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RADIOACTIVE QUARTZ-PEBBLE CONGLOMERATES OF THE SIERRA MADRE AND MEDICINE BOW MOUNTAINS, SOUTHEASTERN WYOMING

by

Robert S. Houston

Karl E. Karlstrom

Paul J. Graff

With an Introduction by

W. Dan Hausel

Edited by

Gary B. Glass

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INTRODUCTION

Metasedimentary rocks of Blind River, Canada; Witwatersrand, South Africa; and Jacobina, Brazil, contain enormous economic deposits of Precambrian placer uranium, gold, and additional heavy minerals. Blackwelder (1935) and Houston, and others (1968) noted similar tectonic settings between the Blind River deposits and the metasediments located in the Sierra Madre and Medicine Bow Mountains of southern Wyoming. Because these observed similarities could be both geologically and economically significant, the Geological Survey of Wyoming in collaboration with the University of Wyoming's Geology Department initiated a study of Precambrian metasediments in southeastern Wyoming. This work was supported by Grant No. 14-08-0001-G-411 from the Office of Energy Resources, Branch of Uranium and Thorium Resources, U. S. Geological Survey in Denver, Colorado.

It was the purpose of this study to refine the stratigraphy of Precambrian metasediments of Houston, and others (1968), and to determine if economical placer uranium could be identified in the quartz-pebble conglomerates and quartzites of the Sierra Madre and Medicine Bow Proterozoic deposits.

Toward this end, a 750 square kilometer area in the Sierra Madre (Graff, 1978) and a 260 square kilometer area in the Medicine Bow Mountains (Karlstrom, 1977) were mapped and studied (Figure 1). The results of these two studies are summarized in this report.

In the Sierra Madre and Medicine Bow Mountains, two major horizons that contained radioactive quartz-pebble conglomerate were identified: one at the base of the upper Phantom Lake Group and one at the base of the Magnolia Formation of the Deep Lake Group, which is more than 3,000 meters higher in the section. Because these two horizons are lithologically similar, additional mapping is required before their distribution is fully understood. It is clear, however, that radioactive conglomerate is distributed over large areas in both the Sierra Madre and Medicine Bow Mountains. It is also clear that conglomerate layers are thick enough (greater than three meters), at least locally, that they could be mined.

The uranium- and thorium-bearing minerals in the quartz-pebble conglomerate of the Sierra Madre and Medicine Bow Mountains, are considered detrital

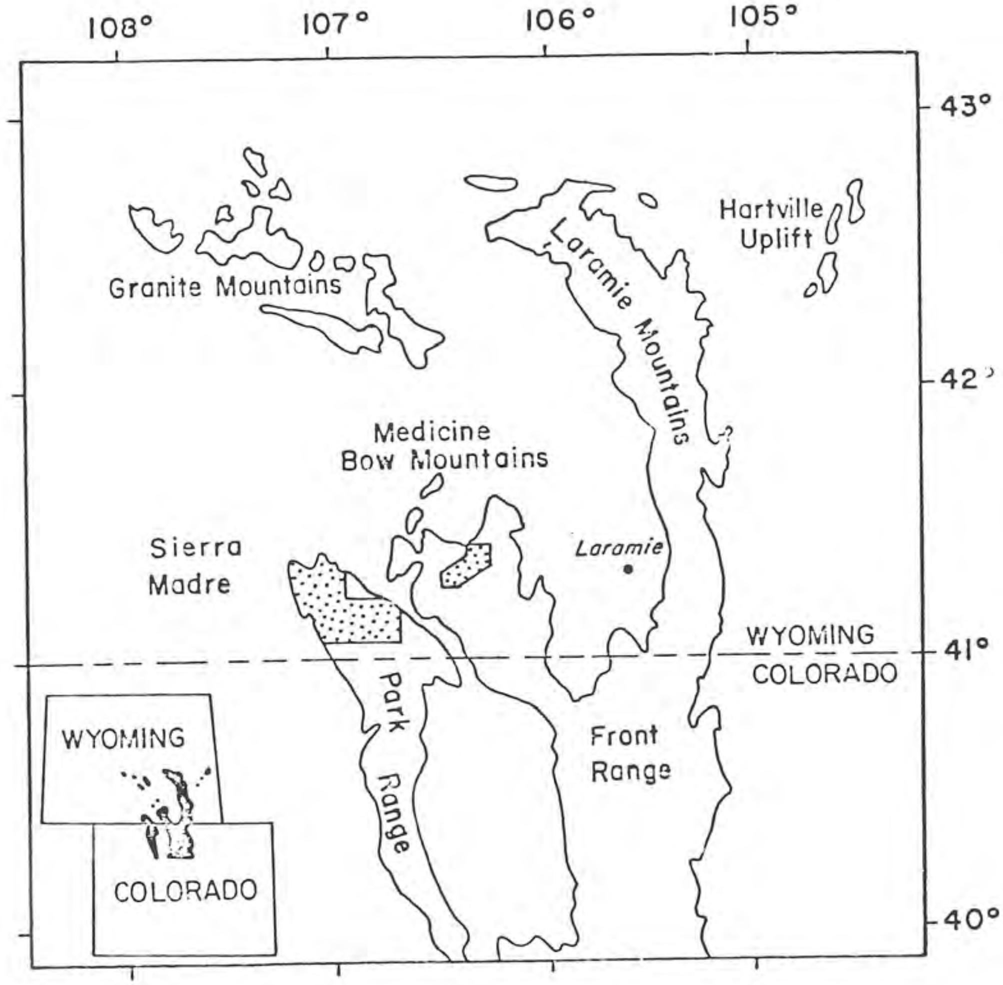


Figure 1. Index map of Precambrian outcrops in southeastern Wyoming and northern Colorado (stippled areas depict the study areas for this report).

by the authors, deposited in channels of braided rivers that flowed south or southwest from the Archean source area located to the north-northeast of the present site of deposition of the conglomerate.

Although economic placer uranium deposits have not yet been discovered, it is significant that placer uranium mineralization was identified as the result of this study. It is apparent that the search for economical uranium will have to be conducted below the zone of oxidation since geochemical studies indicate that oxidation has removed a portion of the near-surface uranium.

Interestingly, field studies of gold- and uranium-bearing conglomerate of the Witwatersrand of South Africa led most South African geologists to the conclusion that those deposits were of placer origin. Detailed studies, especially of the mineralogy, texture, and paragenesis of the deposits, led others (Davidson, 1953) to the conclusion that the ores were not of placer origin. Eventually irrefutable evidence of placer origin was obtained from mineralogic examination of relatively unmetamorphosed specimens collected underground. It is apparent that conclusive evidence for the origin of the radioactive minerals in southern Wyoming Precambrian conglomerates will be derived from future studies of unaltered and unmetamorphosed core samples, if such samples become available.

