 215 ppm La, 40 ppm Y, 11,100 ppm Ti and 1650 ppm Zr, with 366 ppm eTh, and 21 ppm cU3O8 (18 ppm eU) (Damp and Jennings, 1982). Norton reference #64 in Wilson (1960) reported anomalous radioactivity in the Flathead Formation in section 26 that may or may not be the same site as that of Damp and Jennings (1982). This area warrants further examination because of its similarity to the rich rare earth paleoplacers in the Flathead Formation on Bald Mountain.

6-6) southern Bear Lodge Mountains center E1/2E1/2 sec. 33, T.52N., R.63W. (Gersic and others, 1990)

A not obviously mineralized sample (#55) of a xenolith of Deadwood Formation conglomerate in the southern Bear Lodge Mountains alkaline igneous complex contains elevated levels of rare earths. This sample also contained elevated levels of a suite of other elements that are indicative of a placer origin, rather than being related to the mineralization in the igneous complex. The sample contained 108 ppm Th, 3 ppm U, 174 ppm La, 344 ppm Ce, 1.01 % Ti and 590 ppm Zr, with only 498 ppm Ba, 205 ppm F, 23 ppm Nb, 82 ppm Sr and 20 ppm Y (after Gersic and others, 1990). This locality is the furthest east of any known rare earth bearing Cambrian placer in Wyoming. Similar placers in the Black Hills of South Dakota contain gold.

6-7) unnamed NW1/4SE1/4 sec. 22 and NW1/4 SE1/4 sec. 23, T.32N., R.101W. (Gebhardt and others, 1982)

Samples of Flathead Formation sandstone at these two sites contained traces of monazite and slightly more zircon (sec. 22), and assayed 446 ppm eTh (23 ppm cU3O8 and 21 ppm eU) (sec. 23), respectively (Gebhardt and others, 1982). No analyses were done for rare earths, zircon or titanium, but this is probably a paleoplacer. This site is an unverified rare earth locality because rare earth enrichment is usually found with high thorium concentrations in placers.

6-8) unnamed SW1/4 sec. 29, T.30N., R.99W. (Gebhardt and others, 1982)

A sample of Flathead Formation sandstone taken at this locality assayed 312 ppm eTh (20 ppm cU3O8; 17 ppm eU) (Gebhardt and others, 1982). No analyses were done for rare earths, zircon or titanium, but this is probably a paleoplacer. This site is an unverified rare earth locality because rare earth enrichment is usually found with high thorium concentrations in placers.

6-9) unnamed sec. 24, T.2S., R.3W. (WRM) (Malan, 1972)

At this site, a sample of conglomerate from the Flathead Formation contained 366 ppm Th and 11 ppm U (Malan, 1972). No analyses were done for rare earths, zircon or titanium, but this is probably a paleoplacer. This site is an unverified rare earth locality because rare earth enrichment is usually found with high thorium concentrations in placers.

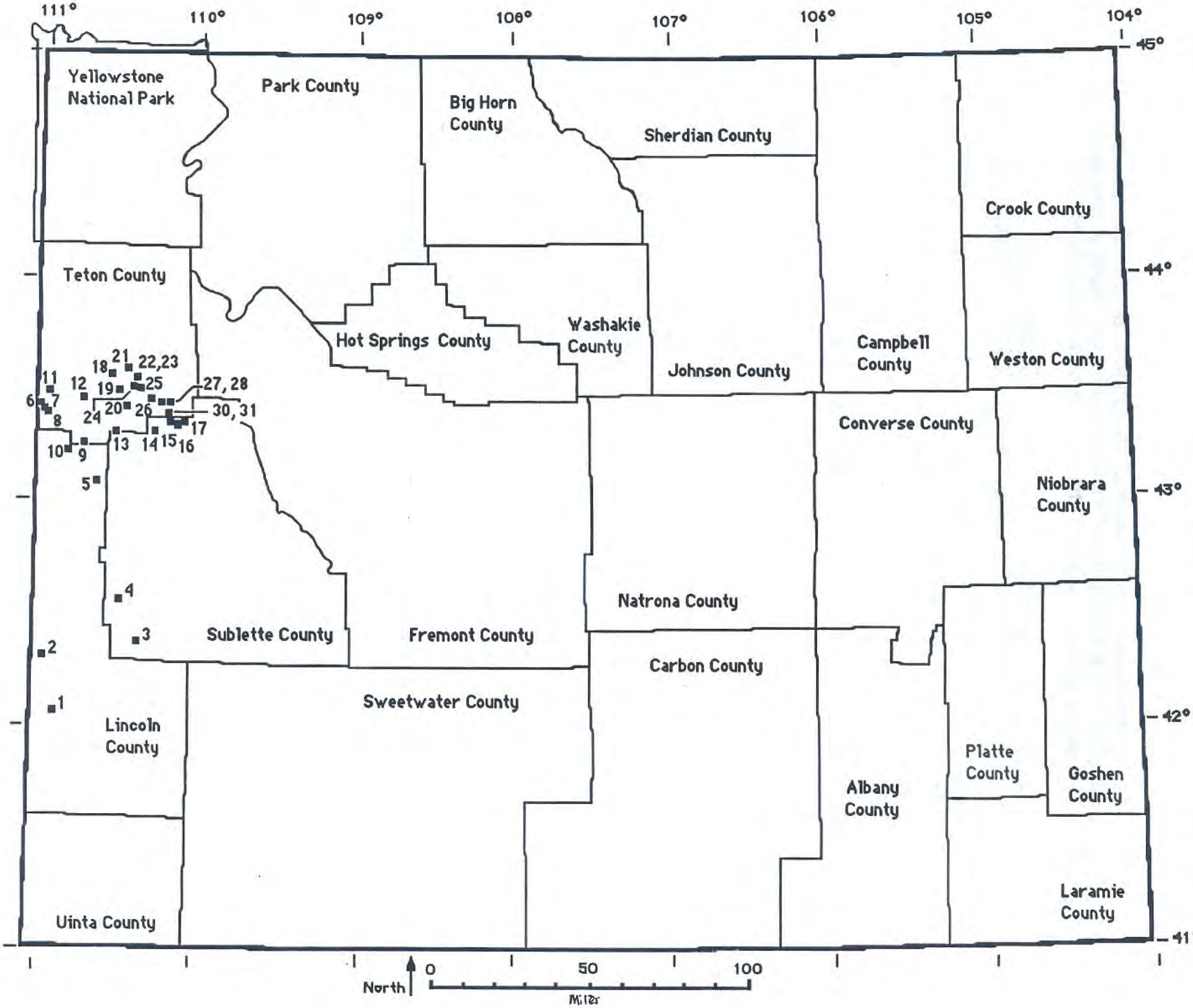
6-10) unnamed (sample 243) center W1/2 sec. 18, T.47N., R.85W.
(Damp and Brown, 1982)

This sample of quartz pebble conglomerate from the Flathead Formation contained 324 ppm eTh (15 ppm e and cU), <100 ppm La, <100 ppm Nd, <40 ppm Y, 8650 ppm Ti and 2650 ppm Zr (Damp and Brown, 1982). Given this suite of element concentrations, this is probably a paleoplacer from which another sample might contain rare earth enrichment. This site is an unverified rare earth locality because rare earth enrichment is usually found with high thorium concentrations in placers.

PHOSPHORIA FORMATION

Phosphorite in the Phosphoria Formation in western Wyoming is a potential source for various metals as by-products from phosphate production. Shale and black shale in the Phosphoria Formation also contain abundant metals at some sites (see for examples Love, 1984; Gulbrandsen, 1977). Because rare earths are often relatively abundant accessory elements in apatite, an important phosphate mineral in phosphorite (Gulbrandsen, 1966), rare earth elements might also be recovered during phosphate production (see for example, Lounamaa and others, 1980). To date, the number of analyses for rare earth elements in the Phosphoria Formation in Wyoming are areally limited, and abundances of all the rare earths have never been reported. The sample locations are scattered and include phosphorite, phosphatic rock, shale and black shales for which phosphorous contents weren't always reported. Therefore, regional trends in rare earth concentrations can not be determined, nor can a relation between phosphorous and rare earth concentrations (Figure 5; Table 7). However, in general, rare earth concentrations are higher in rocks with higher phosphorous contents, because more apatite is present. Therefore, the best phosphate ores are probably the richest in rare earths. The best potential phosphate ores in Wyoming are in western Lincoln County, where the phosphorites are the thickest and most phosphatic (see for example Raymond Canyon; #2 on Figure 5 and Table 7). In Wyoming, a potential resource containing about 700-1000 ppm total REE probably exists in many phosphorites. In Idaho, where phosphate production occurs, the rare earth concentrations are probably higher (after Altschuler and others, 1967; Vine, 1966; Gulbrandsen, 1966; Motooka and others, 1984; Gere and others, 1966; Simons and others, 1988).

Figure 5. Index map of samples from the Phosphoria Formation that contained abundant (5 times crustal abundance) rare earths and yttrium. Numbers by each locality indicate the corresponding number on Table 7 and the numbered description of that locality in the text.


111°
110°
109°
108°
107°
106°
105°
104°
45°
44°
43°
42°
41°
Yellowstone National Park
Park County
Big Horn County
Sherdian County
Crook County
Teton County
Hot Springs County
Washakie County
Johnson County
Campbell County
Weston County
Converse County
Niobrara County
Natrona County
Sublette County
Fremont County
Carbon County
Sweetwater County
Lincoln County
Platte County
Goshen County
Albany County
Laramie County
Uinta County
1
2
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4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22,23
24
25
26
27, 28
30, 31
North
0
50
100
Miles

Fig 5

Table 7. Locations of sample sites of phosphorite, phosphatic rock, shale and black shale in the Phosphoria Formation where the results of rare earth analyses meet or exceed locality criteria (5 times crustal abundance).

No.*	Name	Location sec., Twn., Rng.	Concentration La (ppm)	Y (ppm)	Nd (ppm)	P_2O_5 %
1	Cokeville 2 samples (a; g)	4, T24N, R119W	100	300	300	23.0-32.4
2	Raymond Canyon 31 samples (b; g)	6, T26N, R119W	50-700	50-1000	nd-700	10.73-36.32
3	Deadline Ridge 2 samples (a; g)	7, T27N, R114W	100-300	300	nd	28.0-31.6
4	Middle Piney Lake 2 samples (a; g)	8, T30N, R115W	300	100-300	nd-300	25.0-28.9
5	Steer Creek 2 samples (a; h)	9, T36N, R116W	100-300	300	nd-300	25.0-29.6
6	Siddoway Fork 3 samples (c; i)	unc, T40N, R118W	110-180	150-200	–	19.24-38.93
7	Smokey Hollow 5 samples (c; i)	33, T40N, R118W	130-220	170-270	—	15.11-21.98
8	North Fork Big Elk Ck. 7 samples (c; i)	11, T39N, R118W	97-250	150-520	–	16.26-38.93
9	Hoback 2 samples (c; g; i)	32, T39N, R116W	79-300	86-410	–	15.34-25.19
10	Wolf Creek 9 samples (c; i)	28, T38N, R117W	140-320	170-440	–	27.73-33.44
11	Teton Pass, west pit 1 sample (c; h; i)	23, T41N, R118W	170	220	–	2.34
12	Snow King Mountain 13 samples (d)	9, T40N, R116W	100-700	200-1000	nd-700	15.07-30.98
13	Bear Creek 1 sample (f)	6, T38N, R114W	160	196	96	—
14	Dell Creek 1 sample (e)	28, T39N, R112W	<200	300	—	29.8
15	Wilderness boundary 3 samples (e)	13, T39N, R112W	200-300	200-300	—	13.74-27.48
16	Tosi Creek 3 samples (e)	18, T39N, R111W	150-500	150-500	—	--- to 27.48
17	West Tosi Creek 1 sample (e)	15, T39N, R111W	200	300	—	13.74

