THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

OPEN FILE REPORT 87-6

COLUMBIUM (NIOBIUM) AND TANTALUM IN WYOMING

by

Ray E. Harris and Jonathan K. King

Laramie, Wyoming
1987

This report has not been reviewed for conformity with the editorial standards of the Geological Survey of Wyoming.

Table of contents

Illustrations

Figures

Tables

INTRODUCTION

Columbium and tantalum are two closely related metallic elements. They have similar physical and chemical properties and often occur together in nature. Chemists use the term niobium in place of columbium. Columbium and tantalum are found in the greatest abundance in alkali syenites, alkali granites, carbonatites, pegmatites, and fossil and modern placers. The majority of the world's tantalum production has been as a by-product from modern tin placers in Thailand and Malaysia and modern titanium-bearing black-sand beach placers in Australia. Most of the columbium production has come from pyrochlore-bearing carbonatites in Brazil and as a by-product from southeast Asian tin placers (Cunningham, 1985a, 1985b).

The common columbium- and tantalum-bearing minerals are pyrochlore-microlite (originally spelled mikrolite), columbite-tantalite, euxenite, and samarskite. Pyrochlore-microlite and columbite-tantalite are solid-solution series between columbium-rich (pyrochlore, columbite) and tantalum-rich (microlite, tantalite) end members. All the minerals but the columbite-tantalite series are titanium-bearing, and can contain thorium and rare earths. The composition of the minerals is quite variable, and the radioactive elements in the minerals often destroy their physical structure, producing metamict minerals. The exact mineralogy of columbium-tantalum-bearing minerals is often indecipherable due to this variable composition and structural destruction.

Columbium is used primarily as an alloying agent to produce corrosion resistant and heat tolerant steels. These alloy steels are used for construction (40 percent), transportation (primarily aircraft components) (27 percent), in the oil and gas industry (refinery parts and cracking agents) (11 percent), and in other applications (for example electronic components) (11 percent). Demand for columbium in the United States has been weak recently due to the overall low demand for steel (Table 1). The price of concentrated columbium ore (columbium and pyrochlore) reflects the weakening demand over the last five years (Table 2) (Cunningham, 1986a).

Tantalum is used primarily in alloy steels. Tantalum alloy steels are used in electronic components (63 percent), and in corrosion resistant and heat tolerant alloy steels (primarily aircraft components) (31 percent). Domestic consumption of tantalum had been increasing due to its "high-tech" applications until the recent slump in the electronics industry (Table 1). The price of tantalum ore has fallen significantly in the past five years (Table 2) (Cunningham, 1986b), probably because it is a by-product of increased titanium production. This increase in titanium production has produced surplus tantalum. The price of tantalum ore, however, is higher than that of columbium ore because tantalum is less abundant than columbium.

Table 1. Domestic columbium and tantalum consumption 1981-1985 (in short tons) (Cunningham, 1986a, b).

Year	Columbium	Tantalum
1981	4,059	631
1982	3,300	530
1983	2,875	590
1984	3,835	840
1985	2,850	600

Table 2. Price of columbium and tantalum ore concentrates 1981-1985 (in U.S. dollars/pound) (Cunningham, 1986a,b).

Year	Columbium	Pyrochlore (columbium ore)	Tantalum
1981	9.83	3.25	81.50
1982	8.88	3.25	40.90
1983	6.00	3.25	25.06
1984	5.50	3.25	30.66
1985	4.25	3.25	27.00

Production and resources of columbium and tantalum in the United States are limited. Small known reserves are located in modern and Pleistocene titanium-bearing beach placers in Florida and Georgia, pegmatite-derived stream placers in Idaho, carbonatites and carbonatite-related rocks in Colorado and Arkansas, and in pegmatites in South Dakota and New Mexico. The last domestic production of columbium and tantalum was in 1982. The U.S. is now entirely dependent on imports of these elements from foreign countries. These supplies are in turn largely dependent on the production of tin and titanium.

Columbium and tantalum resources in Wyoming have not been adequately assessed. The possible sources of these elements are diverse (see Figures 1 and 2 for locations). Known resources are limited to pegmatites. The total production from pegmatites in Wyoming is around 11,000 pounds of columbium- and tantalum-bearing minerals (Hanley and others, 1950; Houston, 1961; Platt, 1986). Columbium and tantalum are also present in carbonatites and related rocks in the northern Black Hills, and in titanium-bearing, black-sand beach placers of Late Cretaceous age that are scattered throughout Wyoming. Preliminary studies indicate that the concentrations of columbium and tantalum in these occurrences are high enough that further study is warranted (Staatz, 1973; Houston and Murphy, 1962; Welch, 1974; Madsen, 1983).

The alkalic syenites in the Laramie Range anorthosite complex are another possible source of columbium and tantalum. This possible source has not been tested.