GENERAL GEOLOGY

The Sierra Madre and Medicine Bow Mountains of Wyoming are Laramide uplifts located within the Central Rocky Mountain Province. Both mountain ranges are subdivided into two separate tectonic facies by a major shear zone (Figure 2). This Mullen Creek-Nash Fork shear zone separates rocks of the eugeosynclinal facies in the south from rocks of the miogeosynclinal facies in the north. Engel (1963) considered the miogeosynclinal rocks and the Archean basement that underlies them to be a southwestern extension of the Superior Province of the Canadian Shield.

The miogeosynclinal rocks in the Wyoming Province are low-grade

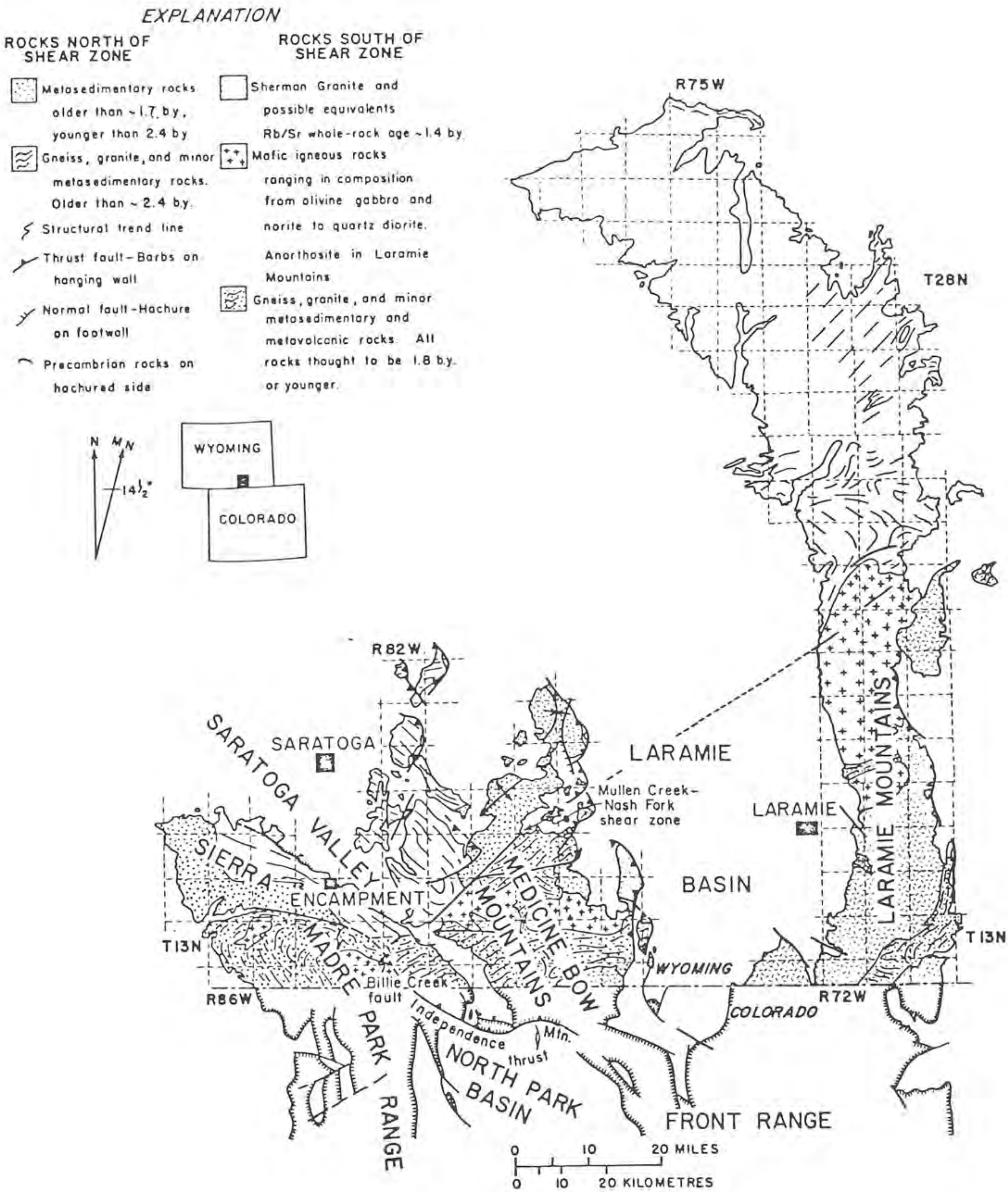


Figure 2. Location of Proterozoic metasediments and other Precambrian rocks in southeastern Wyoming

metasedimentary rocks, which unconformably overlie Archean granitic gneisses and granites. These metasediments are believed to have been deposited in shallow marine to continental margin environments under low oxygen pressures. Such conditions might have existed prior to 2,000 m.y. before the present (Cloud, 1968).

Three sequences of metasedimentary rocks are defined and informally named, from oldest to youngest: the Phantom Lake Group, the Deep Lake Group, and the Libby Creek Group (Table 1). Rocks of the Libby Creek Group are not recognized in the Sierra Madre Mountains (Graff, 1978).

The great thickness of metasedimentary rocks in the Wyoming Province (up to 12 km) suggests that the deposition of these sequences occurred during a period of extensive tectonic stability. This period of deposition should correlate with the deposition of the Blind River, Witwatersrand, and Jacobina sequences. The dating of these events lie between 2,155 m.y. and 2,500 m.y. for the Blind River deposits (Robertson, 1976), about 2,220 m.y. for the Witwatersrand (Stanton, 1972), and probably a Proterozoic age for the Jacobina deposits (Bateman, 1958). Radiometric dating suggests that the Wyoming deposits are between 2,500 and 1,800 m.y. old (Hills and others, 1968).