18 Flat Creek 4 samples (e)	1, T41N, R115W	nd-200	200-300	—	25.7-40.0
19 Table Mountain 1 sample (e)	18, T41N, R114W	500	500	—	27.48
20 Granite Creek 3 samples (e)	3, T40N, R114W	500-1000	500-1000	—	27.48
21 East Miners Creek 1 sample (e)	1, T41N, R114W	200	500	—	—
22 Crystal Creek 5 samples (e)	34, T42N, R113W	nd-700	100-300	—	27.5-31.5
23 Crystal Creek 3 samples (e)	32, T42N, R113W	150-1000	200-1000	—	--- to 27.48
24 unnamed 2 samples (e)	8, T41N, R113W	500	500	—	10.31-20.61
25 Six Lakes 2 samples (e)	12, T40N, R113W	300-500	200-300	—	20.61
26 Crystal Peak 1 sample (e)	35, T41N, R113W	500	500	—	27.48
27 Bear Cabin Creek 1 sample (e)	14, T40N, R112W	500	700	—	27.48
28 unnamed 2 samples (e)	20, T39N, R112W	150-300	150-300	—	--- to 13.74
29 unnamed 2 sample (e)	26, T40N, R112W	200-700	300-700	—	6.87-27.48
30 Triangle Peak 1 sample (e)	2, T39N, R112W	200	300	—	27.48
31 Clear Creek 4 samples (e)	6, T39N, R111W 32, T40N, R111W	150-200	200-500	—	13.74-28.6

NOTES

unc = uncertain; nd = not detected; -- = no analysis performed.
* Number on Figure 5

REFERENCES

a = Gulbrandsen, 1966; b = Vine, 1966; c = Motooka, 1984; d = Gere and others, 1966; e = Simon and others, 1988; f = Schofield and Haskin, 1964; g = Sheldon and others, 1953; h = Cheney and others, 1953; i = Benham, 1985.

7-1) Cokeville section NW1/4 sec. 4, T.24N., R.119W. (Sheldon and others, 1953)

These two samples of pellet phosphorite from the Meade Peak Member of the Phosphoria Formation taken at this stratigraphic section contained 0.004 and 0.021 percent cU (0.004 and 0.020 % eU), with 23.0 and 32.4 percent P2O5, 2.03 and 3.55 percent F, and some rare earth element enrichment (300 ppm Y, 300 ppm Nd, with 100 ppm La, 10 ppm Yb)(Gulbrandsen, 1966). The exact units sampled are not known.

7-2) Raymond Canyon NW1/4NE1/4 sec. 6, T.26N., R.119W. (Sheldon and others, 1953)

Thirty-one samples of phosphorite and phosphate rich rock taken across 109 feet stratigraphically of the Meade Peak Member of the Phosphoria Formation at this section contained from 0.002 to 0.030 percent eU, with 10.73 to 36.32 percent P2O5 and some rare earth enrichment (50 to 700 ppm La, 50 to 1000 ppm Y, no data to 700 ppm Nd)(Vine, 1966).

7-3) Deadline Ridge sec. 8, T.27N., R.114W. (after Sheldon and others, 1953; Lake Mountain 7-1/2 minute Quadrangle map)

These two samples of pellet phosphorite and oolite-pellet phosphorite from the Retort Member of the Phosphoria Formation contained 0.003 and 0.002 percent cU (0.003 and 0.003 % eU) with 31.6 and 28.0 percent P2O5, 3.15 and 3.08 percent F, and some rare earth element enrichment (300 and 100 ppm La, 300 ppm Y)(Gulbrandsen, 1966).

7-4) Middle Piney Lake NE1/4NW1/4 sec. 8, T.30N., R115W. (Sheldon and others, 1953)

These two samples of pellet phosphorite from the Meade Peak Member of the Phosphoria Formation contained 0.004 and 0.012 percent cU (0.006 and 0.011 % eU) with 28.9 and 25.0 percent P2O5, 2.92 and 3.10 percent F, and some rare earth element enrichment (300 ppm La,100 and 300 ppm Y, 300 ppm Nd, 10 ppm Yb)(Gulbrandsen, 1966).

7-5) Steer Creek sec. 9, T.36N., R.116W. (Cheney and others, 1953)

These two samples of pellet phosphorite from the Meade Peak Member of the Phosphoria Formation contained 0.012 and 0.015 percent cU (0.010 and 0.012 % eU), with 29.6 and 25.0 percent P2O5, 3.03 and 2.33 percent F, and some rare earth element enrichment (100 and 300 ppm La, 300 ppm Y, 300 ppm Nd, 10 ppm Yb) (Gulbrandsen, 1966).

7-6) Siddoway Fork (JB-7; BM-7) sec. 8 T.1N., R.46E. in Idaho; extending into T.40N., R.118W. unsurveyed in Wyoming (Benham, 1985)

Four samples of phosphorite from this stratigraphic section in the Phosphoria Formation contained 110 to 180 pp, La, 150 to 200 ppm Y and 21 to 44 ppm Ce and 8.4 to 17 percent P (Motooka and others, 1984). In this case it is not possible to correlate the samples of Motooka and others (1984) with those of Benham (1985).

7-7) Smokey Hollow (JB-8; BM-8)
S1/2 sec. 33, T.40N., R.118W. (Benham, 1985)

Five samples of phosphorite and phosphate rich rock from this stratigraphic section in the Phosphoria Formation contained 130 to 220 ppm Y, 130 to 270 Y, 32 to 59 ppm Ce, and 6.6 to 9.6 percent P (Motooka and others, 1984). In this case it is not possible to correlate the samples of Motooka and others (1984) with those of Benham (1985).

7-8) North Fork Big Elk Creek (JB-9; BM-9) roughly sec. 11, T.39N., R.118W. unsurveyed (Benham, 1985)

Eleven samples of phosphorite and phosphate rich rock in this stratigraphic section of the Phosphoria Formation contained 97 to 520 ppm La, 150 to 520 ppm Y, and 26 to 140 ppm Ce, and 7.1 to 17 percent P (Motooka and others, 1984). In this case it is not possible to correlate the samples of Motooka and others (1984) with those of Benham (1985).

7-9) Hoback (Astoria Hot Springs; JB-10, BM-10) SW1/4NE1/4 sec. 32, T.39N., R.116W. (Sheldon and others, 1953; Benham, 1985)

Ten samples of phosphorite and phosphate rich rock from this stratigraphic section in the Phosphoria Formation contained 79 and 300 ppm La, 86 and 410 ppm Y, and 20 to 130 ppm Ce, and 6.7 to 11 percent P (Motooka and others, 1984). In this case it is not possible to correlate the samples of Motooka and others (1984) with those of Benham (1985).

7-10) Wolf Creek (JB-11; BM-11) roughly SW1/4 sec. 28, T.38N., R.117W. unsurveyed (Benham, 1985)

Nine samples of nine phosphorite units from the Phosphoria Formation at this site contained 140 to 320 ppm La, 170 to 440 ppm Y, 48 to 90 ppm Ce

(Motooka and others, 1984). These samples probably also contained 0.004 to 0.016 percent U3O8, with 2.45 to 2.90 percent F and 27.73 to 33.44 percent P2O5 (Benham, 1985). No consistent relationship between rare earths, and uranium, fluorine or phosphate content was present.

7-11) Teton Pass, west pit (JB-12; BM-12) sec. 23, T.41N., R.118W. unsurveyed (Cheney and others, 1953; Benham, 1985)

Benham (1985) reported a low phosphate unit (2.34 % P2O5) west of the Pass contained 0.013 percent U3O8. The sample also probably contained 170 ppm La, 220 ppm Y and 36 ppm Ce (Motooka and others, 1984).

7-12) Snow King Mountain NE1/4NE1/4 sec. 9, T.40N., R.116W. unsurveyed (Gere and others, 1966).

Thirteen samples of phosphate rich rock (15.07 to 30.98 % P2O5) from this stratigraphic section in the Phosphoria Formation contained 15.07 to 30.98 percent P2O5, 200 to 1000 ppm Y, no data to 700 ppm Nd, 100 to 700 ppm La, and no data to 50 ppm Yb (Gere and others, 1966).

7-13) Bear Creek (Gulch)--Hoback Canyon roughly sec. 6, T.38N., R.114W. unsurveyed (after Schofield and Haskin, 1964)

A sample of Phosphoria Formation phosphorite from this site was analyzed for rare earths. The sample contained 196 ppm Y, 160 ppm La, 34 ppm Pr, 96 ppm Nd, 24 ppm Sm, 5.8 ppm Eu, 3.5 ppm Tb, 3.9 ppm Ho, 2.09 ppm Tm and 11 ppm Yb. The sample was not actually analyzed for phosphorous (Schofield and Haskin, 1964).

7-14) Dell Creek (USBM sample #41) roughly center W1/2 sec. 28, T.39N., R.112W. unsurveyed (Simons and others, 1988)

This sample of phosphorite from the Phosphoria Formation contained 300 ppm Y, <200 ppm La, 29.8 percent P2O5, with 0.009 percent U, 3.0 percent F, 500 ppm Cr, <60 ppm V, and 1000 ppm Sr. The sample was chips across 1.5 feet of outcrop (Simons and others, 1988).

7-15) Wilderness boundary (USGS samples #296, #298 & #300) roughly N1/4 sec. 13-14 line, T.39N., R.112W., unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that these roughly 0.1, unstated, and 2 foot samples of phosphorite [and phosphate-rich rock] from the Phosphoria Formation contained 200, 300 and 200 ppm La, 200, 300 and 200 ppm Y, 6, 9 and 12 percent P, with 72, no data and 95 ppm U, 300, 500 and 500 ppm Cr and 50, 20 and 200 ppm V, respectively.

7-16) Tosi Creek (USGS sample #327-329) E1/2SE1/4 sec. 18, T.39N., R.111W. (Simons and others, 1988)

Here, Simons and others (1988) reported 500, 200 and 150 ppm La, 500, 200 and 150 ppm Y, and 6, 12 and no data P, with 1.5, 2 and 5 ppm Ag in two samples (#327-328) of Phosphoria Formation [phosphate-rich rock and] phosphorite and another (#329) of Phosphoria black shale. No phosphorous data was reported for sample # 329, so this could be a phosphatic unit and not a simple shale.

7-17) West Tosi Creek area (USGS sample #319) roughly center W1/2 sec. 15, T.39N., R.111W. (Simons and others, 1988)

Simons and others (1988) reported that this 0.5 foot sample of phosphorite [actually phosphate-rich rock] from the Phosphoria Formation contained 200 ppm La, 300 ppm Y and 6 percent P, with 68 ppm U, 500 ppm Cr and 70 ppm V.

7-18) Flat Creek (USBM sample #58-61) NE1/4SE1/4 sec. 1, T.41N., R.115W. (Simons and others, 1988)

These four samples of phosphorite from the Phosphoria Formation contained 200 to 300 ppm Y, no data to 200 ppm La, 25.7 to 40.0 percent P2O5, with 0.006 to 0.007 percent U, 2.3 to 3.2 percent F, 500 to 1000 ppm Cr, 60 to 1000 ppm V, and in one sample 1000 ppm Sr. The samples were chips across 0.5 to 2.5 feet of outcrop (Simons and others, 1988).

7-19) Table Mountain area (USGS sample #54) roughly E1/2 sec. 18, T.41N., R.114W. unsurveyed (Simons and others, 1988)

This 0.5 foot sample of phosphorite from the Phosphoria Formation contained 500 ppm La, 500 ppm Y and 12 percent P, with 115 ppm U, 1000 ppm Cr and 500 ppm V (Simons and others, 1988).