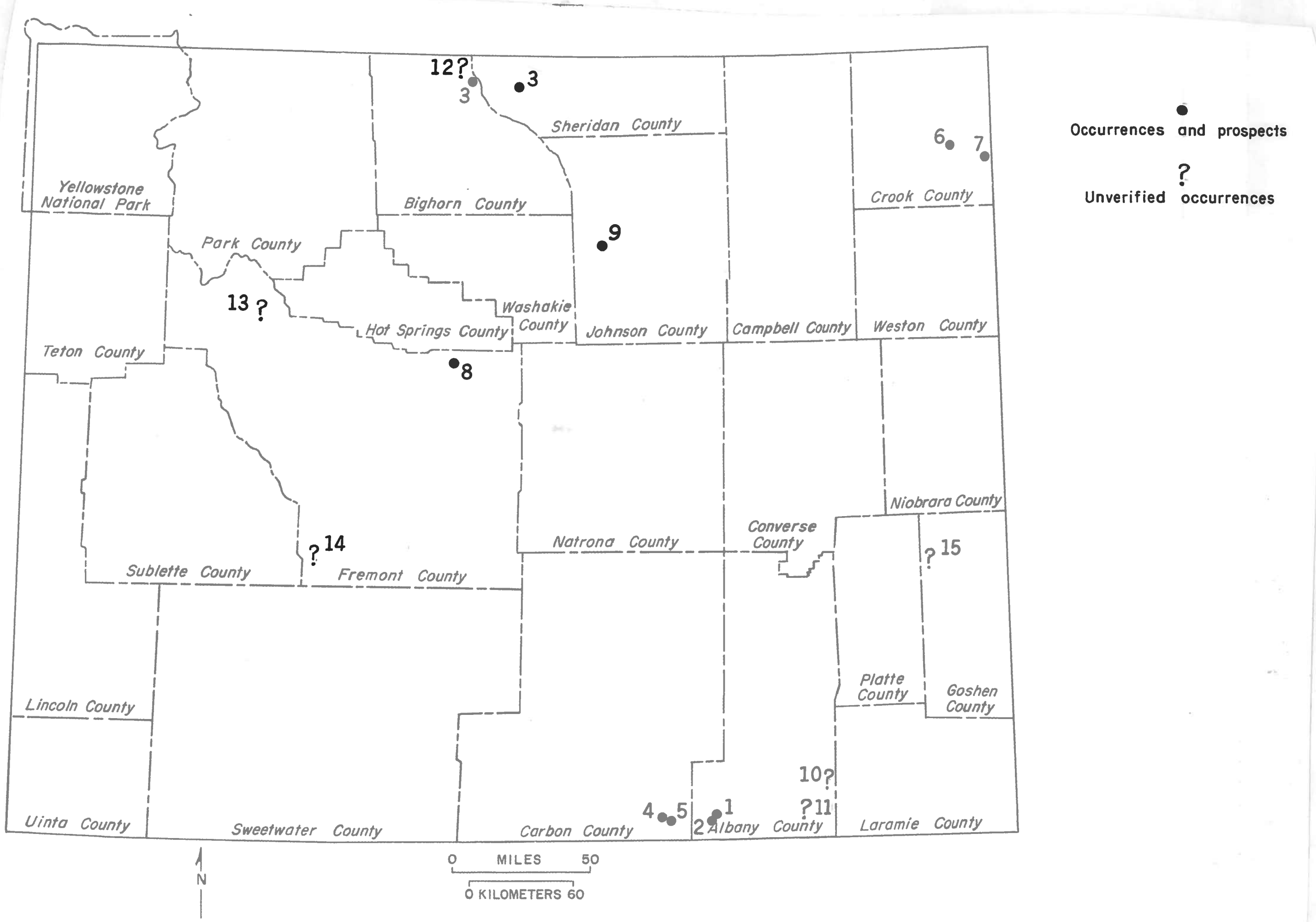

Figure 1. Locations of columbium and tantalum occurrences and prospects in Wyoming, exclusive of Mesozoic beach placer locations.

1. Fox Creek area
2. Many Values and Ione prospects
3. Northern Bighorn Mountains
4. Platt pegmatite
5. Big Creek pegmatite area
6. Bear Lodge Mountains
7. Mineral Hill area
8. Bonneville no. 1 and no. 8 claims
9. Beaver Creek allanite prospect
10. Middle Lodgepole Creek area
11. Tie Siding area
12. Rainbow claims
13. East Fork of Wind River
14. Anderson Ridge Quadrangle
15. Ruth prospect

PROSPECTS AND OCCURRENCES
(exclusive of Mesozoic black-sand beach placers)

The Mesozoic beach placers are discussed in a specific section following the information on other prospects and occurrences.

Albany County

Fox Creek area — SW1/4SE1/4 sec. 13, T.13N., R.78W.
NE1/4 sec. 24, T.13N., R.78W.

Orback (1960) reports that two of the Precambrian pegmatites in this area contain traces of columbium. Both these pegmatites are poorly exposed. The pegmatite in Section 13 is cross-cut by a small quartz vein (six to eight inches wide) that contains about one percent columbite. This pegmatite is mapped as 1,300 feet long and up to 200 feet wide. The other columbium-bearing pegmatite (in Section 24) is 2,100 feet long and less than 50 feet wide (Orback, 1960). Although Orback (1960) also mapped a 1,000 feet long, up to 50 feet wide quartz vein that cross-cut the pegmatite in Section 13, he contradictorily noted in his text that all quartz veins are only six to 12 inches wide. The pegmatite in Section 24 is apparently like unmineralized pegmatites in the area while the one in Section 13 is less resistant to erosion and much wider than other unmineralized pegmatites in this area. Therefore, the relative erosional resistance and size of the pegmatites cannot be used as an indication of columbium mineralization.

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

This prospect is developed in a poorly exposed pegmatite in Precambrian schists and gneisses. The location is from Beckwith (1937). Beckwith 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 (Hanley and others, 1950). Minor tantalite and possibly fergusonite were identified in the pegmatite in 1942. Eighty-five pounds of tantalite were produced from the pegmatite (Hanley and others, 1950; Beckwith, 1937, see also Hagner, 1942a).