STRATIGRAPHY

Since the work of Houston, and others (1968), several changes in the stratigraphic nomenclature were necessitated by more detailed mapping (Table 1). In general, the Deep Lake Formation of Houston, and others (1968) is now mapped as two groups separable by a radioactive quartz-pebble conglomerate, which is used as a marker bed. The two groups are informally named the Phantom Lake Group and the Deep Lake Group, the latter being the younger of the two. More detailed mapping is necessary before the Phantom Lake Group can be subdivided into formations. Detailed mapping of the Deep Lake Group enabled Karlstrom (1977) to recognize six formations in the Medicine Bow Mountains. Graff (1978) subdivided the Deep Lake Group into seven formations in the Sierra Madre. The third sequence of metasedimentary rocks found in the Medicine Bow Mountains, the Libby Creek Group, retains its previous

MEDICINE BOW MTNS. BLACKWELDER, 1926		MEDICINE BOW MTNS. HOUSTON, 1968		MEDICINE BOW MTNS. KARLSTROM, 1977 (INFORMAL)			SIERRA MADRE GRAFF, 1978 (INFORMAL)			MEDICINE BOW MTNS. THIS REPORT (INFORMAL)	SIERRA MADRE THIS REPORT (INFORMAL)
FRENCH SLATE	LIBBY CREEK GROUP	FRENCH SLATE	LIBBY CREEK GROUP	FRENCH SLATE	SNOWY RANGE SUPERGROUP	LIBBY CREEK GROUP	UPPER LIBBY CREEK GROUP NOT PRESENT	SNOWY RANGE SUPERGROUP	LIBBY CREEK GROUP	FRENCH SLATE	UPPER LIBBY CREEK GROUP NOT PRESENT
TOWNER GREENSTONE		TOWNER GREENSTONE		TOWNER GREENSTONE						TOWNER GREENSTONE	
RANGER MARBLE		NASH FM.		NASH FM.						NASH FM.	
ANDERSON PHYLLITE											
NASH MARBLE											
SUGARLOAF QUARTZITE		SUGARLOAF QUARTZITE		SUGARLOAF QUARTZITE						SUGARLOAF QTZT.	
LOOKOUT SCHIST		LOOKOUT SCHIST		LOOKOUT SCHIST						LOOKOUT SCHIST	
MEDICINE PEAK QUARTZITE		MEDICINE PEAK QUARTZITE		MEDICINE PEAK QUARTZITE						MEDICINE PEAK QUARTZITE	
HEART METAGRAYWACKE		HEART FM.		HEART FM.			- - - SHEAR ZONE - - -			HEART FM.	- - SHEAR ZONE - - -
HEADQUARTERS SCHIST		HEADQUARTERS SCHIST		HEADQUARTERS SCHIST			SLAUGHTERHOUSE FM.			HEADQUARTERS FM.	SLAUGHTERHOUSE FM.
DEEP LAKE METAQUARTZITE		DEEP LAKE FM.	DEEP LAKE GROUP	ROCK KNOLL FM.		DEEP LAKE GROUP	COPPERTON QUARTZITE		DEEP LAKE GROUP	ROCK KNOLL FM.	COPPERTON QUARTZITE
				VAGNER FM.			VAGNER FM.			VAGNER FM.	VAGNER FM.
				CASCADE QUARTZITE			CASCADE QUARTZITE			CASCADE QUARTZITE	CASCADE QUARTZITE
				CAMPBELL LAKE FM.			CAMPBELL LAKE FM.			CAMPBELL LAKE FM.	CAMPBELL LAKE FM.
				LINDSEY QUARTZITE			SINGER PEAK FM.			LINDSEY QUARTZITE	SINGER PEAK FM.
				MAGNOLIA FM. oooooooooooooooooo			MAGNOLIA FM. oooooooooooooooooo			MAGNOLIA FM. oooooooooooooooo	MAGNOLIA FM. oooooooooooooooooo
				ARRASTRE VOLCANICS		PHANTOM LAKE GROUP	SILVER LAKE CONGLOMERATE		PHANTOM LAKE GROUP	UPPER	UPPER
							SPRING LAKE VOLCANICS				
				oooooooooooooooooo			oooooooooooooooooo			oooooooooooooooo	oooooooooooooooooo
				PHANTOM FM.			JACK CREEK FM.			LOWER	LOWER

Table 1. Development of Precambrian stratigraphic nomenclature in the Sierra Madre and Medicine Bow Mountains, southeastern Wyoming, (oooo denotes radioactive quartz-pebble conglomerate zones).

terminology except that the Headquarters Schist is informally renamed, the Headquarters Formation (Table 1).

Archean

The Archean basement consists of quartzo-feldspathic gneiss, biotite gneiss, and associated syntectonic granite gneiss and granite (Houston, Schuster, and Ebbett, 1975, p. 9-11). Amphibolite, hornblende gneiss, and minor bodies of fine-grained quartzite are interlayered with the felsic gneisses locally, and although some gneisses have textures suggestive of volcanic origin, there are no greenstone belts in this immediate area. The Archean gneisses are cut by large gabbroic intrusions and by dikes of tholeiitic composition. Zones of migmatite and agmatite along with discrete unzoned pegmatite are common in the felsic gneiss. The petrography and mineralogy of the Archean gneiss and pegmatite has not been studied in detail, but minerals containing radioactive elements that might be the source of radioactive elements in the pyritic quartz-pebble conglomerate have not been detected to date. Archean gneisses and syntectonic granite have been dated in the Medicine Bow Mountains by Hills, and others (1968) and in the Sierra Madre by Divis (1976). Ages range from about 2,500 m.y. for granite to about 2,700 m.y. for gneiss.

Phantom Lake Group

Metasedimentary rocks of the Phantom Lake Group were named for a lake in the central Medicine Bow Mountains (Plate 1; sec. 16, T. 16 N., R. 80 W.) where rocks of this group were first discovered (Houston, and others, 1968; Karlstrom, 1977). Phantom Lake Group rocks include paraconglomerate, quartz-pebble conglomerate, slate, marble, quartzite, phyllite, and metavolcanic rocks (Table 2). Locally these rocks are interlayered with amphibolite, hornblende gneiss and schist, and felsic gneiss; all of possible volcanic origin. So far as has been determined, these rocks lie unconformably on the Archean basement, but most contacts between basal units of the Phantom Lake Group and the Archean basement are faulted or are occupied by mafic intrusive rock. The basal unit of the Phantom Lake Group is fine-grained feldspathic quartzite -- no basal conglomerate has been found.