7-20) Granite Creek area (USGS samples #80-82) roughly NE1/4 sec. 3, T.40N., R.114W. unsurveyed (Simons and others, 1988)

In this area, Simons and others (1988) reported that roughly 0.20 and 0.33 foot samples of Phosphoria Formation phosphorite contained 1000 and 500 ppm La, 1000 and 700 ppm Y, and 12 percent P, with 500 and 700 ppm Cr, 300 and 100 ppm V for samples 80 and 81, respectively. Sample #82, also of

Phosphoria Formation phosphorite in this same general area contained 62 ppm U with no other data reported (Simons and others, 1988).

7-20) Granite Creek area (USGS sample #84) roughly center sec. 3-4 line, T.40N., R.114W. unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that this 0.33 foot sample Phosphoria Formation phosphorite contained 500 ppm La, 500 ppm Y and 12 percent P, with 91 ppm U, 700 ppm Cr and 500 ppm V.

7-21) East Miners Creek (USGS sample #370) roughly NW1/4 sec. 1, T.41N., R.114W. unsurveyed (Simons and others, 1988)

Simons and others (1988) reported 200 ppm La, 500 ppm Y, 86 ppm U, 300 ppm Cr and 300 ppm V in this sample of Phosphoria Formation shale. No phosphorous data was reported, so this could be a phosphatic unit and not a simple shale.

7-22) Crystal Creek area (USBM sample #10-14) roughly S1/2 sec. 34, T.42N., R.113W. unsurveyed (Simons and others, 1988)

Five samples of phosphorite from the Phosphoria Formation in this area contained 100 to 300 ppm Y, no data to 700 ppm La, and 27.5 to 31.5 percent P2O5, with 0.007 to 0.012 percent U, 2.6 to 3.2 percent F, 100 to 500 ppm Cr, <60 to 500 ppm V, and in one sample 1000 ppm Sr. The samples were chips across 0.75 to 3.3 feet of outcrop (Simons and others, 1988).

7-23) Crystal Creek (USGS samples #15-17) roughly sec. 32-33 line, T.42N., R.113W. unsurveyed (Simons and others, 1988)

Here, Simons and others (1988) reported that samples (#15 & 17) of Phosphoria Formation phosphorite contained 500 and 1000 ppm La, 700 and 1000 ppm Y and 12 and 9 percent P, with 1500 ppm Cr, 500 and 70 ppm V, not detected and 3 ppm Ag, and not detected and 100 ppm Zn. Sample #16 contained 150 ppm La, 200 ppm Y, 5 ppm Ag, 1000 ppm Cr and 700 ppm Zn, but was of a Phosphoria Formation black shale (Simons and others, 1988). No phosphorous data was reported, so this could be a phosphatic unit and not a simple shale.

7-24) unnamed (USGS samples #1002 & #1003) roughly NE1/4SE1/4 sec. 8, T.41N., R.113W. unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that these 0.5 and 0.67 foot samples (#1002 & #1003) of Phosphoria Formation phosphorite [and phosphate-rich rock] contained 500 ppm La, 500 ppm Y and 9 and 4.5 percent P, with 1500 and 1000 ppm Cr, and 200 and 70 ppm V, respectively.

7-25) The Six Lakes area (USGS sample #178 & #179) roughly SE1/4 sec. 12, T.40N., R.113W. unsurveyed (Simons and others, 1988)

In this area, Simons and others (1988) reported that a 0.83 foot sample (#178) and another sample (#179) of Phosphoria Formation phosphorite contained 500 and 300 ppm La, 300 and 200 ppm Y, and 9 percent P, with 70 and no data ppm U, 500 and 700 ppm Cr and 70 and 200 ppm V.

7-26) Crystal Peak (USGS sample #34) roughly NW1/4NW1/4 sec. 35, T.41N., R.113W. unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that this 2 foot sample of Phosphoria Formation phosphorite contained 500 ppm La, 500 ppm Y and 12 percent P, with 1000 ppm Cr and 500 ppm V.

7-27) Bear Cabin Creek (USGS #103) roughly center SE1/4 sec. 14, T.40N., R.112W. unsurveyed (Simons and others, 1988)

This sample of phosphorite from the Phosphoria Formation contained 500 ppm La, 700 ppm Y and 12 percent P, with 700 ppm Cr and 300 ppm V (Simons and others, 1988).

7-28) unnamed (USGS samples #308 & #309) NW1/4NW1/4 sec. 20, T.39N., R.112W. unsurveyed (Simons and others, 1988)

Here, Simons and others (1988) reported 300 ppm La, 300 ppm Y and 6 percent P, with 1 ppm Ag, 300 ppm Cr, 50 ppm V and 700 ppm Zn in a roughly 0.60 foot sample (#308) of Phosphoria Formation phosphorite [actually phosphate-rich rock]. In the same area, a sample (#309) of Phosphoria Formation black shale contained 150 ppm La, 150 ppm Y, 5 ppm Ag, 1000 ppm Cr and 1000 ppm Zn (Simons and others, 1988). No phosphorous data was reported, so this could be a phosphatic unit and not a simple shale.

7-29) unnamed (USGS sample #302) S1/2SW1/4SE1/4 sec. 26, T.40N., R.112W. unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that this sample of Phosphoria Formation phosphorite contained 200 ppm La, 300 ppm Y and 12 percent P, with 300 ppm Cr and 150 ppm V.

7-29) unnamed (USGS sample #124) roughly center N1/2 sec. 26, T.40N., R.112W. unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that this sample of Phosphoria Formation phosphorite [actually phosphate-rich rock] contained 700 ppm La, 700 ppm Y and 3 percent P, with 1000 ppm Cr and 300 ppm V.

7-30) Triangle Peak area (USGS sample #290) roughly center sec. 2, T.39N., R.112W., unsurveyed (Simons and others, 1988)

Simons and others (1988) reported that this 10 foot sample of phosphorite from the Phosphoria Formation contained 200 ppm La, 300 ppm Y and 12 percent P, with 87 ppm U, 300 ppm Cr and 100 ppm V.

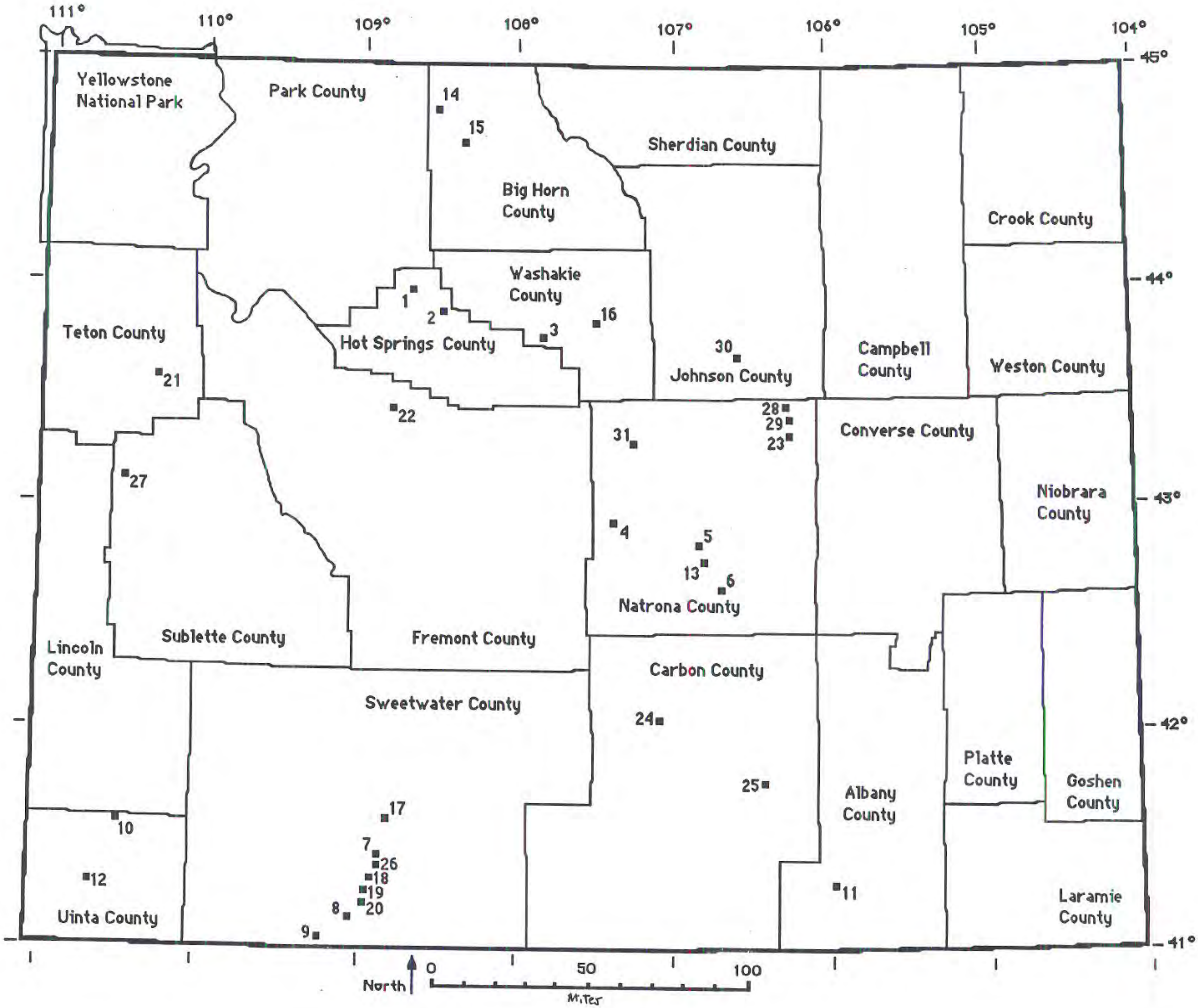
7-31) Clear Creek (USGS samples #204 & #205, USBM sample #57, and USGS sample # 406) NE1/4NE1/4NE1/4 sec. 6, T.39N., R.111W. down valley in order listed to W1/2NE1/4 sec. 32, T.40N., R.111W. unsurveyed (Simons and others, 1988)

These samples of phosphorite [and phosphate-rich rock] from the Phosphoria Formation contained 500, 300, 200 and 300 ppm Y, 200, 150, <200 and 200 ppm La, and 9 and 6 percent P, 28.6 percent P2O5 and 6 percent P, with 500, 500, 600 and 700 ppm Cr, and 200, 70, <60 and 70 ppm V. The USBM sample (#57) was chips across 2.5 feet of outcrop and also contained 0.002 percent U and 2.0 percent F (Simons and others, 1988).

MESOZOIC BLACK SANDSTONE BEACH PLACERS

Rare earth-bearing, radioactive, titaniferous, black sandstones of Late Cretaceous age are present at many locations in Wyoming (Figure 6 and Table 8). These black sandstones are known to contain abundant niobium and zirconium, and have been interpreted as fossil beach placers. They were formed by wave action on beaches. Repeated wave surges removed light minerals, and left behind lag concentrations of heavy minerals (Houston and Murphy, 1977). Roehler (1989) says the black sandstones exposed in the Rock Springs Uplift formed due to wave action, as well as long shore currents, fluvial currents and wind action. These black sandstones are known from the Jurassic Stump Formation, and the Cretaceous Bacon Ridge Sandstone, Mesaverde Formation and it's Parkman and Teapot members, Rock Springs Formation, Fox Hills Formation, Frontier Formation, Lewis Shale, and possibly the Lance Formation.

Figure 6. Index map of Mesozoic black sandstones. Numbers by each locality indicate the corresponding number on Table 8 and the numbered description of that locality in the text.