Big Horn and Sheridan Counties

Northern Bighorn Mountains — Sec. 26, T.56N., R.92W.
Secs. 10 and 11, T.55N., R.89W.
Approx. sec. 6, T.55N., R.88W., unsurveyed.
Secs. 31 and 32, T.56N., R.88W., unsurveyed.

Tantalite and tapiolite are present in poorly exposed, Precambrian metamorphosed and unmetamorphosed dikes near Burgess Junction and Medicine Mountain. These minerals were identified through microscopic examinations and confirmed by x-ray diffraction. Traces of columbium are also present in the dikes. The dikes have roughly northeast-southwest and northwest-southeast trends. The dikes vary in composition from quartz diorite to metapyroxenite. The tantalum minerals appear to be concentrated in the more mafic rocks (Harris, 1987b; see also Ross and Heimlich, 1972; Manzer and Heimlich, 1974). One tantalite crystal, taken from a dike south of Medicine Mountain, was peanut sized (John Sans, personal communication, 1984).

Limited analytical data show that the amount of tantalum within the dikes is extremely variable. Concentrations in the rocks analyzed to date vary from less than five ppm to about 2,450 ppm tantalum oxide and from no detectable columbium oxide to about 740 ppm columbium oxide (Harris, 1987b).

Carbon County

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

This zoned pegmatite 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) and columbite are most abundant in the center of the pegmatite and in gash veins. In order of abundance, these minerals are "euxenite", monazite, and columbite. These minerals are for the most part metamict so that x-ray identifications are suspect. Some crystals of each of these minerals reportedly exceeded three inches in length. The "euxenite" is most probably samarskite or a columbium-rich yttrium-bearing tantalite based on its chemical composition and x-ray pattern. This mine produced the greatest amount of columbium and tantalum in Wyoming (10,000 pounds "euxenite"; 200 pounds columbite) (after Houston, 1961a, 1961b; Platt, 1986).

Samarskite is reported from a granite on the King claims in Section 32 of the same township (Gruner and Knox, 1956). This occurrence probably refers to the Platt pegmatite because (1) there are no granites in Section 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.

Big Creek pegmatite area — Approximately sec. 19, T.13N., R.80W. and sec. 22, T.13N., R.81W.

A sketch map by Houston (1961) shows columbium-bearing pegmatites at these locations. This is the only information available on these localities.

Crook County

Bear Lodge Mountains — Roughly T.52N., R.63W.

The southern portion of these mountains contains Tertiary trachytes, phonolites, and carbonatites which intrude lower Paleozoic sedimentary rocks. These igneous and sedimentary rocks are enriched in rare earths, thorium, uranium, and columbium. Columbium-bearing minerals have not been identified, but concentrations of up to 3,000 ppm elemental columbium have been reported. These rocks have not been analyzed for tantalum (Staatz, 1983; Staatz and others, 1980). This area has only been evaluated for its rare earth, thorium, and uranium potential. These elements apparently occur in a porphyry deposit that is physically similar to porphyry copper deposits. In these porphyry-type mineral deposits, minerals are disseminated in extensive systems of microfractures. 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, crystobalite, and sometimes altered trachyte and phonolite, fluorite, and(or) calcite are also present in the veins and veinlets. The columbium concentration apparently has no correlation with the rare earth, thorium, or uranium concentrations (Staatz, 1983; Staatz and others, 1980; Wilmarth and Johnson, 1953). Jenner (1984) described carbonatites south of these previously examined areas. Gold mineralization might be present in this porphyry deposit (Dewitt and others, 1986).

The published information about this district coupled with the common association of columbium and tantalum with silicic alkalic rocks and carbonatites means the Bear Lodge Mountains are an unexplored, potentially economic source of columbium and tantalum. An evaluation of the combined value of gold, thorium, rare earths, strontium, columbium, and tantalum in the Bear Lodge igneous complex and surrounding sedimentary units is needed.

Mineral Hill (Tinton, Negro Hill) area Wyoming and South Dakota

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 cassiterite-, spodumene-, and columbium-tantalum-bearing Precambrian pegmatites as well as barren Precambrian pegmatites that are elongate roughly parallel to the foliation in the schists (Welch, 1974; Smith and Page, 1940). Gold is present in both the Precambrian schists and Tertiary intrusive complex (Norby, 1984; Welch, 1974).

This area encompasses three separate sites of columbium and tantalum mineralization. An alkalic intrusive complex underlies Mineral Hill on the western edge of the Tinton mining district in Wyoming. The Mineral Hill area also contains placer deposits. Negro Hill, an area of mineralized pegmatites, straddles the state line within the Tinton mining district.

Mineral Hill intrusive complex, Wyoming — Roughly T.51N., R.60W. and N1/2 T.50N., R.60W.

The Mineral Hill intrusive complex has not been adequately sampled to determine gold, rare earths, columbium, or tantalum contents. The concentrations of rare earths and columbium were low in the single analysis reported. Gold values vary from 0.5 to 10's of ppm (Welch, 1974). Considering the possible presence of carbonatite and a gold- and columbite-tantalite-bearing Precambrian basement, the intrusive complex could contain resources of columbium, tantalum, rare earths, and gold.

Mineral Hill area placers — Approximately center sec. 20, and NW1/4 sec. 28, T.51N., R.60W.

Columbite-tantalite-, gold-, and tin-bearing placers are present in the Mineral Hill area in Wyoming. However, the known placers are upstream from the Federal Fish Genetics Lab (Welch, 1974), and this may preclude production from the placers. Welch (1974) reports the placer one-half mile below the junction of Spotted Tail and Sand Creeks (Section 20) was worked prior to 1960 and contained 1.34 pounds/cubic yard columbite-tantalite as well as gold and tin. The other placers, above Sand Creek Crossing (Section 28; Section 8 [sic] in the text of Welch, 1974) is about 2,000 feet long, 300 feet wide, and may be more than 40 feet thick (Welch, 1974).