The most distinctive marker bed in the Phantom Lake Group is a micaceous

	Medicine Bow Mountains		Sierra Madre		
LIBBY CREEK GROUP	FRENCH SLATE	GRAY SLATE	LIBBY CREEK GROUP NOT PRESENT		
	TOWNER GREENSTONE	CHLORITE SCHIST			
	NASH FM.	GRAPHITIC PHYLLITE AND META-DOLOMITE			
	SUGARLOAF QUARTZITE	MASSIVE QUARTZITE			
	LOOKOUT SCHIST	LAMINATED SCHIST WITH QUARTZITE LAYERS			
	MEDICINE PEAK QUARTZITE	QUARTZITE AND CONGLOMERATE QUARTZ-PEBBLE CONGLOMERATE AND QUARTZITE QUARTZITE			
	HEART FM.	QUARTZITE PHYLLITE QUARTZITE			
	HEADQUARTERS FM	PHYLLITE ARKOSIC QUARTZITE PARACONGLOMERATE			
			SHEAR ZONE		
		UNCONFORMITY	SLAUGHTERHOUSE FM	METADOLOMITE AND CALCAREOUS PHYLLITE	
DEEP LAKE GROUP	ROCK KNOLL FM	CONGLOMERATE AND QUARTZITE QUARTZITE AND PHYLLITIC QUARTZITE QUARTZITE	COPPERTON QUARTZITE	SHEARED, MASSIVE QUARTZITE; MINOR PHYLLITE	
	VAGNER FM	PHYLLITIC QUARTZITE MARBLE PARACONGLOMERATE	VAGNER FM	PHYLLITE QUARTZITE METADOLOMITE PARACONGLOMERATE	
		UNCONFORMITY		*UNCONFORMITY*	
	CASCADE QUARTZITE	PEBBLY ARKOSIC QUARTZITE PEBBLY QUARTZITE QUARTZITE	CASCADE QUARTZITE	ARKOSIC QUARTZITE AND QUARTZ-ARENITE QUARTZ-PEBBLE CONGLOMERATE	
	CAMPBELL LAKE FM	QUARTZ-RICH PHYLLITE PARACONGLOMERATE	CAMPBELL LAKE FM	GREEN PHYLLITE QUARTZITE PARACONGLOMERATE	
	LINDSEY QUARTZITE	QUARTZITE	SINGER PEAK FM	PHYLLITE PHYLLITE WITH THIN QUARTZITE INTERBEDS	
	MAGNOLIA FM	COARSE-GRAINED QUARTZITE QUARTZ-GRANULE CONGLOMERATE RADIOACTIVE QUARTZ-PEBBLE CONGLOMERATE	MAGNOLIA FM	ARKOSIC QUARTZITE QUARTZ-GRANULE CONGLOMERATE RADIOACTIVE QUARTZ-PEBBLE CONGLOMERATE	
		UNCONFORMITY		*UNCONFORMITY*	
PHANTOM LAKE GROUP				WEST	EAST
	UPPER	PHYLLITE, BASALT, AND CONGLOMERATE MICACEOUS QUARTZITE PHYLLITE QUARTZITE QUARTZITE AND RADIOACTIVE QUARTZ-PEBBLE CONGLOMERATE	UPPER	PHYLLITE AND SLATE PHYLLITIC QUARTZITE MARBLE AND QUARTZITE PARACONGLOMERATE QUARTZITE AND RADIOACTIVE QUARTZ-PEBBLE CONGLOMERATE	METAVOLCANIC ROCKS AND PARACONGLOMERATE QUARTZITE METAVOLCANIC ROCKS AND PARACONGLOMERATE QUARTZITE
	LOWER	VOLCANOCLASTIC METAGRAYWACKE, METAFLOWS, METATUFFS, QUARTZITE, QUARTZ-PEBBLE CONGLOMERATE, AND PARACONGLOMERATE	LOWER	VOLCANOCLASTIC METAGRAYWACKE, METAFLOWS, METATUFFS, QUARTZITE, QUARTZ-PEBBLE CONGLOMERATE, AND PARACONGLOMERATE	
ARCHEAN GRANITE, METASEDIMENTS, AND GNEISSES					

Table 2. Stratigraphic assemblages of Precambrian metasedimentary rocks in the Sierra Madre and Medicine Bow Mountains, southeastern Wyoming.

quartzite containing beds of radioactive quartz-pebble congolomerate. This unit is used to separate the Phantom Lake Group into an upper and lower part.

Beds of the lower Phantom Lake Group crop out in both the Sierra Madre (Plate 1) and Medicine Bow Mountain (Plate 2) study areas. They are also present in the Arlington area, northeast of the Medicine Bow Mountain study area. Some of the rocks shown as lower Phantom Lake Group in the Arlington area of the Medicine Bow Mountains may be younger -- the marker bed has not been fully mapped in this area. The lower Phantom Lake Group consists of fine-grained feldspathic quartzite interbedded with phyllite (metagraywacke?); locally beds of coarse-grained pebbly quartzite, marble, amygdaloidal metabasalt, meta-agglomerate, and meta-paraconglomerate are present. Amphibole gneiss, amphibolite, and felsic gneisses are interlayered with the metasedimentary rocks locally; these rocks are considered to be largely metavolcanic rocks. The stratigraphy has not been established for the lower Phantom Lake Group, in part, because these rocks have not been mapped in detail. Also because these rocks are probably isoclinally folded, are of relatively high metamorphic rank (amphibolite facies), and retain few primary structures, a reliable stratigraphic reconstruction may not be possible.

The age of rocks of the lower Phantom Lake Group is unknown. Some interlayered gneisses resemble rocks dated as Archean in other areas, but no gneisses have been dated from the lower Phantom Lake succession. Two samples of a staurolite-garnet-muscovite schist from a locality three kilometers southwest of Arlington were analyzed by Hill, and others (1968, p. 1771). These two points gave an isochron solution of 1,913 m.y. which is probably a metamorphic date for these rocks. Certainly two points are inadequate to establish a reliable isochron, but the date of 1,913 m.y., is about two hundred million years older than ages determined by whole-rock Rb/Sr methods for schists of the Libby Creek Group. This information, though not conclusive, supports the concept that the lower Phantom Lake Group rocks were deformed and metamorphosed earlier than metasedimentary rocks that overlie them.

Granite which resembles Archean granite of this area is locally in contact with lower Phantom Lake Group rocks. In some areas field relationships suggest that lower Phantom Lake Group rocks lie unconformably on the granite, but in other areas the granite has gradational or cross-cutting contacts with lower Phantom Lake Group rocks. There are no reliable age determinations in these granitic rocks. Three samples were analyzed by Hills, and others (1978, p. 1963) from gneissic granite near Arlington. These samples formed an isochron with an apparent age of 2,350 m.y. with an error of $\pm$ 84 m.y. This is too few samples for a reliable isochron, but it does suggest that some of the lower Phantom Lake Group rocks are earliest Proterozoic or Archean.

If these lower Phantom Lake Group rocks prove to have an age and/or geologic history distinct from upper Phantom Lake Group rocks, a new group name will be proposed. We prefer, however, to complete the mapping program before adding new terminology (Table 1).

No strongly radioactive rocks have been found in the lower Phantom Lake Group to date, but rocks having radioactivity 2-3 times background for the area have been found in a number of places. These localities are listed in Table 3 and illustrated on Figure 3. Beds of quartz-pebble conglomerate and beds of paraconglomerate are the most common rocks with above-background radioactivity, but some micaceous quartzite also shows above-background radioactivity.