111°
110°
109°
108°
107°
106°
105°
104°
45°
44°
43°
42°
41°
Yellowstone National Park
Park County
Big Horn County
Sherdian County
Crook County
Teton County
Hot Springs County
Washakie County
Johnson County
Campbell County
Weston County
Converse County
Niobrara County
Natrona County
Lincoln County
Sublette County
Fremont County
Carbon County
Sweetwater County
Platte County
Goshen County
Albany County
Laramie County
Uinta County
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26
27
28
29
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31
North
0
50
100
Miles

Fig 6

Table 8. Mesozoic black sandstone fossil beach placer deposits in Wyoming

No.*	Name / Formation	Location sec., town., range	Extent (maximum in feet) length	width	thick	Concentration La (ppm) / Th max %	Y (ppm) / Ti max. %
Significant occurrence							
1	Grass Creek						
	northern	8,9,16, T46N, R98W	5600+	680+	16.0	1374	
	southern	33,34, T46N, R98W	un.	1600	5.0	1020	
	Mesaverde					0.17 %	33.36 %
Other mineral occurrences							
2	Cottonwood Ck.	26, T45N, R97W	150	150	9.0	1687	
	Mesaverde					0.04 %	16.84 %
3	Dugout Creek	34,35, T45N, R89W	14,256	1500+	25.0	312	
	Mesaverde	2,11, T44N, R89W				0.02 %	14.80 %
4	Coalbank Hills	5, T34N, R88W	1400+	un.	5.0		
	Mesaverde					0.12 %	12.5 %
5	Poison Spider	1, T33N, R84W	300+	un.	7.0	50-1000	10-300
	Lewis Shale	36, T34N, R84W				0.08 %	10.99 %
6	Clarkson Hill	20, T31N, R82W	150+	20+	5.6		
	Mesaverde, Parkman Sandstone member					0.04 %	9.7 %
7	Black Butte Ck.	30, T18N, R101W	1500+	un.	4.0	1000-1500	100-500
	Rock Springs					0.06 %	33.0 %
8	Salt Wells Creek	7, T14N, R103W	500	un.	3.0	500	100
	Rock Springs					0.07 %	35.50 %
9	Red Creek	22, T12N, R105W	1500	un.	6.6	700	
	Rock Springs					0.07 %	36.50 %
10	Cumberland Gap	25, T18N, R117W	13,200+	200	un.		
	Frontier	18,19,30, T18N, R116W				0.02 %	14.50 %
11	Sheep Mountain	10,14, T15N, R77W	4300	50	17.0	706	
	Mesaverde					0.05 %	23.68 %
12	Spring Gap	8,17,30, T16N, R117W	900+	30	2.5+	230-1000	40-80
	Frontier or possibly Aspen					0.066 %	22.0 %
13	Ranger	22,27, T34N, R84W	un.	un.	un.	500-1000	70-500
	Lance or possibly Lewis Shale					0.144 %	0.5 %
Sites of rare earth enrichment							
14	Cowley	1, T56N, R97W	900+	un.	3.5	135-400	<10
	Mesaverde					0.01 %	6.0 %
15	Lovell	7, T55N, R95W	5000+	un.	4.0	50-316	<10
	Mesaverde	12, T55N, R96W				0.01 %	15.1 %

16	Mud Creek Mesaverde	19, T44N, R91W	1500+	100+	7.5	500 0.02 %	 8.1 %
17	Beacon Rock Springs	19, T19N, R101W	2700	150	7+	500-700 0.10 %	100-300 21.1 %
18	Honnes Ranch Rock Springs	11, T17N, R102W	2500	50-100	6	1000 0.06 %	100 22.2 %

Sites of very high thorium concentrations (>30 times crustal abundance)

19	Pretty Water Ck. Rock Springs	8, T16N, R102W	1270	un.	4.2	 0.07 %	 26.3 %
20	Dans Creek Rock Springs	13, T15N, R103W	un.	250	5.5+	 0.08 %	 26.3 %

Unverified rare earth localities

21	Dry Cttnwd. Ck. Bacon Ridge Sandstone	27, T42N, R112W	un.	un.	un.		
22	Shotgun Bench Mesaverde	18, T5N, R1E	un.	300	5.0		
23	Salt Creek northern	 24,25,36, T39N, R78W 31, T39N, R77W	 8976+	 un.	 un.		
	southern Fox Hills	19,30, T38N, R77W	5280+	750	un.		
24	Seminoe Fox Hills	35, T25N, R85W 15, 28, T24N, R85W	un.	un.	un.		
25	Fiddler's Green Lewis Shale	21, T21N, R80W	2600	un.	13.0	 0.005 %	
26	Cooper Ridge Rock Springs	1, T17N, R102W	120		3.3		 28.00 %
27	Cliff Creek Stump	33, T38N, R114W	un.	un.	4+		 20.15 %
28	unnamed Mesaverde, Teapot member	5, T40N, R78W	un.	un.	un.	 0.007 %	
29	unnamed Mesaverde, Teapot member	27, T40N, R78W	un.	un.	un.	 0.011 %	 5.14 %
30	unnamed Mesaverde, Parkman member	22, T43N, R81W	un.	un.	un.	 0.01 %	
31	unnamed Fox Hills	13, T38N, R87W	un.	un.	un.	 0.018 %	

Notes * Number on Figure 6 un. = unknown

Rare earth bearing minerals present in Wyoming Mesozoic fossil beach placers include monazite, uraniferous zircon and an unidentified opaque radioactive mineral. Zircon makes up about 5 to 17 percent of the black sands while the monazite content varied from 0 to 4 percent. The abundances of the unidentified opaque mineral have not been reported (Houston and Murphy, 1962), but are probably less than 1/2 percent. X-ray diffraction patterns from this niobium-bearing, opaque mineral do not match those for columbite, tantalite or euxenite, but the mineral contains cerium, lanthanum and niobium (Houston and Murphy, 1962). Tantalum, niobium, thorium, yttrium and rare earth elements are also constituents in other heavy minerals. The most abundant heavy minerals in these beach placers are the non-radioactive minerals magnetite, titaniferous-magnetite, and ilmenite (Houston and Murphy, 1962, 1970, 1977).

The typical Wyoming beach placer deposit is an elongate body oriented parallel to the paleo-shoreline. The black sandstones average 15 percent heavy minerals and contain thin (1/4-inch-thick) individual layers composed of up to 90 percent heavy minerals. These sandstones are resistant and are exposed as ridges. The host rocks for most of these sandstones are of late Cretaceous age and are associated with regressive beach sandstones (Houston and Murphy, 1962, 1970, 1977). There is one documented Jurassic black sandstone (Houston and Love, 1956)(site #27). The existence of this Jurassic black sandstone means additional black sandstones that are not Late Cretaceous in age may be present in Wyoming.

Reliable analyses for lanthanum have been done on 16 sandstones; the results vary from 50 to 1687 ppm La and do not correlate with known monazite contents. Analyses on 9 sandstones have been done for yttrium; the results vary from <10 to 500 ppm yttrium (Table 8). Sites of very high thorium concentrations are included in Table 8 because rare earth enrichment usually accompanies that of thorium in placers. Other black sandstones are included on Table 8 because of the paucity of thorium and heavy mineral analyses on samples from these black sandstones, and the fact that they are potentially rare earth bearing placers.

None of the black sandstones have been systematically examined as a source of rare earths, niobium or tantalum. A systematic sampling program and chemical analyses are needed in order to determine the potential value of the black sandstones. Other undiscovered occurrences of niobium, tantalum and rare earths in black sandstones of Late Cretaceous age cannot be ruled out, because several previously unreported examples were found during field work for NURE projects in the late 1970s (see localities 12, 13, 28-31).

The information in Table 8 and on Figure 6 is from Houston and Murphy (1962, 1970, 1977); Houston and Love (1956); Dow and Batty (1961); Madsen (1978); Morris and Stanley (1982); Garrand and others (1982); Griffin and Milton (1982); Dribus and Nanna (1982); Damp and Brown (1982); Garrand and others (1982); Madsen and Reinhart (1982); and Roehler (1989).

8-1) Grass Creek area, **see significant occurrence 8.**

8-2) Cottonwood Creek (Waugh) SE1/4 sec. 26, T.45N., R.97W.
(Houston and Murphy, 1962)

This radioactive, titaniferous black sandstone is present in the basal Cretaceous Mesaverde Formation. Zircon makes up 18.5 percent of the heavy mineral fraction, and monazite comprises 1.0 percent. This paleobeach placer is exposed in a 150 feet across erosional remnant. The maximum thickness of the black sandstone is 9 feet. Average uranium content in four samples of the sandstone was 0.006 percent eU, varying from 0.004 to 0.011 percent eU, and all had less than 0.001 percent cU (Houston and Murphy, 1962). A sample reported in Dow and Batty (1961) contained 0.04 percent eTh. Hesse (1982) reported a low grade (buff) sample contained 29 ppm U, 145 ppm Th and 3,660 ppm Zr, with no REE data. Another sample reportedly contained 1687 ppm La (Madsen, 1978), the most lanthanum reported in any sample of Mesozoic black sandstone from Wyoming.

8-3) Dugout Creek secs. 34 and 35, T.45N., R.89W., and secs. 2 and 11, T.44N., R.89W (Houston and Murphy, 1962);

This radioactive, titaniferous black sandstone occurs in the upper part of the basal Mesaverde Formation (Cretaceous). The exposure of this paleo-beach placer is over 14,000 feet long and is up to about 1,500 feet wide; making it the largest individual exposure of Mesozoic black sandstone reported in Wyoming. The maximum thickness of the sandstone is 25 feet. Monazite and zircon are present in the sandstone as 1 percent and 5 percent of the total heavy minerals, respectively. The uranium content in samples of the black sandstone reportedly varied from 0.001 to 0.021 percent eU, yet, a maximum of only 0.009 percent eU is shown in Table 13 (Houston and Murphy, 1962). The four sample analyses reported by Dow and Batty (1961) were only 0.01 to 0.02 percent eTh. Another sample reportedly contained 312 ppm La (Madsen, 1978).

8-4) Coalbank Hills roughly center sec. 5, T.34N., R.88W. (Houston and Murphy, 1962)

This radioactive, titaniferous, black sandstone in the Mesaverde Formation is about 1,400 feet long, at most 5 feet thick and is of an undetermined width. The bedding in the black sandstone strikes N40°W and dips 23°NE, but the trend of the original strand line is not known. No radioactive minerals were originally identified in this fossil beach placer (Houston and Murphy, 1962; see also Loomis and Holmquist, 1954). Dow and Batty (1961) reported a composite sample contained 0.004 percent eTh. Later, samples (#149, 154-155) of the black sandstone contained 41, 140 and 1,170 ppm eTh, and 8, 22 and 125 ppm cU3O8 (8, 32, 160 ppm eU), with no analyses for REE. Spectrometer readings at six sites showed 24 to 378 ppm eTh and 5 to 68 ppm eU, with eTh below 100 ppm on unmineralized sandstones. Heavy mineral analyses revealed xenotime and zircon (Griffin and Milton, 1982).

8-5) Poison Spider area NE1/4NE1/4NE1/4 sec. 1, T.33N., R.84W. and SE1/4SE1/4SE1/4 sec. 36, T.34N., R.84W. (Houston and Murphy, 1962)

This radioactive, titaniferous, black sandstone is in the lower marine tongue of the Cretaceous Lewis Shale. The deposit is at most 7-feet-thick, and can be traced for approximately 300 feet along outcrop. The size of the deposit is obscured by faulting on its north end. One percent and 6.2 percent of the heavy mineral fraction of the deposit are monazite and zircon, respectively. Thirteen samples collected from weathered rock average 0.008 percent cU (0.003 % eU). Table 13 shows a range from 0.001 to 0.009 percent eU, and less than 0.001 to 0.003 percent cU (Houston and Murphy, 1962). Two other composite samples contained 0.02 and 0.03 percent eTh (Dow and Batty, 1961). Partial analyses of another six samples (#177, 181-182, 184-186) showed they contained 50 to 1000 ppm La, <10 to 50 ppm Nb, 1500 to >10,000 ppm Ti, 10 to 300 ppm Y, 100 to 1000 ppm Zr, 5 to 36 ppm cU3O8 (7 to 37 ppm eU), and 52 to 805 ppm eTh. Heavy mineral analyses revealed allanite, xenotime and zircon . The samples were reportedly from both the Lewis Shale (#184-186) and Lance Formation (#177, 181-182) (Griffin and Milton, 1982).