Negro Hill pegmatites in Wyoming E1/2SE1/4 sec. 21, T.51N., R.60W.

A few tin-bearing pegmatites are present in the Wyoming portion of the Negro Hill area, but all the mining of pegmatites occurred in South Dakota. Columbite-tantalite is spatially associated with cassiterite and spodumene in the pegmatites, but the amounts are apparently inversely proportional. The presence of columbite or tantalite in the Wyoming portion of this area is not certain. Claim holders have reported tantalite on their claims in Wyoming, but this was not confirmed by independent examinations (after Smith and Page, 1940; Johnson, 1938b; Gardner, 1939). Because the abundance of tin and columbite-tantalite are inversely proportional, the limited amount of tin in the pegmatites located in Wyoming (Gardner, 1939) implies that the Wyoming pegmatites should be rich in columbium or tantalum. For this reason a reexamination of the pegmatites in Wyoming is needed.

Fremont County

Bonneville no. 1 claim (Whippet no. 1 prospect) Center sec. 28, T.40N., R.93W.

This claim on the southern flank of the Owl Creek Mountains contains tantalum- and columbium-bearing pegmatites. In the 1970s feldspar was produced from a pit on the claim. Beryl and columbium-tantalum-bearing minerals were being hand-cobbed on the claim in 1986. The pegmatites are concordant with the foliation in the enclosing Precambrian metamorphic rocks. The sizes of the pegmatites are uncertain; estimates vary from 50 to 60 feet wide and from 320 to over 500 feet long. The pegmatites contain pyrochlore-microlite, tapiolite, beryl, and lepidolite. Tantalite crystals up to one by four by four inches in size have been found on this claim (after Harris, 1987a; Hanley and others, 1950; McLaughlin, 1940).

Bonneville no. 8 claim (Whippet no. 8 prospect) SW1/4SW1/4SW1/4 sec. 22 and NW1/4NW1/4NW1/4 sec. 27, T.40N., R.93W.

A tantalum- and columbium-bearing pegmatite is present on this claim on the southern flank of the Owl Creek Mountains. The pegmatite is elongate parallel to the foliation in the adjacent Precambrian metamorphic rocks. The size of the pegmatite is not certain. It is apparently 20 to 30 feet wide at its thickest point and thins to a wedge edge. The pegmatite is at least 400 feet long and might be over 700 feet long. Columbite-tantalite, pyrochlore-microlite, tapiolite, beryl, and petalite are present in the pegmatite (Harris, 1987a; Hanley and others, 1950; McLaughlin, 1942). In 1942, columbium-tantalum-bearing minerals were quite abundant in a 200 feet long, two feet wide zone in the northeastern portion of the pegmatite. At least 250 pounds of tantalum-rich minerals had been removed from this zone prior to 1942 (Hanley and others, 1950).

Reserve estimates in 1942 were 1,375 pounds of tantalite (Hanley and others, 1950; see also Hagner, 1942b). Harris (1987a) reported a zone 50 or more feet long and three feet wide that contained 20 percent tantalum-rich minerals, identified as tapiolite by x-ray diffraction. Kopp (1965) reports some portions of the pegmatite contain 20 to 30 pounds of tantalite per ton of pegmatite. The grade and reserve estimates, however, are not accurate because the entire pegmatite has not been examined in detail or in three dimensions.

Well-formed crystals of several minerals in this pegmatite are suitable for mineral specimens. Aquamarine beryl crystals were being hand-cobbed for this purpose in 1986. Tapiolite crystals up to one-half by one-quarter inch in size and fan-shaped aggregates of columbite-tantalite crystals up to one inch in diameter are present in the pegmatite. The pegmatite also contains petalite crystals measuring one by three by four inches in size (Harris, 1987a).

Johnson County

Beaver Creek allanite prospect (Lyle Ramsbottom property) SE1/4SW1/4 sec. 31, T.47N., R.83.W.

Armbrustmacher and Sargent (1982) report 1,000 ppm columbium oxide in a sample of metamorphosed calc-silicate rock from this site in the southern Bighorn Mountains. The sampled unit is a small, Precambrian calc-silicate body that is concordant with the foliation in the enclosing Precambrian quartz-feldspar gneiss. The body is from a few inches to six feet wide and extends for about 3,750 feet across the southern half of Section 31 into the northeast quarter of Section 6 and northwest quarter of Section 5 (T.46N., R.83W.). Columbium-bearing minerals have never been reported at this site. The interest in this property has been for allanite (a uranium-, thorium-, and rare-earth-bearing silicate mineral). The exact origin of the columbium, uranium, thorium, and rare-earth enrichment is not known, but it is thought to be related to regional metamorphism during Precambrian time (Wilson, 1952; Magleby, 1952; Sargent, 1960; Armbrustmacher and Sargent, 1982). The columbium content in the calc-silicate body, based on four samples, varies from 30 to 1,000 ppm elemental columbium and is inversely related to the concentrations of rare-earth elements in the body. No tantalum was found. Columbium and tantalum (if present) might be produced as a by-product to the estimated 18,250 tons of rare earths present in the calc-silicate body (Armbrustmacher and Sargent, 1982).