Beds of the upper Phantom Lake Group crop out in two overturned synclines in the northwest Sierra Madre and in an east-striking belt that extends throughout the northcentral Sierra Madre (Plate 1). In the Medicine Bow Mountains, upper Phantom Lake Group rocks are in an overturned syncline located southeast of Arlington, in the core of an anticline southeast of Sand Lake, and in the general area east and west of Phantom Lake (Plate 2). The basal unit of the upper Phantom Lake Group is a coarse-grained, radioactive, micaceous quartzite containing beds of strongly radioactive quartz-pebble conglomerate. This radioactive unit is variable in thickness, but in the Onemile Creek area north of the Medicine Bow study area (sec. 6. T. 18 N., R. 78 W.) and in the Deep Gulch area of the Sierra Madre (Plate 1; sec. 36 T. 16 N., R. 88 W.) the unit is over 100 meters thick (uppermost portion of Jack Creek Formation of Graff, 1978).

In the Sierra Madre, the radioactive unit grades upward into a unit containing fining-upward sets. These sets contain quartz-pebble conglomerate that grades upward into quartzite with trough cross-bedding. The quartz-pebble conglomerate of these sets is better sorted than that of the radioactive unit, but it has a radioactivity only slightly above background. The unit with fining-upward sets grades upward into finer grained quartzite with less well-developed or preserved cross-bedding. The total thickness of quartz-rich beds above the radioactive unit is 200 meters. These beds are overlain by a fine-grained, biotite-amphibole schist containing thin pebble layers. These schists may represent turbidites (Graff, 1978). The thickness of the schist unit is unknown because of poor exposure and the fact the schist is invaded by abundant diabase sills, but it is probably in excess of 200 meters. The schist unit is overlain by a bluish-white, fine- to medium-grained quartzite in which planar cross-bedding can be recognized locally. This quartzite unit is also cut by diabase sills. It has an approximate thickness of 200 meters. The quartzite is overlain by a fine-grained marble unit marked by thin layers of silica and containing one thick bed of phyllite near the middle of the unit. The marble unit is overlain by medium- to fine-grained quartzite containing numerous diabase sills. This quartzite is approximately 400 meters thick; it is succeeded by biotite-amphibole gneisses and schists that have beds of paraconglomerate. The paraconglomerate contains scattered clasts of granite and quartzite. This gneiss-schist unit is also cut by sills of diabase -- its thickness is approximately 550 meters. Exposures in the Sierra Madre are such that it is not possible to establish the stratigraphy of beds overlying the gneiss-schist unit, but these upper metasedimentary rocks are chiefly phyllitic, fine-grained quartzite. The uppermost unit of the upper Phantom Lake Group in the Dexter Peak area of the Sierra Madre is light gray phyllite, at least 200 meters thick (Plate 1; sec. 21, T. 15 N., R. 87 W.). The total thickness of the upper Phantom Lake Group is not well established, but the thickness in the western and central Sierra Madre is thought to average about 5,000 meters (a 30 percent reduction in thickness might be reasonable if sills are not considered).

From west to east there are distinct facies changes in the upper Phantom Lake Group of the Sierra Madre. Metavolcanic rocks and paraconglomerate become more abundant in the east and make up over 50 percent of the total section in the vicinity of South Spring Creek Lake (Plate 1; sec. 11, T. 14 N., R. 86 W.). Metavolcanic rocks are metatuffs, metagraywacke (probably volcano-sedimentary rocks), amygdaloidal metabasalt and metabasalt, containing pillow structures.

The metavolcanics occur as discrete lenticular masses in the succession or they may have an associated suite of paraconglomerate. For example, south of Bridger Peak in the Sierra Madre, metavolcanic rocks are overlain by paraconglomerate and metagraywacke. (Plate 1; sec. 14, T. 14 N., R. 86 W.). The paraconglomerates are lenticular masses that are locally 600 meters thick. These paraconglomerates change in character from base to top of the succession. Paraconglomerate at the base of the succession contains a higher percentage of volcanic rock fragments than paraconglomerate at the top of the succession; they are also characterized by an amphibolitic matrix. These basal paraconglomerates are interbedded with lithicwacke composed mostly of volcanic rock clasts. Granite clasts may be present in any paraconglomerate but become far more abundant in the upper part of the succession where the matrix of the paraconglomerate is arkosic. The upper paraconglomerate has lithicwacke associated with it that is composed mostly of granite clasts. The changing composition of the clasts in paraconglomerate and associated lithicwacke probably reflect a change in source through time. We must emphasize, however, that paraconglomerate is found throughout the Phantom Lake Group in both upper and lower successions, and it varies greatly in the nature of clasts and matrix (Graff, 1978).

Upper Phantom Lake Group rocks of the Medicine Bow Mountains (Plate 2) are not as well exposed as in the Sierra Madre (Plate 1), but lithologies are very similar. In the Phantom Lake region at the southwest limit of exposure of these rocks (Plate 2; sec. 16, T. 16 N., R. 80 W.), the lower Phantom Lake Group is not well exposed but includes fine-grained quartzite, phyllites, and paraconglomerate exposed west of the confluence of Little Brush Creek and South Brush Creek (Plate 2; sec. 24, T. 16 N., R. 81 W.). The radioactive micaceous quartzite with conglomerate beds that marks the boundary between the lower and upper Phantom Lake Group is not exposed, but is believed to be present above the paraconglomerate which is strongly radioactive and better sorted in this area than in most localities of either the Sierra Madre or Medicine Bow Mountains. Quartzite exposed east of the radioactive paraconglomerate has characteristics very much like that overlying the radioactive marker in the Deep Gulch area of the Sierra Madre

(Plate 1; sec. 36, T. 16 N., R. 88 W.), further reinforcing the concept that the marker bed is present in this area. The lower part of the upper Phantom Lake Group is poorly exposed in this south Brush Creek area, but exposures of the upper part along lower Arrastre Creek are chiefly fine- to medium-grained quartzite with interbedded sericite schist and fine-grained sericitic quartzite (Plate 2; sec. 16, T. 16 N., R. 80 W.). These quartzites grade upward into a section consisting of metavolcanic rocks and paraconglomerate. Sills and dikes of metadiabase are abundant. The thickness of the upper part of the upper Phantom Lake Group in the Medicine Bow Mountains, less sills, is estimated to be about 3,000 meters; thus the total thickness of the upper Phantom Lake Group probably approaches the 5,000 meters in the Sierra Madre.