8-6) Clarkson Hill NE1/4NE1/4NE1/4 sec. 20, T.31N., R.82W. (Houston and Murphy, 1962)

A 150 foot long by 20 foot wide, east-west elongate exposure of radioactive, titaniferous, black sandstone in the upper portion of the Parkman Sandstone Member of the Mesaverde Formation is present at this site. The maximum thickness of the black sandstone is 5.6 feet. The original strand line orientation was probably north-south, so the exposed 150 foot measurement is probably the original width of the black sandstone. Monazite and zircon are present in the heavy mineral fraction. One sample contained 0.001 percent cU and 0.004 percent eU (Houston and Murphy, 1962), while another analysis reported in Dow and Batty (1961) was 0.04 percent eTh. A sample (#66) that is probably from this black sandstone contained 9 ppm cU3O8 (11 ppm eU) and 100 ppm eTh, with no analyses for REE. Heavy mineral analyses showed allanite(?), xenotime, zircon and apatite were present in this sample (Griffin and Milton, 1982).

8-7) Black Butte Creek (Zalenka) center E1/2SE1/4 sec. 30, T.18N., R.101W. (Roehler, 1989-plate; Houston and Murphy, 1962)

This radioactive, titaniferous black sandstone is on the east flank of the Rock Springs uplift in the Rock Springs Formation. The exposure is about 1,500 feet long and is 3 to 4 feet thick (Houston and Murphy, 1962). On his plate, Roehler (1989) portrays the mineralization as about 400 feet long and up to 4 feet thick, but he does not show the entire deposit on his plate. The orientation of the strand line is not known. Samples of the black sandstone contained monazite and zircon. Four samples on average contained 14.0 percent TiO_2, with 1.34 to 33.0 percent TiO_2. Assays for uranium were from less than 0.001 to 0.003 percent cU (0.003 to 0.017 % eU) (Houston and Murphy, 1962). Another composite sample contained 0.06 percent eTh (Dow and Batty, 1961). Two samples of black sandstone from the SE1/4 of sec. 30 contained 19 and 22 ppm cU_3O_8, with 1000 and 1500 ppm La, and 100 and 500 ppm Y, respectively (Morris and Stanley, 1982). This latter sample with another from the Ranger black sandstone are the most yttrium rich reported in Wyoming. The lanthanum concentration in this same sample is the second highest reported in the state for a Mesozoic black sandstone.

8-8) Salt Wells Creek (Titsworth Gap; Murphy No. 1)
roughly center SE1/4 sec. 7, T.14N., R.103W.
(Roehler, 1989-plate; Houston and Murphy, 1962)

This radioactive, titaniferous black sandstone deposit is in the Rock Springs Formation at the southern end of the Rock Springs uplift. The sandstone is a lens shaped outcrop that is about 250 feet long in a northeast-southwest direction, and at most 3 feet thick. The orientation of the strand line is not known (Houston and Murphy, 1962). Roehler (1989) portrays this occurrence as about 500 feet long and 3 feet thick on his plate, but he says its 2000 feet long in his text. The topographic map on his plate supports the 500 foot length. Samples of the black sandstone contained monazite and zircon. Two assays were both 0.003 percent cU (0.009 and 0.011 % eU) (Houston and Murphy, 1962). Two additional samples assayed 0.06 and 0.07 percent eTh (Dow and Batty, 1961). Morris and Stanley (1982) report 500 ppm La and 100 ppm Y, with only 36 ppm cU_3O_8, in a sample from this black sandstone.

8-9) Red Creek (Richards Gap) SE1/4 sec. 22, T.12N., R.105W.
(Roehler, 1989-plate; Houston and Murphy, 1962)

This radioactive, titaniferous black sandstone is in the Cretaceous Rock Springs Formation about 0.5 mile north of Colorado. The sandstone is a east-west elongate lens about 800 feet long with concentrated heavy minerals for only 125 feet of this length. The sandstone is 6 feet thick in the higher grade rock on the western end of the exposure and tapers to 4 feet and then a wedge edge to the east. The orientation of the strand line is not certain but it appears the longest axis of the deposit should extend down dip (20°N). The east-west distance of 800 feet is therefore probably the width of the deposit (Houston and Murphy, 1962). Roehler (1989) states that the mineralization is at most 6.6 feet thick. He shows one large and 3 separate smaller black sandstones on his plate. The large black sandstone is shown as being about 1500 feet long with about 400 feet of this being over 4 feet thick. The smaller black sandstones are shown as about 250, 100 and 400 feet long and have thicknesses of 0.4, 0.6 and <1 foot, respectively (Roehler, 1989). Samples of what is probably the largest of these black sandstone contained monazite and zircon, and assayed on average 0.005 percent cU (0.011 % eU). Table 13 shows 8 analyses with less than 0.001 to 0.012 percent cU (0.001 to 0.023 % eU) (Houston and Murphy, 1962). Four other samples contained 0.01 to 0.07 percent eTh (Dow and Batty, 1961). Another sample reportedly contained 700 ppm La (Madsen, 1978).

8-10) Cumberland Gap roughly SE1/4 sec. 25, T.18N., R.117W., and E1/4 sec. 18, E1/2 sec. 19 and NW1/4 sec. 30, T18N., R.116W. (after Houston and Murphy, 1962; Love and Christiansen, 1985)

A trace of monazite was detected in a composite made from five samples of this radioactive, titaniferous black sandstone in the Late Cretaceous, lower Frontier Formation. The uranium content of four samples was 0.001 to 0.002 percent cU (0.002 to 0.015 % eU). Radioactivity was only 5 times background along the outcrop. The longest continuous exposure of this paleo-beach placer is 600 feet long, with a strike of N42°E and a dip of 15°NE. The total length is estimated as being in excess of 13,200 feet with a width of at most 200 feet (Houston and Murphy, 1962). A sample from the northeast end of the deposit contained less than 0.01 percent eTh, while another from the southwest end of the deposit contained 0.02 percent eTh (Dow and Batty, 1961). Dow and Batty (1962) report the black sandstone is one linear trend starting in sec. 7, T.18N., R.116W. that has intermittent exposures for 22,000 feet into sec. 36, T.18N., R.117W. Samples from this black sandstone need to be analyzed for rare earths given the great extent.

8-11) Sheep Mountain SE1/4 sec. 10, NW1/4NW1/4 sec. 14, T.15N., R.77W. (Hausel and Jones, 1982)

This radioactive, ilmenite-bearing, black sandstone is in the lower part of the Mesaverde Formation (Upper Cretaceous) (Houston and Murphy, 1962). The black sandstone is exposed at intervals over a distance of about 4,300 feet along strike near the northeastern flank of Sheep Mountain (Hausel and Jones, 1982). The trend of the exposures is N30°W to N45°W and the dip is 25°NE to 35°NE. The outcrop width is about 50 feet. The black sandstone has a maximum thickness of 17 feet (exposed in a cross-cutting prospect pit near the northwest end of the exposure) and tapers to about 2 feet at the southeastern end of the trend (Houston and Murphy, 1962). Magnetic data suggest the deposit does not extend down dip (Hausel and Jones, 1982). Heavy mineral analyses of six samples gave an average of 63 percent heavy minerals, of which 84.2 percent are opaque minerals, 10.3 percent was zircon, and 1 percent was monazite. Chemical analysis of six samples showed five with less than 0.001 percent cU and one with 0.006 percent cU. Radiometric analysis of seven samples averaged 0.007 percent eU, varying from 0.002 to 0.016 percent eU (Houston and Murphy, 1962). Three more recent analyses of samples from the Crescent lode #1 property on this black sandstone were 8 to 43 ppm cU_3O_8 and 88 to 357 ppm eTh. On analysis showed <100 ppm La, <40 ppm Y, but 32,300 ppm Ti, 7179 ppm Zr and 262 ppm Nb. Monazite and thorite are present in this fossil beach placer (Dribus and Nanna, 1982). Another sample reportedly contained 706 ppm La (Madsen, 1978).

8-12) Spring Gap center sec. 30, T.16N., R.117W.
(Madsen and Reinhart, 1982)

An altered sandstone in the Cretaceous Frontier (occurrence data) or Aspen (sample data) Formation contained limonite, pyrite, manganese oxides (?), a rare earth-bearing mineral and leucoxene. The exposure is about 900 feet long and up to 20 feet wide, with the black sandstone about 2.5 feet thick. Chemical analyses revealed the characteristic beach placer assemblage of elements. Despite containing less than 25 ppm eU and cU3O8, the two samples contained 130 and 660 ppm eTh. Rare earth element content is 230 and 1,000 ppm La with only 40 and 80 ppm Y, and less than 100 ppm Nb (Madsen and Reinhart, 1982). As located, the sample could be from either the Aspen or Frontier Formation (after Love and Christiansen, 1985).

8-12) Spring Gap (sample 83) SW1/4SW1/4NW1/4 sec. 8, T.16N., R.117W.
(Madsen and Reinhart, 1982)

This sample contained 600 eTh with 25 ppm eU (12 ppm cU3O8). Chemical analyses revealed the characteristic beach placer assemblage of elements. The rare earth content is 650 ppm La with only 50 ppm Y, yet the sample contains 120 ppm Nb (Madsen and Reinhart, 1982). The sample was from the Frontier Formation (after Love and Christiansen, 1985) or the Aspen Formation (Madsen and Reinhart, 1982). This sample shows that the main Spring Gap black sandstone in sec. 30 is present, if not continuous, 3 miles to the north.

8-12) Spring Gap (sample 82) SW1/4NE1/4NW1/4 sec. 17, T.16N., R.117W.
(Madsen and Reinhart, 1982)

This sample contained 780 ppm eTh with 38 ppm eU (12 ppm cU3O8). Chemical analyses revealed the characteristic beach placer assemblage of elements. The rare earth content is 870 ppm La with only 50 ppm Y, and less than 100 ppm Nb (Madsen and Reinhart, 1982). The sample was from the Frontier Formation (after Love and Christiansen, 1985) or the Aspen Formation (Madsen and Reinhart, 1982). This sample shows that the main Spring Gap black sandstone in sec. 30 is present, if not continuous, 2 miles to the north.

8-13) Ranger no. 1 claim NE1/4 sec. 22, T.34N., R.84W.
(Griffin and Milton, 1982; Hadfield, 1954)

This is probably a fossil beach placer in the Cretaceous Lance Formation.

In early examinations, no radioactive minerals were recognized, but up to 20 times background radioactivity was reported in a black lens. This lens in part cut bedding in a white to brown, very coarse-grained, massive, arkosic sandstone in the Lewis or Lance Formation. The black lens was associated with abundant limonite, carbonaceous material and possibly manganese oxides (Hadfield, 1954). A grab sample contained 0.319 percent cU3O8 (0.342 % eU3O8) (Geslin, 1955). This description would permit the mineralization to be in a roll front. The extent of the mineralization is not known.