UNVERIFIED OCCURRENCES

(exclusive of Mesozoic beach placers)

Unknown Location

Eight hundred pounds of samarskite were reportedly shipped to California from an undisclosed location in Wyoming in 1930 (Marzel, 1933).

Albany County

Ione (Funk Mica) prospect E1/2NE1/4SW1/4 sec. 32, T.13N., R.78W.

Beckwith (1937) reports two pegmatites in Precambrian rocks at this location. A western one is 450 feet long with a maximum width of 25 feet and an eastern one is 800 feet long with a maximum width of 80 feet. He noted workings on the eastern pegmatite and implies tantalite is present in this pegmatite. However, later workers did not report tantalite in place in the pegmatite (Hanley and others, 1950; Hagner, 1942c). This prospect is adjacent to and west of the Many Values prospect (page 5).

Middle Lodgepole Creek area Sec. 2, T.15N., R.71W.

A 75 feet wide euxenite(?)-bearing pegmatite that cuts Precambrian granite is reported at this location (Wilson, 1961). Euxenite was not seen during an examination in 1978, but high radioactivity is reportedly associated with biotite in this pegmatite. A sample of the pegmatite contained only 50 ppm elemental columbium (Griffin and Warner, 1982).

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

Many pegmatites are present in the Precambrian Sherman Granite near Tie Siding. Pyrochlore is reported in one pegmatite in this area (Smith, 1954). Smith's (1954) map implies this pegmatite is in the west half of the southwest quarter of Section 29 (T.13N., R.72W.). During an examination in 1978 by Griffin and Warner (1982), columbium- and tantalum-bearing minerals were not noted, but high radioactivity reportedly was associated with biotite. Two pegmatites sampled during the 1978 examination contained more columbium than others in the area. These pegmatites contained 1,000 ppm (SW1/4NE1/4 sec. 6, T.12N., R.71W.) and 200 ppm elemental columbium (SE1/4SW1/4 sec. 2, T.12N., R.72W.) (Griffin and Warner, 1982).

Big Horn County

Rainbow claims Location estimated as T.58N., R.82W., unsurveyed

Parker (1963) reports euxenite in a pegmatite on these claims in the northern Bighorn Mountains. His location is just east of Cookstove Basin where radioactive pegmatites are present. The location given is for the Cookstove Basin.

Fremont County

East Fork of Wind River Mostly sec. 30, T.43N., R.109W.

Ely (1971) reports columbium and tantalum in a pegmatite mined for feldspar. The pegmatite is in Precambrian gneiss and granite.

Anderson Ridge Quadrangle NW1/4SE1/4SW1/4 sec. 32, T.29N.,R.101W.

El-Etr (1963) reports very minor amounts of columbite in a pegmatite at this site.

Goshen County

Ruth prospect Center sec. 35, T.28N., R.65W.

This columbite(?)-bearing pegmatite is a concordant lens in Precambrian schists and gneisses; the lens is 155 feet long and as much as 80 feet wide (Hanley and others, 1950).

OCCURRENCES IN MESOZOIC BEACH PLACERS

Radioactive, titaniferous, black sandstones of Late Cretaceous age are present at many locations in Wyoming (Figure 2 and Table 3). These black sandstones have been interpreted as fossil placers and are known to contain columbium and rare-earth elements. Elemental columbium is present in an unknown opaque mineral that contains cerium and lanthanum. X-ray diffraction patterns from the columbium-bearing opaque mineral do not match those for columbite, tantalite, or euxenite (Houston and Murphy, 1962). Eighteen reliable analyses for columbium have been done on 15 sandstones (Table 3); the results vary from 10 to 126 ppm elemental columbium. These 15 black sandstones were not analyzed for tantalum (Madsen, 1982; Morris and Stanley, 1982; Garrand and others, 1982; Griffin and Milton 1982; Madsen and Reinhart, 1982).

None of the black sandstones have been systematically examined as a source for columbium, tantalum, and rare-earth resources. A systematic sampling program and chemical analyses are needed to determine the potential value of the black sandstones. Other unreported black sandstones may be found in the rock units shown on Figure 2. Occurrences of columbium, tantalum, and rare earths in these unreported black sandstones of Late Cretaceous age cannot be ruled out either.

Site 25 (Figure 2 and Table 3) is a Late Jurassic titaniferous, black sandstone of uncertain origin. It is not known if this black sandstone contains columbium, tantalum, or rare-earth elements (Houston and Love, 1956). The existence of this Jurassic black sandstone means additional black sandstones that are not Late Cretaceous in age may be present in Wyoming.

The information in Table 3 and on Figure 2 is from Houston and Murphy (1962, 1970); Houston and Love (1956); Dow and Batty (1961); Madsen (1982); Morris and Stanley (1982); Garrand and others, (1982); Griffin and Milton (1982); and Madsen and Reinhart (1982).