The upper Phantom Lake Group rocks in the Arlington area north of the study area in the Medicine Bow Mountains are better exposed than those in the Phantom Lake area, and the radioactive marker bed is well-developed. This area has not been mapped in detail, but the upper Phantom Lake Group section appears to be thinner than elsewhere, perhaps averaging less than 3,000 meters. Quartzite is the most common rock type in the succession due south of Arlington whereas metavolcanic rocks and paraconglomerate are more abundant from Rock Creek to the Medicine Bow River.

The age of rocks of the upper Phantom Lake Group is unknown. No rocks in this group have been dated. Lithologically these metasedimentary rocks resemble rocks of Early Proterozoic age and the presence of pyritic-quartz-pebble conglomerate suggests an age greater than 2,000 m.y.

Deep Lake Group

The Deep Lake Group is defined in the northcentral Medicine Bow Mountains where the rocks of this group are best exposed and where they are least deformed and metamorphosed (Plate 2). A tentative stratigraphic succession has been established by Karlstrom (1977, p. 10) who has subdivided the Deep Lake Group into six formations: the Magnolia Formation, Lindsey Quartzite, Campbell Lake Formation, Cascade Quartzite, Vagner Formation, and Rock Knoll Formation (Table 1).

In the Sierra Madre, Graff (1978) also recognizes the Deep Lake Group but some lithologies differ enough from those of the Medicine Bow Mountains to require new names (Table 2). For example, beds in the stratigraphic position of the Lindsey Quartzite of Karlstrom (1977) are named the Singer Peak Formation; beds in the stratigraphic position of the Rock Knoll Formation of Karlstrom (1977) are named the Copperton Quartzite; and a new formation, the Slaughterhouse Formation, is added at the top of the succession (Table 1).

The Magnolia Formation is the basal rock succession of the Deep Lake Group, and it overlies rocks of the Phantom Lake Group unconformably. It crops out in the Medicine Bow Mountains in the Arrastre Lake area (Plate 2; sec. 10, T. 16 N., R. 80 W.), where it lies on metavolcanic rocks of the Phantom Lake Group, and along the North Fork of Rock Creek (Plate 2; sec. 12, T. 17 N., R. 79 W.) where outcrops extend from near the head of the North Fork of Rock Creek to its confluence with Rock Creek proper. Near the head of the North Fork of Rock Creek, the Magnolia Formation lies on metavolcanic rocks of the Phantom Lake Group. North of the study area and near the confluence of the North Fork of Rock Creek and Rock Creek, it appears to be in fault contact with younger rocks. The Magnolia Formation also crops out along the south side of Deep Creek in the Medicine Bow Mountains where it lies on paraconglomerates of the Phantom Lake Group (Plate 2; sec. 10, T. 17 N., R. 79 W.). The Magnolia Formation may also extend east of Rock Creek in the Medicine Bow Mountains where it may lie on quartzite of the Phantom Lake Group. The occurrence east of Rock Creek is speculative because no detailed mapping has been done in this area.

Beds that are believed to be correlatives of the Magnolia Formation have been mapped by Graff (1978) in the Sierra Madre. In the western Sierra Madre, they are in a syncline with its axis located near Dexter Peak (Plate 1; sec. 21, T. 15 N., R. 87 W.). They probably also extend beneath Tertiary cover south of this area and appear in another syncline north of Deep Creek (Plate 1; sec. 34, T. 15 N., R. 87 W.). Linear outcrop of the Magnolia Formation continues to an area near the head of Haggerty Creek where it is cut out by a mafic intrusion (Plate 1; sec. 16, T. 14 N., R. 86 W.). In most of this area the rocks of the Magnolia Formation lie on phyllite of the upper Phantom Lake Group. Beds of the Magnolia Formation are also present in an east-striking belt that extends from a locality east of Haggerty

Creek to Bottle Creek (Plate 1; sec. 24. T. 14 N., R. 85 W.). Contact relationships with older rocks are uncertain in this area, but here the Magnolia Formation may be thrust over older rocks.

The basal beds of the Magnolia Formation in the Medicine Bow Mountains are referred to as the conglomerate member by Karlstrom (1977, p. 23-25), and these beds are a radioactive, coarse-grained, arkosic quartzite with conglomerate layers that is remarkably similar to the basal unit of the upper Phantom Lake Group. In fact, these units are so similar that the writers are still uncertain which of these radioactive beds has been mapped in the area of the Medicine Bow Mountains east of Rock Creek and in the northwest Sierra Madre. The basal beds of the Magnolia Formation vary somewhat from one locality to another. For example, in the Medicine Bow Mountains north of Arrastre Lake (Plate 2; sec. 9, T. 16 N., R. 80 W.) a lenticular, relatively coarse-grained conglomerate with clasts up to 16 cm diameter is present at the base of the unit. This conglomerate is up to three meters thick in places and is strongly radioactive (7-8 times background). It is green to yellowish-red and contains rounded clasts of quartzite, micaceous quartzite, phyllite, metavolcanic rocks, and granite in a pyritic arkosic matrix. The basal conglomerate is overlain by a more continuous quartz-pebble conglomerate that contains pebble-sized clasts of quartz, quartzite, fine-grained sericitic quartzite, phyllite, and altered rocks of probably volcanic origin in a sericitic, feldspathic-quartzite matrix. In the Arrastre Lake area the conglomerate member of the Magnolia Formation is not continuous. It pinches out west of Arrastre Lake where it apparently grades laterally into fine-grained quartzite (Plate 2). The conglomerate member that crops out near the head of the North Fork of Rock Creek consists of arkosic quartzite interbedded with dark colored, conglomeratic quartzite (Plate 2; sec. 22, T. 17 N., R. 79 W.). The dark colored conglomeratic layers are more radioactive than the arkosic quartzite. Outcrops of the conglomerate member west of Rock Creek have not been examined in any detail, but are radioactive, pebbly arkosic quartzite. The conglomerate member of the Magnolia Formation is 150 meters thick at Arrastre Lake and 200 meters thick near the head of the North Fork of Rock Creek.

In the western Sierra Madre, rocks thought to be the equivalent of the conglomerate member of the Magnolia Formation are pebbly, sericitic quartzite with beds of quartz-pebble conglomerate (Graff, 1978) The quartz-pebble conglomerate is strongly radioactive locally, and, as in the Medicine Bow Mountains, the entire unit shows radioactivity above background for the area. In the Dexter Peak area of the Sierra Madre, vein quartz is the major constituent of the pebble fraction of conglomerate layers; quartzite, and altered rocks of possible volcanic origin are also present (Plate 1; sec. 21, T. 15 N., R. 87 W.). The matrix of the conglomerate is a pyritic, sericitic quartzite. The pyrite is completely altered to goethite, and its former presence is indicated in most samples by vugs with goethite coatings. An interesting feature of the conglomerate member at Dexter Peak is the presence of fining-upward sets with conglomerate at the base of each set and trough cross-bedded quartzite at the top, suggesting fluvial origin for the unit.