Later, partial analyses of samples (#179-178) of what are reportedly coarse-grained, arkosic sandstones contained 500 and 1,000 ppm La, 70 and 500 ppm Y, 1000 and 5000 ppm Ti, <10 ppm Nb, and 50 and 200 ppm Zr, with 12 and 57 ppm cU3O8 (41 ppm eU) and 1,440 ppm eTh. The samplers repeated the earlier description of carbonaceous material, and iron oxide staining, but they also noted concentrations of heavy minerals and called the unit the Lance Formation. Because of these analytical results, and heavy mineral analyses that revealed magnetite and ilmenite, their alteration products, xenotime, and zircon (Griffin and Milton, 1982), this is most likely a fossil placer. If this black sandstone really is in the Lance Formation, it is the only documented black sandstone in the Lance in the state of Wyoming. This black sandstone and the Black Butte Creek black sandstone contain the most yttrium of any Mesozoic black sandstone reported in Wyoming.

8-13) Ranger (sample 180)
NE1/4 sec. 27, T.34N., R.84W. (Griffin and Milton, 1982)

A sample of sandstone from the Lance Formation at this site contained 195 ppm eTh, 300 ppm La, 2000 ppm Ti, 70 ppm Y, 100 ppm Zr, <10 ppm Nb and 7 ppm cU3O8 (13 ppm eU)(Griffin and Milton, 1982). This suite of placer elements indicate that this locality is probably an extension of the Ranger #1 black sandstone.

8-14) Cowley deposit
roughly center sec. 1, T.56N., R.97W. (Houston and Murphy, 1962)

This radioactive, titaniferous black sandstone in the Mesaverde Formation is exposed for about 900 feet in a northwesterly direction and reaches a maximum thickness of 3.5 feet. It averages one foot in thickness. The strike of the black sandstone is N60°W; the dip is 9°SW. The south end of the deposit is covered by alluvium, and it is not known how far the deposit extends in that direction under the alluvial cover. Radiometric analyses of heavy minerals gave equivalent uranium of 0.001 percent. Zircon was reported, while monazite was not reported in samples of this paleobeach placer (Houston and Murphy, 1962). A 50 pound sample contained 0.01 percent eTh (Dow and Batty, 1961), but may have included unmineralized material. Other reported analyses, from airborne anomaly no. 6, are 0.001% cU3O8 (0.01 and 0.02 % eU3O8)(Brooke, 1953). Other samples (#27 and #28) contained <20 and 400 ppm La, 30 and <20 ppm Nb, <10 ppm Y, 2000 and 60,000 ppm Ti, 100 and 800 ppm Zr, and 3 and 25 ppm cU3O8 (10 and 60 ppm eU3O8), with no analyses for thorium (Garrand and others, 1982). Another sample reportedly contained only 135 ppm La (Madsen, 1978). Elevatorski (1976) mislocates anomaly no. 6 in section 4 of this township.

8-15) Lovell deposit W1/2 sec. 7, T.55N., R.95W. and E1/2 sec. 12, T.55N., R.96W. (Houston and Murphy 1962)

The deposit is a radioactive, titaniferous black sandstone in the Mesaverde Formation. The black sandstone extends for at least 3,000 and possibly more than 5,000 feet along a N34°W trend with a dip of 11°SW. The maximum thickness is four feet and the average about three feet. This deposit is a paleobeach placer. Radiometric analysis of one high-grade sample gave equivalent uranium as 0.003 percent. Zircon was reported while monazite was not reported in this deposit (Houston and Murphy, 1962). A 50 pound sample contained 0.01 percent eTh (Dow and Batty, 1961), but may have included unmineralized material. A more recent sample (#26) contained only 50 ppm La, <20 ppm Nb, 40 ppm Y, 200 ppm Zr, and 8 ppm cU3O8 (20 ppm eU3O8), with no analysis for thorium (Garrand and others, 1982). Another sample reportedly contained 316 ppm La (Madsen, 1978).

8-16) Mud Creek center sec. 19, T.44N., R.91W. (Houston and Murphy, 1962)

This radioactive, titaniferous black sandstone occurs in the uppermost part of the basal Mesaverde Formation (Cretaceous). The black sandstone was used in the construction of a nearby ranch house, now abandoned. The exposure of this paleo-beach placer is about 1,500 feet long, and about 100 feet wide at its greatest extent. The exposed length of the outcrop is apparently the original width of the deposit, so the black sandstone has been extensively eroded. The maximum thickness of the sandstone is 7.5 feet. Five percent zircon was identified in the heavy mineral suite, but no chemical analyses were performed (Houston and Murphy, 1962). Analyses of the two composite samples reported by Dow and Batty (1961) were both 0.02 percent eTh. Another sample reportedly contained 500 ppm La (Madsen, 1978).

8-17) Beacon (Union Pacific Railroad Company No. 1) sec. 19, T.19N., R.101W. (Dow and Batty, 1961)

This radioactive, titaniferous black sandstone in the Rock Springs Formation (Houston and Murphy, 1962), is exposed for 2,700 feet with an average width of 150 feet and an average thickness of 7 feet. A composite sample contained 0.10 percent eTh (Dow and Batty, 1961). Two samples of what is probably this black sandstone, from the SW1/4 of the section, contained 500 and 700 ppm La, and 100 and 300 ppm Y, with 28 and 40 ppm cU3O8, respectively (Morris and Stanley, 1982).

8-18) Honnes Ranch (Bradey Road; Union Pacific Railroad Company No. 2)

SW1/4 sec. 11, and center N1/2NW1/4 sec. 14, T.17N., R.102W. (Roehler, 1989-plate; Dow and Batty, 1961)

Houston and Murphy (1970) place this radioactive, titaniferous black sandstone in the Rock Springs Formation. The sandstone caps a ridge for 2,500 feet, is between 50 and 100 feet wide and averaged 4 feet in thickness. A composite sample contained 0.06 percent eTh (Dow and Batty, 1961). On his plate, Roehler (1989) portrayed the mineralization as about 2000 feet long in a northeast-southwest direction, with about another 800 feet length on the southwest end that is perpendicular to the longer exposed length. He shows the deposit as at least 3 feet thick over its entire length and stated that it is 3 to 6 feet thick. Another sample contained 55 ppm cU3O8, with 1000 ppm La and 100 ppm Y (Morris and Stanley, 1982). More chemical analyses might demonstrate that this is a significant occurrence.

Schneider and Ruzycki (1956) reported that an iron-rich sandstone in the Ericson Formation at airborne anomaly 57-8 contained 0.012 percent U3O8. This is probably the Honnes Ranch site given the description and map of the anomaly by Schneider (1955).

8-19) Pretty Water Creek (Camel Rock; Murphy no. 2) roughly W2/3S1/2 sec. 8, T.16N., R.102W. (Roehler, 1989-plate; Dow and Batty, 1961)

This radioactive, titaniferous black sandstone is in the Rock Springs Formation (Houston and Murphy, 1970) on the east flank of the Rock Springs uplift. The exposure is about 450 feet long and it averages 3 feet in thickness. Two samples of the sandstone contained 0.04 and 0.07 percent eTh (Dow and Batty, 1961). Roehler (1989) portrays this occurrence as being three separate exposures. On the east side of a canyon the mineralization is 270 feet long and up to 4.2 feet thick. The two exposures on the west side of the canyon are shown on his plate as being about 800 feet long and up to 3.5 feet thick, and 200 feet long and 1 foot thick. These western exposures are separated and truncated by a paleochannel (Roehler, 1989). Rare earth element enrichment has not been confirmed in this fossil beach placer, so this is an unverified locality.

8-20) Dans Creek (Yenko) sec. 13, T.15N., R.103W. (Dow and Batty, 1961)

This radioactive, titaniferous black sandstone in the Rock Springs Formation (Houston and Murphy, 1970), averages about 5.5 feet thick and is exposed for about a width of 250 feet in the wall of a mesa. The orientation of the strand line is not known. Two composite samples each contained 0.08 percent eTh (Dow and Batty, 1961). Rare earth element enrichment has not been confirmed in this fossil beach placer, so this is an unverified locality.

8-21) Dry Cottonwood Creek

sec. 27, T.42N., R.112W. (Houston and Murphy, 1970)

Houston and Murphy (1970) report a fossil beach placer at this location in the Bacon Ridge Sandstone. They supply no other information. This site is considered an unverified locality, because most Mesozoic fossil beach placers in Wyoming contain rare earth bearing minerals and/or high rare earth concentrations.

8-22) Shotgun Bench
sec. 18, T.5N., R.1E. (WRM) (Houston and Murphy, 1970).

Houston and Murphy (1970) report a black sandstone in the Mesaverde Formation at this site. The exposure is reportedly 300 feet wide with no length given and has a maximum thickness of 5.0 feet. The shoreline of this fossil beach placer was roughly north-south trending (Houston and Murphy, 1970). This site is considered an unverified locality, because most Mesozoic fossil beach placers in Wyoming contain rare earth bearing minerals and/or high rare earth concentrations.

8-23) Salt Creek
northern segment--secs. 24, 25 and 36, T.39N., R.78W., and sec. 31, T.39N., R.77W.
southern segment--secs. 19 and 30 T.38N., R.77W.
(Houston and Murphy, 1970)

These two segments on the east flanks of Salt Creek anticline are titaniferous black sandstones in a Fox Hills Formation. The northern segment is at least about 9000 feet long, while the southern segment is 750 feet wide and at least a mile long (Houston, and Murphy, 1970; 1977). The presence of rare earth bearing minerals or rare earth enrichment has not been confirmed in this fossil beach placer. So this is an unverified locality, because most Mesozoic fossil beach placers in Wyoming contain rare earth bearing minerals and/or high rare earth concentrations.

8-24) Seminoe sec. 35, T.25N., R.85W.; and secs. 15 and 28, T.24N., R.85W. (Houston and Murphy, 1970)

The exact extent of this radioactive, titaniferous black sandstone paleobeach placer has not been determined (Houston and Murphy, 1970). The placer is reportedly in the Fox Hills Sandstone (Houston and Murphy, 1977). It is not known for certain if the black sandstone contains elevated levels of rare earths So this is an unverified locality, because most Mesozoic fossil beach placers in Wyoming contain rare earth bearing minerals and/or high rare earth concentrations.

8-25) Fiddlers Green sec. 21, T.21N., R.80W. (Houston and Murphy, 1970)

This is a radioactive, titaniferous, black sandstone beach placer in the Lewis Shale. The paleoplacer is exposed for 2600 feet and is up to 13 feet thick (Houston and Murphy, 1970). Dribus and Nanna (1982) report radioactivity only up to 2.5 times background and that the lone sample assayed for thorium contained 49 ppm eTh. It is not known for certain if the black sandstone contains elevated levels of rare earths. So this is an unverified locality, because most Mesozoic fossil beach placers in Wyoming contain rare earth bearing minerals and/or high rare earth concentrations.

8-26) Cooper Ridge N1/2N1/2SE1/4 sec. 1, T.17N., R.102W. (Roehler, 1989-figure)

This poorly exposed black sandstone in the Rock Springs Formation dips gently to the southeast, is about 1 foot thick and caps a low ridge. A sample contained 0.015 percent eU (0.003 % cU) with 28.0 percent TiO_2 (Love and Murphy, 1962). Roehler (1989) says the deposit is 3.3 feet thick and 120 feet long. This is an unverified locality though no rare earth enrichment has been demonstrated, because most Mesozoic fossil beach placers in Wyoming contain rare earth bearing minerals and/or high rare earth concentrations.

8-27) Cliff Creek center south line sec. 33, T.38N., R.114W.