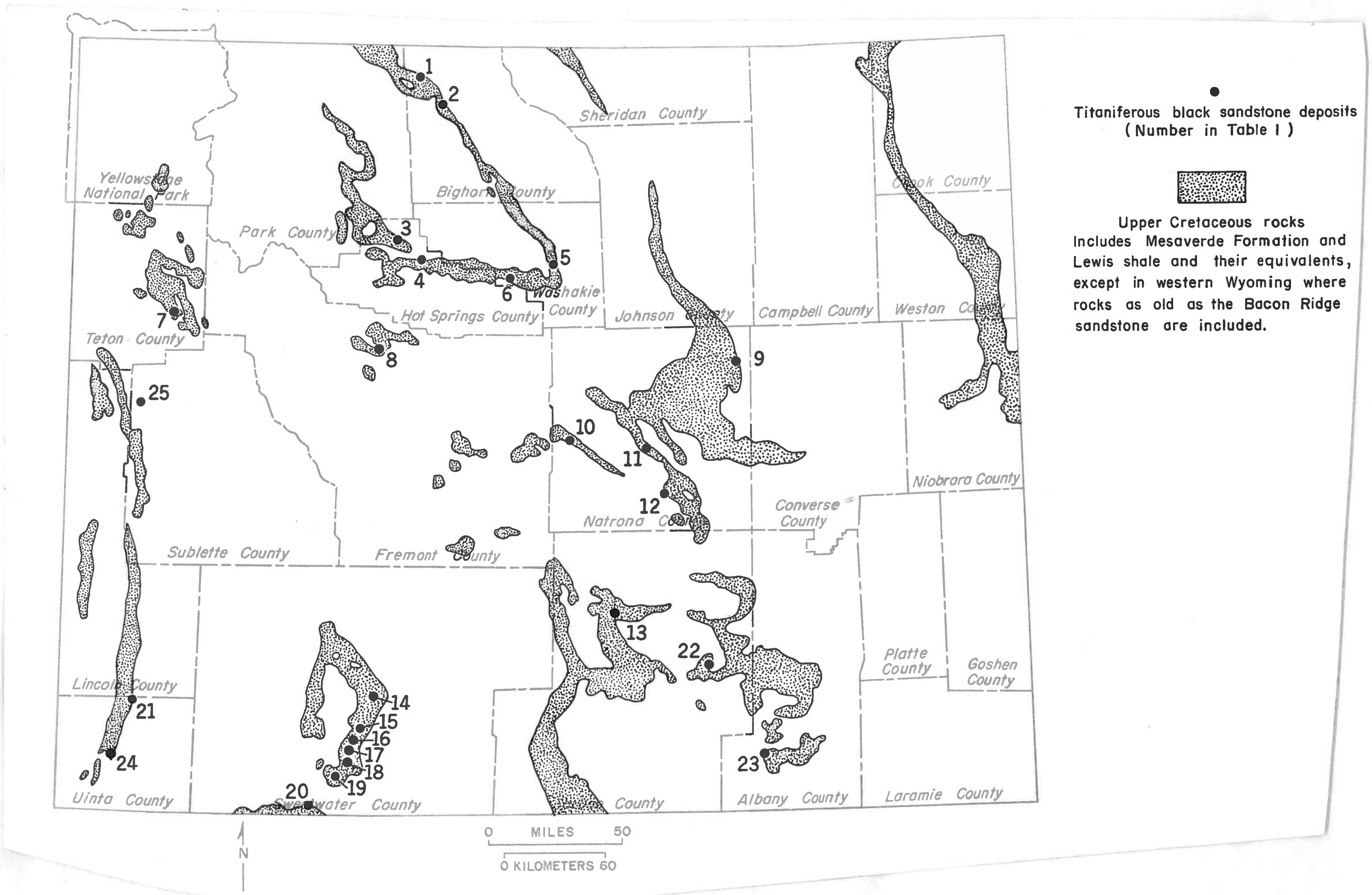

Figure 2. Locations of Mesozoic black sandstone (beach placer) depoists and outcrops of their host formations in Wyoming. Numbers refer to listings in Table 3.

Table 3. Mesozoic black sandstone (beach placer) deposits in Wyoming.

AREA	No.*	Location Section	T.N.	R.W.	Extent (feet) Length	Width	Thickness (feet) Maximum	Average	Columbium content (elemental) (ppm)
Cowley	1	1, 4	56	97	900+	Unknown	3.5	1	11- 30
Lovell	2	7	55	95	3,000+	Unknown	4.0	3	18
		12	55	96					
Grass Creek	3								
Northern segment		8, 9, 16	46	98	5,600+	680+	16.0	11	126
Southern segment		33, 34	46	98	Unknown	1,600	5.0+	Unknown	58
Cottonwood Creek	4	26	45	97	150	150	9.0	Unknown	42
Dugout Creek	5	34, 35	45	89	14,256	1,500+	25.0	11	10
		2, 11	44	89					
Mud Creek	6	19	44	91	1,500+	100+	7.5	Unknown	20
Dry Cottonwood Creek	7	27	42	112	Unknown	Unknown	Unknown	Unknown	
Shotgun Bench	8	18	5	1E.	Unknown	300	5.0	Unknown	
Salt Creek	9								
Northern segment		24, 25, 36	39	78	8,976+	Uknown	Unknown	Unknown	
		31	39	77					
Southern segment		19, 30	38	77	5,280+	750	Unknown	Unknown	
Coalbank Hills	10	5	34	88	1,400+	Unknown	5.0	Unknowm	
Poison Spider	11	1	33	84	300+	Unknown	7.0	Unknown	<10- 50
		36	34	84					
Clarkson Hill	12	20	31	82	150+	20+	5.6	Unknown	
Seminoe	13	35	25	85	Unknown	Unknown	Unknown	Unknown	
		15, 28	24	85					
Beacon	14	19	19	101	2,700	150	Unknown	7	50
Black Butte Creek	15	30	18	101	1,500+	Unknown	4.0	Unknown	50-100
Honnes Ranch	16	11	17	102	2,500	50-100	Unknown	4	50
Pretty Water Creek	17	8	16	102	450+	Unknown	Unknown	3	
Dans Creek	18	13	15	103	Unknown	250	Unknown	5.5	
Salt Wells Creek	19	7	14	103	250	Unknown	3.0	Unknown	50
Red Creek	20	22	12	105	800	Unknown	6.0	5	120
Cumberland Gap	21	25	18	117	13,200+	200	Unknown	Unknown	
		18, 19, 30	18	116					
Fiddler's Green	22	21	21	80	2,600	Unknown	13.0	Unknown	
Sheep Mountain	23	10	15	77	1,900	50	17.0	Unknown	62
Spring Gap	24	8, 17, 30	16	117	900+	30	Unknown	2.5	120
Cliff Creek	25	33	38	114	Unknown	Unknown	Unknown	4	

* = number on Figure 2.