The conglomerate member of the Magnolia Formation mapped in the eastern Sierra Madre is a finer-grained quartz-pebble conglomerate that appears to be better sorted than the western conglomerate member. It is also less radioactive.

In the Medicine Bow Mountains, the conglomerate member grades upward into a unit referred to as the quartzite member of the Magnolia Formation (Plate 2). The quartzite member is a coarse-grained, well sorted quartzite consisting largely of well rounded quartz granules that average 1-2 mm in diameter and less common pebbles that are up to one cm. in diameter. The quartzite member contains less matrix than the underlying conglomerate (less than five percent) and is relatively low in feldspar (less than five percent).

The quartzite member has well-developed trough cross-beds with troughs approximately 5 to 15 cm deep. The quartzite member has a more consistent thickness than the conglomerate member, averaging 425 meters.

The Magnolia Formation is overlain by the Lindsey Quartzite of Karlstrom (1977, p. 29) that crops out in the Medicine Bow Mountains in the axis of a northeast-plunging anticline located west of Dipper Lake (Plate 2; secs. 2 and 11, T. 16 N., R. 80 W.) and in a doubly-plunging anticline that extends from Deep Lake (Plate 2; sec. 32, T. 17 N., R. 79 W.) to sec. 24, T. 17 N., R. 79 W. The Lindsey Quartzite is also present in the trough of a syncline that crops out near Mutt and Jeff Lakes (Plate 2; sec. 28, T. 17 N., R. 79 W.) and near Rock Creek, north of the study area (sec. 36, T. 18 N., R.

79 W.). In the Dipper Lake area the Lindsey Quartzite is light gray, medium-grained quartzite with layers of pebbles concentrated on foreset beds of crossbeds and in smaller scours. The overall characteristics of the Lindsey Quartzite suggest a fluvial origin for the unit in the Dipper Lake area whereas Karlstrom (1977, p. 35) suggests a marine origin for a finer-grained facies of the Lindsey Quartzite located east of Deep Lake (Plate 2; sec. 33, T. 17 N., R. 79 W.).

In the Sierra Madre the stratigraphic position of the Lindsey Quartzite is occupied by a thick sequence of metasedimentary rocks that are mostly phyllite (Table 2). These rocks are referred to by Graff (1978) as the Singer Peak Formation, and they crop out in two synclines in the western Sierra Madre (Plate 1) and in an east-striking belt that extends from Deep Creek (Plate 1; sec. 3, T. 14 N., R. 87 W.) to Cow Creek (Plate 1; sec. 19, T. 14 N., R. 85 W.). The formation is thickest in the west where the upper part contains beds of quartz-pebble conglomerate and quartzite of possible fluvial origin (Table 4). In the east, the upper part of the Singer Peak Formation of Graff is cut out by a thrust fault (Plate 1).

The Lindsey Quartzite of Karlstrom (1977) is overlain unconformably by the Campbell Lake Formation, which contains distinctive marker beds useful in mapping. The Campbell Lake Formation of Karlstrom, consists of a paraconglomerate overlain by a quartz-rich phyllite. The paraconglomerate has an arkosic matrix containing rounded clasts of white granite, phyllite, quartzite, and metabasalt that are up to 76 cm in diameter. The conglomerate grades into a dark gray to black phyllite, which becomes quartz-rich at the top. The Campbell Lake Formation crops out in two localities in the northern half of T. 16 N., R. 80 W., and in two localities in the southern half of T. 17 N., R. 80 W. (Plate 2). It is also on the west side of the Medicine Bow River (Plate 2; sec. 23, T. 17 N., R. 80 W.), and in three localities north, south, and east of Deep Lake (Plate 2; sec. 33, T. 17 N., R. 79 W.). Although it is exposed over a wide area of the Medicine Bow Mountains, it is not continuous. Where it is absent, this is thought to be non-depositional. Rocks that are considered correlatives of the Campbell Lake Formation are present at one locality in the Sierra Madre, in the western Sierra Madre on Deep Creek (Plate 1; secs. 8 and 9, T. 14 N., R. 87 W.).

The Campbell Lake Formation is overlain conformably by the Cascade

Quartzite of Karlstrom (1977, p. 41). The Cascade Quartzite of Karlstrom crops out over a large area of the northcentral Medicine Bow Mountains and probably occurs in a block of Precambrian exposed between Cooper Hill (Plate 2; sec. 4, T. 16 N., R. 80 W.) and Rock Creek northeast of the Medicine Bow study area. It also occurs in an east-striking belt in the Sierra Madre, from Big Sandstone Creek (Plate 1; sec. 16, T. 14 N., R. 87 W.) to the Encampment River (Plate 1, sec. 36, T. 14 N., R. 84 W.). The unit has a distinctive lithology in both mountains (Table 2); it is marked by pebble layers ranging from a thickness of one pebble to channels 20 meters thick that contain pebbles of quartz, quartzite, black chert, and pink granite. The black chert is readily identified and serves to distinguish the Cascade Quartzite from other similar units. For the most part, the Cascade Quartzite is a more mature rock-type than most quartzites that underlie it. For example, it contains more resistant clasts, and it is not feldspathic except at the very top of the unit where a feldspathic quartzite is locally developed. The Cascade Quartzite is thought to be fluvial (Table 4).

The Cascade Quartzite is unconformably overlain by the Vagner Formation of Karlstrom (1977, p. 48-53). The Vagner Formation is a three-fold unit consisting of a basal paraconglomerate, a middle marble, and an upper phyllitic quartzite (Table 2). The Vagner Formation crops out in the Medicine Bow Mountains in a northeast-striking belt that extends from Dipper Lake (Plate 2, sec. 11, T. 16 N., R. 79 W.) northeast to Trail Creek (Plate 2, sec. 24, T. 17 N., R. 79 W.). It can be recognized in a locality outside the study area on the west side of Rock Creek (sec. 6, T. 17 N., R. 78 W.), and probably occurs in the block of Precambrian rocks exposed west of Cooper Hill (Plate 2, sec. 4, T. 16 N., R. 80 W.) and east of Rock Creek northeast of the study area.

In the Medicine Bow Mountains, the matrix of the paraconglomerate is arkosic and clasts in order of abundance are red granite, white granite, quartzite, phyllite, and rare metavolcanic(?) rocks. This paraconglomerate and associated phyllite have features suggestive of glacial origin. As first noted by Blackwelder (1926) and later by Sylvester (1973), these paraconglomerates are poorly sorted, have more angular clasts, and have larger clasts (some boulder-sized) than paraconglomerates described previously.