Outcrops of Late Jurassic Stump Formation sandstone along Gibbs Creek in Sublette County are radioactive, and similar to the Cretaceous black sandstones in Wyoming. Some zones in these sandstones contain 90 percent heavy minerals. Uraniferous zircon is present in this Jurassic sandstone; but, the REE bearing monazite and REE- and niobium-bearing opaque that are in the Cretaceous black sandstones are absent. From spectrographic analyses, the Cretaceous sandstones contain 10 to 100 times the La and Nd that this Jurassic sandstone contains. In addition, samples of this Jurassic sandstone do not even contain traces of cerium and niobium. The Cretaceous sandstones are about 10 to 60 times more radioactive than this Jurassic sandstone Three ferruginous looking sandstones that are 0.5 2.7 and 0.4 feet thick were sampled One sample assayed 20.15 percent TiO_2 and 54.93 percent Fe_2O_3, with 0.001 percent U (0.003 % eU). Other samples contained at most 13.4 percent Fe_2O_3, 7.66 percent TiO_2 and 0.002 percent eU (Houston and Love, 1956). This is an unverified locality though no rare earth enrichment has been verified. Rare earth analyses of this sandstone are needed to determine if rare earth enriched Jurassic black sandstones might be present in Wyoming, or if this is a false lead.

8-28) unnamed (sample 86) SW1/4 sec. 5, T.40N., R.78W. (Damp and Brown, 1982)

About 6 percent allanite and 1 percent sphene are reported in a sample of black, magnetite-bearing sandstone in the Teapot member of the Mesaverde Formation. Yet the sample only contained 67 ppm eTh (8 and 6 ppm cU and eU) (after Damp and Brown, 1982). As described the allanite may not really be allanite. No REE or trace element analyses are available for this locality, so this remains an unverified locality.

8-29) unnamed (sample 83)
roughly S1/2 sec. 27, T.40N., R.78W. (Damp and Brown, 1982)

Damp and Brown (1982) reported heavy mineral concentrations of 7.3 % by weight in a sample of beach facies sandstone in the Teapot member of the Mesaverde Formation at this site. Their sample contained <100 ppm La, 195 ppm Nb, 51,400 ppm Ti, 622 ppm W, <40 ppm Y and 907 ppm Zr, with 111 ppm eTh and 22 ppm eU (7 ppm cU)(Damp and Brown, 1982). Note that rare earth elements are not present in high enough concentrations in the lone sample to meet locality criteria (i.e. 320 ppm Ce, 150 ppm La, 110 ppm Y, etc.) is not present in the lone sample. So the locality is unverified, because most Mesozoic fossil beach placers in Wyoming contain rare earth bearing minerals and/or high rare earth concentrations.

8-30) unnamed (sample 96)
roughly sec. 22, T.43N., R.81W. (Damp and Brown, 1982)

Damp and Brown (1982) report heavy mineral concentrations of 6.7 % by weight in a sample of beach facies sandstone in the Parkman member of the Mesaverde Formation at this site. Their sample contained 98 ppm eTh and 20 ppm eU, but no rare earth or trace element analyses were reported (Damp and Brown, 1982). So this may or may not be an locality. At present it is an unverified locality, because most Mesozoic fossil beach placers in Wyoming contain rare earth bearing minerals and/or high rare earth concentrations.

8-31) unnamed (sample 138)
E1/4 sec. 13-24 line, T.38N., R.78W. (Damp and Brown, 1982)

A trace of monazite is reported in a sample of black sandstone from the Fox Hills Formation; the sample contained 176 ppm eTh (28 ppm eU and 21 ppm cU), but no REE or trace element analyses were performed (Damp and Brown, 1982). So this may or may not be an locality. At present it is an unverified locality, because most Mesozoic fossil beach placers in Wyoming contain rare earth bearing minerals and/or high rare earth concentrations.

EOCENE LACUSTRINE ROCKS

Rare earth-bearing carbonate minerals, burbankite, mckelveyite and ewaldite, have been found in the Eocene Wilkins Peak member of the Green River Formation. The Wilkins Peak is a lacustrine unit noted for it's thick trona beds. The abundances of these rare earth-bearing minerals are described as extremely scarce to never abundant (Milton, 1971). In most samples, the minerals are dark green to black due to admixed organic material (Milton and others, 1965); therefore, these minerals could be overlooked in most examinations, and could be more abundant. The locations of the reported occurrences of these minerals are shown in Table 9 and on Figure 7. Most are in the lowermost Wilkins Peak member. The rare earth-bearing minerals are apparently in and associated with uraniferous phosphatic zones (zones 1 and 2a) and a trona bed (bed 17)(Love, 1964). No geochemical analyses for rare earth elements are available for any trona bed. Semiquantitative spectrographic analyses indicate that on average rare earth enrichment in uraniferous phosphatic zone 1 is over 1000 ppm total REE, with some enrichment in zone 2a that is less than 1000 ppm total REE. The seven analyzed samples of uraniferous phosphatic zone 1 contained 3.6 to 14.7 percent P2O5 with on average 150 ppm La and Sm, 500 ppm Y and Ce, and 300 ppm Nd. The three or four analyzed samples from zone 2a contained 3.1 to 10.56 percent P2O5 with on average 300 ppm Y, 150 ppm Nd and 70 ppm La. The rest of the uraniferous phosphatic zones on average are not notably enriched in rare earths (see Table 9 and Figure 7)(after Love, 1964, table 17). Mott's (1978) analyses also show some evidence of rare earth enrichment. However, lateral changes are apparent in both Love's (1964) and Mott's (1978) data, so the REE enrichment is <u>not</u> homogeneous in a given uraniferous phosphatic zone.

The extent of rare earth-bearing trona and uraniferous phosphatic rock is probably larger than that encompassing the localities shown in Figure 7, but it is not know which other trona beds or uraniferous phosphatic zones, or portions of these beds and zones are mineralized. The outline of the U.S. Geological Survey's trona resources area is shown in Culbertson (1971). An outline for uraniferous phosphatic rocks is not shown because lateral changes are quite common (Love, 1964; see also Mott, 1978).

It might be possible to obtain rare earths as a by-product from trona mining and processing. Rare earth-bearing carbonate minerals have been reported in trona bed 17 (Love, 1964), which is presently being exploited, as well as in waste from soda ash production (Milton and others, 1965). Also of possible economic importance is the fact that yttrium and HREE are selectively enriched in intimately intergrown mckelveyite-ewaldite, while LREE are selectively enriched in burbankite. Additional information on the mineralogy of these minerals from Wyoming is in Milton and others (1965), Donnay and Donnay (1971), Donnay and Preston (1971), and Fitzpatrick and Pabst (1977). However, it should be noted that these mineralogist's information on mineral localities are different than those of Love (1964), who was the source of the samples. Love's (1964) locations have been used for all but one site (#5, Figure 7 and Table 9).

Figure 7. Index map of rare earth and yttrium bearing Eocene lacustrine rocks. Numbers by each locality indicate the corresponding number on Table 9 and the numbered description of that locality in the text.

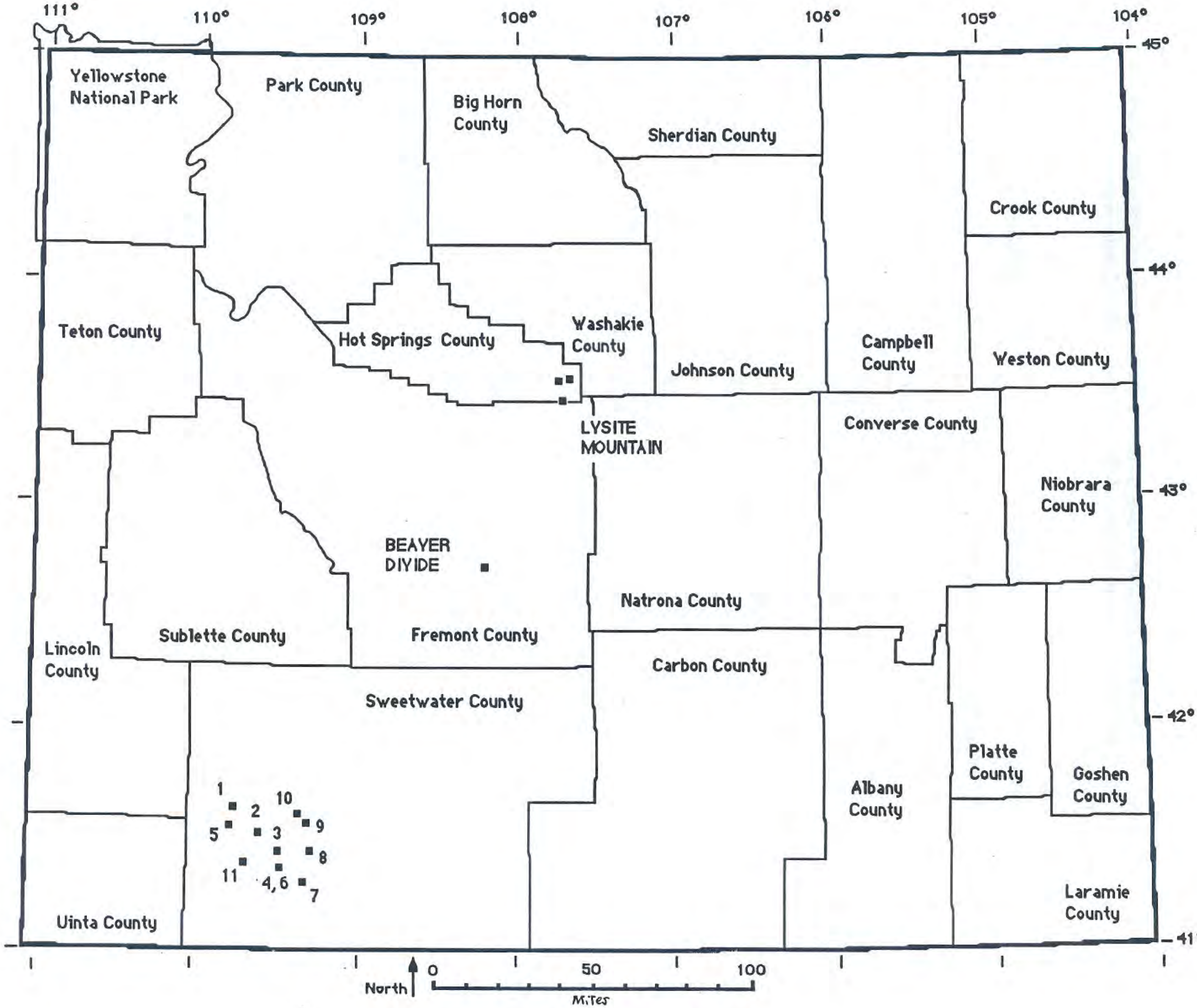
111°
110°
109°
108°
107°
106°
105°
104°
45°
44°
43°
42°
41°
Yellowstone National Park
Park County
Big Horn County
Sherdian County
Crook County
Teton County
Hot Springs County
Washakie County
Johnson County
Campbell County
Weston County
LYSITE MOUNTAIN
Converse County
Niobrara County
BEAVER DIVIDE
Natrona County
Lincoln County
Sublette County
Fremont County
Carbon County
Sweetwater County
Platte County
Goshen County
Albany County
Laramie County
Uinta County
1
2
3
4,6
5
7
8
9
10
11
North
0
50
100
Miles

Fig 7

Table 9. Locations of occurrences of rare earth-bearing minerals and sites of rare earth enrichment in the Wilkins Peak member of the Green River Formation.