REFERENCES

Armbrustmacher, T.J., and Sargent, K.A., 1982, Allanite-bearing calc-silicate rocks, southern Bighorn Mountains Wyoming - Geologic setting and resources of thorium, uranium, and rare-earth elements: U.S. Geological Survey Open File Report 82-298, 12 p.

Beckwith, R.H., 1937, The geology of the Muscovite and Ione mining claims: Geological Survey of Wyoming mineral report MR37-3 (unpublished), 5 p.

Cunningham, L.D., 1985a, Columbium *in* Mineral facts and problems, 1985 edition: U.S. Bureau of Mines Bulletin 675, p. 185-196.

Cunningham, L.D., 1985b, Tantalum *in* Mineral facts and problems, 1985 edition: U.S. Bureau of Mines Bulletin 675, p. 811-822.

Cunningham, L.D., 1986a, Columbium: U.S. Bureau of Mines Mineral Commodity Summaries 1986, p. 40-41.

Cunningham, L.D., 1986b, Tantalum: U.S. Bureau of Mines Mineral Commodity Summaries 1986, p. 158-159.

Dewitt, E., Redden, J.A., Wilson, A.B., Buscher, D. and Dersch, J.S., 1986, Mineral resource potential and geology of the Black Hills National Forest, South Dakota and Wyoming: U.S. Geological Survey Bulletin 1580, 135 p., 4 plates.

Dow, V.T., and Batty, J.V., 1961, Reconnaissance of titaniferous sandstone deposits of Utah, Wyoming, New Mexico, and Colorado: U.S. Bureau of Mines Report of Investigations 5860, 52 p.

El-Etr, H.A., 1963, Pegmatites of the Anderson Ridge Quadrangle, Fremont County, Wyoming: M.S. thesis, Univeristy of Missouri-Rolla, 102 p., 1 plate.

Ely, J.P., II, 1971, Mineral possibilities of the Arm, Pole Creek, and Gray Ghost claim groups, Fremont County, Wyoming: Geological Survey of Wyoming mineral report MR71-2 (unpublished), 19 p.

Gardner, E.D., 1939, Tin deposits of the Black Hills, South Dakota: U.S. Bureau of Mines Information Circular 7069, 78 p.

Garrand, M.S., Kopp, R.S., and Cohenour, R.E., 1982, National uranium resource evaluation, Cody Quadrangle, Wyoming: Department of Energy Report PGJ/F-43(82), 63 p., 7 sheets microfiche.

Griffin, J.R., and Milton, E.J., 1982, National uranium reource evaluation, Casper Quadrangle, Wyoming: Department of Energy Report PGJ/F-33(82), 65 p., 10 sheets microfiche.

Griffin, J.R., and Warner, A.J., Jr., 1982, National uranium resource evaluation, Cheyenne quadrangle, Wyoming, Colorado and Nebraska: Department of Energy Report PGJ/F-115(82), 63 p., 5 sheets microfiche.

Gruner, J.W., and Knox, J.A., 1957, Annual report for April 1, 1956, to March 31, 1957: U.S. Atomic Energy Commission Technical Report RME-3148, 51 p.

Hagner, A.F., 1942a, George-Funk Mica: Geological Survey of Wyoming mineral report MR42-22 (unpublished), 1 p.

Hagner, A.F., 1942b, Kin Sabe or Whippet No. 8: Geological Survey of Wyoming mineral report MR42-4 (unpublished), 1 p.

Hagner, A.F., 1942c, Funk Mica: Geological Survey of Wyoming mineral report MR42-21 (unpublished), 1 p.

Hanley, J.B., Heinrich, E.W., and Page, L.R., 1950, Pegmatite investigations in Colorado, Wyoming, and Utah, 1942-1944: U.S. Geological Survey Professional Paper 227, 125 p.

Harris, R.E., 1987a, The Bonneville pegmatite claims, Copper Mountain, Fremont County, Wyoming: Geological Survey of Wyoming mineral report MR87-1 (unpublished), 6 p.

Harris, R.E., 1987b, Tantalum-bearing mafic dikes in the northern Bighorn Mountains, Sheridan and Big Horn Counties, Wyoming: Geological Survey of Wyoming mineral report MR87-3 (unpublished), 9 p.

Hose, R.K., 1955, Geology of the Crazy Woman Creek area, Johnson County, Wyoming: U.S. Geological Survey Bulletin 1027-B, 118 p.

Houston, R.S., 1961a, Field notes on Platt mine: Geological Survey of Wyoming mineral report MR61-2 (unpublished), 2 p.

Houston R.S., 1961b, The Big Creek pegmatite area, Carbon County, Wyoming: Geological Survey of Wyoming Preliminary Report 1, 11 p., 1 plate.

Houston, R.S., and Love, J.D., 1956, Titaniferous sandstone in marine rocks of Late Jurassic age, northwestern Wyoming: Wyoming Geological Association 11th Annual Field Conference Guidebook, p. 73-74.