No.*	Name	Location	Comments
Confirmed mineral occurrences (Love, 1964)			
1	FMC Westvaco mine	sec. 15, T19N, R110W (shaft location); in trona bed 17	also green minerals in soda ash waste
2	Diamond Alkali Co. DACO No. 3	NW1/4NW1/4 sec. 17, T18N, R108W in zone 1 in basal Wilkins Peak	at 1369 feet deep in lean uraniferous phosphatic rock
3	J.M. Perkins Green River No. 3	SW1/4 sec. 8, T17N, R107W in zone 1 in basal Wilkins Peak	at 1784 feet deep in uraniferous phosphatic rock
4	Diamond Alkali Co. Reid No. 2	SE1/4SE1/4 sec. 32, T17N, R107W in zone 1 in basal Wilkins Peak	at 1422.5 feet deep in uraniferous phosphatic rock
Unverified mineral occurrence (Milton and others, 1965; Fahey, 1962)			
5	Mountain Fuel Supply Co. John Hay Jr. No. 1	SW1/4NW1/4 sec. 2, T18N, R110W near trona bed 17 (bed 17 at depth of 1590 feet)	at uncertain depth
Sites of rare earth enrichment; all in uraniferous phosphatic rock (Love, 1964, after table 17; Mott, 1978)			
6	Diamond Alkali Co. Reid No. 2	SE1/4SE1/4 sec. 32, T17N, R107W in zone 2a in basal Wilkins Peak	1 sample at 1331 feet deep
7	South Firehole Canyon	SE1/4 sec. 20, T16N, R106W in zone 2a in basal Wilkins Peak	2 surface samples
8	Oro and Lulu claims, and both Ridge sites	secs. 10, 11, 14, T17N, R106W in zone 1 in basal Wilkins Peak	5 surface samples
9	Old Log Inn and Northeast area	secs. 12, 25, T18N, R106W in zone 1 in basal Wilkins Peak	2 surface samples
10	White Mountain No. 1 corehole	NW1/4SW1/4 sec. 7, T18N, R106W	1 sample at 831.5 feet deep
11	UP corehole 41-23	NE1/4NE1/4 sec. 23, T17N, R109W	1 sample at 1878 feet deep

* Number on Figure 7.

Exposed Eocene, lacustrine, uraniferous phosphatic zones along the Beaver Divide and on Lysite Mountain are also enriched in rare earths, but no rare earth-bearing minerals have been reported (Figure 7). In these two areas, six semiquantitative spectrographic analyses have been performed. The lone sample from Beaver Divide appears to contain more than 2500 total REE (700 ppm La and Ce, 300 ppm Y and Nd) with 5.67 percent P_2O_5, and is in Aycross equivalent rocks (sec. 34, T.32N., R.89W.). The five samples from the Lysite Mountains area (sec. 20, T.42N., R.90W.; sec. 34, T.42N., R.91W.; sec. 10, T.40N., R.91W.) are on average not notably enriched in rare earths, except for 300 ppm Ce, and 150 ppm Nd. The phosphate contents of these samples vary from 2.28 to 5.94 percent P_2O_5 (after Love, 1964). The Lysite Mountain surface samples are from the Tepee Trail and possibly Aycross equivalent rocks (Love, 1964). As with the other Eocene uraniferous phosphatic rocks, rare earth mineralization might be more widespread than just the localities shown in Figure 7.

9-1) FMC Westvaco mine
shaft location--sec. 15, T.19N., R.110W. (Love, 1964)

Love (1964) reported a green mineral, like that found in uraniferous phosphatic zone 1 in three cores of the Green River Formation, in trona in this mine. The green mineral is associated with labuntsovite {$(K,Ba,Na,Ca,Mn)(Ti,Nb)(Si,Al)_2(O,OH)_7 \cdot H_2O$} and leucosphenite {$(Ca,Ba,Na_3,B)Ti_3Si_9O_{29}$}. The exact sample site is not known nor is the abundance. This trona bed directly overlies uraniferous phosphatic zone 5 (Love, 1964), making it trona bed 17. The work of Milton and others (1965), with information from Love (1964) implies that the rare earth mineral is mckelveyite.

Donnay and Donnay (1971) identified intergrown mckelveyite and ewaldite from a sample containing a green mineral that was found in the waste of the soda ash refining process at the mine. They state that Milton supplied the sample. This may or may not be the same mineral; it could be modified by the soda ash refining process.

9-2) Diamond Alkali Co. DACO 3
NW1/4NW1/4 sec. 17, T.18N., R.108W. (Love, 1964)

In the Green River Formation, a two foot sample of uraniferous phosphatic zone 1 at a depth of 1,369 feet contained 0.006 percent cU (0.007 % eU) and only 1.25 percent P_2O_5. A rare earth bearing mineral was also noted in the sample, but was extracted prior to analysis (Love, 1964). Milton and others (1965) report that the rare earth mineral is mckelveyite, while the work of Donnay and Donnay (1971) implies that the mineral was intergrown mckelveyite and ewaldite.

9-3) J.M. Perkins Green River No. 3
SW1/4 sec. 8, T.17N., R.107W. (Love, 1964)

A two foot sample from uraniferous phosphatic zone 1 in the Green River Formation at a depth of 1,784 feet contained a rare earth mineral which was removed prior to chemical analysis. An assay of this zone 1 sample showed less than 0.001 percent cU (0.005 % eU) and less than 0.05 percent P2O5 (Love, 1964). The work of Milton and others (1965), with information from Love (1964) implies that the rare earth mineral is mckelveyite, while the work of Donnay and Donnay (1971) implies that the mineral was intergrown mckelveyite and ewaldite. Fitzpatrick and Pabst (1977) identified the rare earth mineral in this well as burbankite (see also Fitzpatrick, 1976).

9-4 & 9-6) Diamond Alkali Co. Reid No. 2 SE1/4SE1/4 sec. 32, T.17N., R.107W. (Love, 1964)

Uraniferous phosphatic zone 1 at a depth of 1,422.5 feet is 2 feet thick, and contained 0.005 percent cU (0.007 % eU) and only 0.22 percent P2O5. A rare earth mineral was present in the sample, but was extracted prior to chemical analysis. Uraniferous phosphatic zone 2a is 2 feet thick at a depth of 1,331 feet and contains 0.021 cU (0.032 % eU) and 5.34 percent P2O5. Both zones are in the Green River Formation. A sample was taken from zone 2a in this well and it was analyzed spectrograghically. This and other semiquantitative spectrographic analyses indicate that on average rare earth enrichment of >150 ppm Y and Nd is present in uraniferous phosphatic zone 2a (Love, 1964). The work of Milton and others (1965) with information from Love (1964) implies that the rare earth mineral is mckelveyite, while the work of Donnay and Donnay (1971) implies that the mineral was intergrown mckelveyite and ewaldite.

9-5) Mountain Fuel Supply Company--John Hay Jr. No. 1 SW1/4NW1/4 sec. 2, T.18N., R.110W. (Fahey, 1962)

Milton and others (1965) report a green mineral, like that that they identified as mckelveyite, in core from this hole. The occurrence is unverified because Milton and others (1965) place the hole at the Westvaco mine, their description is similar to that by Love (1964) for the Westvaco mine, and Love (1964) does not note the occurrence of this mineral in the Hay no. 1 well. Milton and others (1965) place their sample depth in this well at 1557 feet, near the main trona bed. In this well, the main trona bed [17] is actually at a depth of about 1590 to 1600 feet, and a 13-inch-thick, brown, organic trona begins at 1557 feet (Fahey, 1962).

9-6) **see 9-4**

9-7) Locality L-32 (South Firehole Canyon) center SE1/4 sec. 20, T.16N., R.106W. (Love, 1964)

At this locality, two samples of uraniferous phosphatic zone 2a in the Green River Formation taken 0.3 miles apart contained 0.009 percent cU (0.015 and 0.016 % eU), and 3.1 and 10.56 percent P2O5. A sample was taken from zone 2a at this locality and it was analyzed spectrograghically. This and other semiquantitative spectrographic analyses indicate that on average rare earth enrichment of >150 ppm Y and Nd is present in uraniferous phosphatic zone 2a (Love, 1964).

9-8) Locality L-22 (Lulu claim no. 2) NE1/4SW1/4 sec. 10, T.17N., R.106W. (Love, 1964)

At this locality, uraniferous phosphatic zone 1 in the Green River Formation averaged three feet thick and assayed from <0.001 to 0.04 percent cU (0.001 to 0.06 % eU) and 0.05 to 12.9 percent P2O5. A sample was taken from zone 1 at this locality and it was analyzed spectrograghically. This and other semiquantitative spectrographic analyses indicate that on average rare earth enrichment of >1000 ppm total REE is present in uraniferous phosphatic zone 1 (Love, 1964). Morris and Stanley (1982) report that a sample of limonite-stained, calcareous siltstone from this portion of section 10 contained 800 ppm cU3O8. They call the sample a phosphorite without any phosphate analysis.

9-8) Localities L-24, L-24B, and L-25 (Ridge and North Ridge sections) sec. 11, T.17N., R.106W. (Love, 1964)

At these localities, uraniferous phosphatic zone 1 in the Green River Formation contains from 0.001 to 0.15 percent cU (0.002 to 0.16 % eU) and 0.15 to 18.2 percent P2O5. Zone 1 varies from 1 to 7 feet thick. A sample was taken from zone 1 at each these localities and they were analyzed spectrograghically. These and other semiquantitative spectrographic analyses indicate that on average rare earth enrichment of >1000 ppm total REE is present in uraniferous phosphatic zone 1 (Love, 1964).

9-8) Locality L-28 (Oro claim no. 1) SW1/4NW1/4 sec. 14, T.17N., R.106W. (Love, 1964)

At this locality, uraniferous phosphatic zone 1 in the Green River Formation contains 0.024 to 0.12 percent cU (0.025 to 0.1 % eU) and 1.6 to 4.44 percent P2O5. The unit varies from 0.5 to 3 feet thick. A sample was taken from zone 1 at this locality and it was analyzed spectrograghically. This and other semiquantitative spectrographic analyses indicate that on average rare earth enrichment of >1000 ppm total REE is present in uraniferous phosphatic zone 1 (Love, 1964).

9-9) Locality L-5 (Old Log Inn) NW1/4NW1/4NE1/4 sec. 12, T.18N., R.106W. (Love, 1964)

At this locality, uraniferous phosphatic zone 1 in the Green River Formation is 4 feet thick and a sample contained 0.081 percent cU (0.073 % eU) and 15.4 percent P2O5. A sample was taken from zone 1 at this locality and it was analyzed spectrograghically. This and other semiquantitative spectrographic analyses indicate that on average rare earth enrichment of >1000 ppm total REE is present in uraniferous phosphatic zone 1 (Love, 1964).

9-9) Localities L-14 (northeast Wilkins Peak); SE1/4NW1/4SW1/4 sec. 25, T.18N., R.106W. (Love, 1964)

At this locality, uraniferous phosphatic zone 1 in the Green River Formation contains 0.009 to 0.068 percent cU (0.12 to 0.068 % eU) and 0.42 to 6.5 percent P2O5. The zone is 3 to 8.5 feet thick. A sample was taken from zone 1 at this locality and it was analyzed spectrograghically. This and other semiquantitative spectrographic analyses indicate that on average rare earth enrichment of >1000 ppm total REE is present in uraniferous phosphatic zone 1 (Love, 1964).

9-10) White Mountain no. 1 corehole
NW1/4SW1/4 sec. 7, T.18N., R.106W. (Mott, 1978)

In this well, three horizons in the Wilkins Peak member of the Green River Formation were uraniferous (>50 ppm U). Of these horizons, one also contained rare earth enrichment. A 1.8 foot thick sample of mudstone at a depth of 831.5 feet contained 60 ppm uranium, 100 ppm La and 200 ppm Y, with 2.95 percent P2O5 (Mott, 1978).

9-11) UP corehole 41-23 NE1/4NE1/4 sec. 23 T.17N., R.109W. (Mott, 1978)

In this well, three horizons in the Wilkins Peak member of the Green River Formation were uraniferous (>50 ppm U). Of these horizons, one also contained rare earth enrichment. A 0.4 foot sample of mudstone and oil shale at a depth of 1,878 feet contained 195 ppm U, 500 ppm Y, <20 ppm La, 1.35 percent P2O5 and 3.36 percent organic carbon (Mott, 1978). The 500 ppm Y might be a typographic error (50 not 500) given the low lanthanum concentration.

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