Houston, R.S., and Murphy, J.F., 1962, Titaniferous black sandstone deposits of Wyoming: Geological Survey of Wyoming Bulletin 49, 120 p., 7 plates.

Houston, R.S., and Murphy, J.F., 1970, Fossil beach placers in sandstones of Late Cretaceous age in Wyoming and other Rocky Mountain States: Wyoming Geological Association 22nd Annual Field Conference Guidebook, p. 241-249.

Jenner, G.A., Jr., 1984, Tertiary alkalic igneous activity, potassic fenitization, carbonatitic magmatism, and hydrothermal activity in the central and southeastern Bear Lodge Mountains, Crook County, Wyoming: M.S. thesis, University of North Dakota, 232 p., 1 plate.

Johnson, A.I., 1938, Tantalum from the Black Hills: Engineering and Mining Journal, v. 139, no. 11, p. 39-42.

Kopp, R.S., 1965, Evaluation of beryl-bearing pegmatites of the Copper Mountain mining district, Fremont County, Wyoming: The Compass, v. 43, no. 9, p. 21-29.

Manzer, G.K., Jr., and Heimlich, R.A., 1974, Petrology of mafic and ultramafic rocks from the northern Bighorn Mountains, Wyoming: Geological Society of America Bulletin, v. 85, no. 5, p. 703-708.

Madsen, M., 1978, A statistical analysis of heavy mineral variations in Upper Cretaceous black sandstone deposits of the Rocky Mountain States: M.S. thesis, University of Wyoming, 139 p.

Madsen, M.E., and Reinhart, W.R., 1982, National uranium resource evaluation, Ogden Quadrangle, Utah and Wyoming: Department of Energy Report PGJ/F-124(82), 53 p., 3 sheets microfiche.

Magleby, D., 1952, Supplementary [sic] report on the Lyle Ramsbottom property: U.S. Atomic Energy Commission Technical Report RMO-939, 8 p.

Marzell, J.G., 1933, Sixteenth biennial report of the State Geologist: Geological Survey of Wyoming, p. 78.

McLaughlin, T.G., 1940, Pegmatite dikes of the Bridger Mountains, Wyoming: American Mineralogist, v. 25, p. 46-88.

Morris, A.V., and Stanley, D.R., 1982, National uranium resource evaluation, Rock Springs Quadrangle, Wyoming and Colorado: Department of Energy Report PGJ/F-80(82), 42 p., 5 sheets microfiche.

Norby, J.W., 1984, Geology and geochemistry of Precambrian amphibolites and associated gold mineralization, Tinton District, Lawrence County, South Dakota and Crook County, Wyoming: M.S. thesis, South Dakota School of Mines and Technology, 144 p., 3 plates.

Orback, C.J., 1960, Geology of the Fox Creek area, Albany County, Wyoming: M.A. thesis, University of Wyoming, 100 p., 1 plate.

Parker, R.L., 1963, Niobium and tantalum in the United States: U.S. Geological Survey Miscellaneous Investigations Resource Map MR-36, 1 plate with 8 p. text.

Platt, R.E., 1986, The Platt pegmatite (Uranium King mine), Carbon County, Wyoming, *in* Modreski, P.J., editor, Colorado pegmatites: Friends of Mineralogy, Colorado Chapter, Denver, p. 109-110.

Ross, M.E., and Heimlich, R.A., 1972, Petrology of Precambrian mafic dikes from the Bald Mountain area, Bighorn Mountains, Wyoming: Geological Society of America Bulletin, v. 83, no. 4, p. 1117-1124.

Sargent, K.A., 1960, Allanite occurrences in the Horn area, Bighorn Mountains, Wyoming: Ph.D. dissertation, University of Iowa, 136 p., 5 plates.

Smith, E.W., 1954, Reconnaissance for uraniferous deposits in the Laramie Mountains, Wyoming: U.S. Atomic Energy Commission Technical Report RME-1048, 17 p.

Smith, W.C., and Page, L.R., 1941, Tin-bearing pegmatites of the Tinton district, Lawrence County, South Dakota [sic]: U.S. Geological Survey Bulletin 922-T p. 595-630, 4 plates.

Staatz, M.H., 1983, Geology and description of thorium and rare-earth deposits in the Southern Bear Lodge Mountains, northwestern Wyoming: U.S. Geological Survey Professional Paper 1049-D, 52 p., 2 plates.

Staatz, M.H., Conklin, N.M., Bunker, C.M., and Bush, C.A., 1980, Gamma-ray spectrometric and semiquantitative spectrographic analytical data of the thorium and rare-earth disseminated deposits in the southern Bear Lodge Mountains, Wyoming: U.S. Geological Survey Open File Report 80-785, 47 p., 1 plate.

Welch, C.M., 1974, A preliminary report on the geology of the Mineral Hill area, Crook County, Wyoming: M.S. thesis, South Dakota School of Mines and Technology, 83 p., 2 plates.

Wilmarth, V.R., and Johnson, D.H., 1953, Preliminary reconnaissance survey for thorium, uranium, and rare-earth oxides, Bear Lodge Mountains, Crook County, Wyoming: U.S. Geological Survey Trace Element Investigation Report 172, 26 p., 2 plates, (also as U.S. Atomic Energy Commission Technical Report TEI-172).

Wilson, W.H., 1952, Beaver Creek allanite deposit, Big Horn [sic] Mountains, Johnson County: Geological Survey of Wyoming mineral report MR52-3, 3 p.

Wilson, W.H., 1960, Radioactive mineral deposits of Wyoming: Geological Survey of Wyoming Report of Investigation 7, 41 p.