Furthermore, associated phyllites have dropstones. This along with other evidence (Sylvester, 1973), strongly suggests a glacial or possibly glacio-marine origin for the paraconglomerate and phyllite. The origin of the associated metalimestone is uncertain, but these metalimestones may represent calcium carbonate brines deposited in response to the retreat of dry-based glaciers (Carey and Ahmad, 1961, p. 886).

In the Sierra Madre, units thought to be equivalent to the Vagner Formation crop out in a syncline located where Big Sandstone Creek makes an abrupt right angle turn and flows west (Plate 1, sec. 21, T. 14 N., R. 87 W.) and in an east-striking belt that extends along the southern margin of the Sierra Madre metasedimentary rock mass (Figure 1). In the western Sierra Madre, the Vagner Formation is like that of the Medicine Bow Mountains in that it consists of paraconglomerates and associated phyllite layers overlain by metalimestone, which is, in turn, overlain by phyllite. The clasts in paraconglomerates are largely red granite with subordinate quartzite, and some of the phyllites have isolated clasts resembling dropstones. In the eastern Sierra Madre, the metalimestone is missing, but paraconglomerates and phyllites are like that of the Medicine Bow Mountains. In some localities of the Sierra Madre, quartzite layers are found within the unit mapped as Vagner Formation; a feature which is not typical of the unit in the Medicine Bow Mountains.

The Vagner Formation is conformably overlain by the Rock Knoll Formation of Karlstrom (1977, p. 53). In the Medicine Bow Mountains, the Rock Knoll Formation is the youngest formation of the Deep Lake Group. This formation crops out in the eastern and western parts of the study area (Plate 2). In the central area, the formation has apparently been removed by faulting and erosion (Plate 2).

The type section of the Rock Knoll Formation is located on the southeast face of Rock Creek Knoll, where quartzites directly underlie the basal paraconglomerate of the Headquarters Formation (Plate 2; sec. 35, T. 17 N., R. 79 W.). The Rock Knoll Formation is mainly gray, fine- and medium-grained quartzite with thin layers of phyllite (Table 1). Near the base of the Rock Knoll Formation, planar cross-bedding in sets 0.6 to 1.5 meters thick are common; this cross-bedded sequence is overlain by quartzite with olive colored patches. The olive colored patches are distinctive and may character-

METAMORPHISM

In the Sierra Madre, metasedimentary and metavolcanic rocks are metamorphosed to high green schist-low almandine amphibolite facies, or using the terminology of Winkler (1976, p. 64-95), the metasedimentary and metavolcanic rocks lie close to the boundary between low and medium grade. The metamorphic rank is higher (almandine amphibolite) in the northern Sierra Madre where typical mineral assemblages of pelitic(?) schists are quartz, biotite, muscovite, ± garnet, hornblende, plagioclase, chorite, and microcline. In the northern Sierra Madre, chlorite is present in relatively few schists, and although chlorite composition is not known, the temperature of metamorphism was probably above 550°C where relatively iron-rich chlorite might react with muscovite to form higher-temerature mineral suites. Divis (1976, p. 26) reports a garnet composition of $Alm_{46}Sp_2Gr_{52}$ in metasedimentary rocks of the northern Sierra Madre. As Divis (1965, p. 26) points out, the low pyrope composition of the garnet as compared with that of garnets in Archean gneiss of the area (Pyr_{23}, Alm_{39} $Sp_{10}And_{28}$; Divis, 1976, p. 16) suggests lower almandine amphibolite facies for the metasedimentary rocks and upper almandine amphibolite facies for the Archean gneiss.

In the southern Sierra Madre, a line can be drawn from Dexter Peak in the northwest to Bridger Peak in the center of the metasedimentary succession and then southeast to the limit of outcrop of metasedimentary rocks (Plate 1). South of this line the rank of metamorphism is lower. Pelitic schists of this area contain coexisting muscovite and chlorite, but kyanite is also present in the schist, suggesting that the rocks are upper green schist facies. Unfortunately, key index minerals such as staurolite or cordierite have not been recognized in the Sierra Madre so it is difficult to fit the temperature and pressure of metamorphism. However, the presence of kyanite and almandine garnet suggest pressures of five kb or more, and mineral suites suggest temperatures of 550 to 600°C.

Regional studies (Houston, and others, 1968) of the metasedimentary rocks of the Medicine Bow Mountains indicated that the metasedimentary rocks of the central Medicine Bow Mountains were less deformed and of lower metamorphic grade than metasedimentary rocks to the northeast or southwest. Phyllites and slates of the central Medicine Bow Mountains contain muscovite, chlorite, and quartz $\pm$ biotite, plagioclase, garnet, and epidote. Muscovite and chlorite commonly coexist and this association suggests green schist facies, but the presence of garnet and biotite, in the pelitic rocks and kyanite in the matrix of many quartzites, suggests upper green schist facies for most of the metasedimentary rocks of the central Medicine Bow Mountains. Mineral assemblages in pelitic rocks of the southwestern Medicine Bow Mountains are more typical of almandine amphibolite facies metamorphism; suites include quartz, muscovite, biotite, staurolite $\pm$ garnet, and kyanite. Chlorite is not a primary mineral in these rocks.

In the northeast Medicine Bow Mountains, mineral assemblages are also more typical of almandine amphibolite facies metamorphism. For example, mineral assemblages in pelitic schists are quartz, muscovite, biotite, $\pm$ staurolite, garnet, epidote, and chlorite. There is a transition from staurolite-bearing muscovite, chlorite, biotite, quartz schists west of Rock Creek to schist consisting of quartz, biotite, muscovite, staurolite and garnet, $\pm$ epidote in the northern Medicine Bow Mountains (north of Carlson Creek) and in all areas east of Rock Creek. These metasedimentary rocks show a transition from low to medium almandine amphibolite facies, and the presence of labradiorite in many metamorphosed mafic volcanics (especially east of Rock Creek) suggests that locally, at least, upper almandine amphibolite facies may be attained.

The above mineral suites suggest that a temperature of approximately $500^{o}C$ and a pressure of approximately five kb may have been attained in the central Medicine Bow area, and that temperature and possibly pressure increased both to the southwest and northeast. Maximum temperature was probably obtained in the northeastern Medicine Bow Mountains where temperatures of $600^{o}C$ are reasonable for the metamorphic grade.

DESCRIPTION OF RADIOACTIVE UNITS

In the Medicine Bow Mountains, there are several radioactive units in the Phantom Lake and Deep Lake groups. A summary of the characteristics of these units is given in Table 3.

The oldest unit that shows anomalously high radioactivity is a

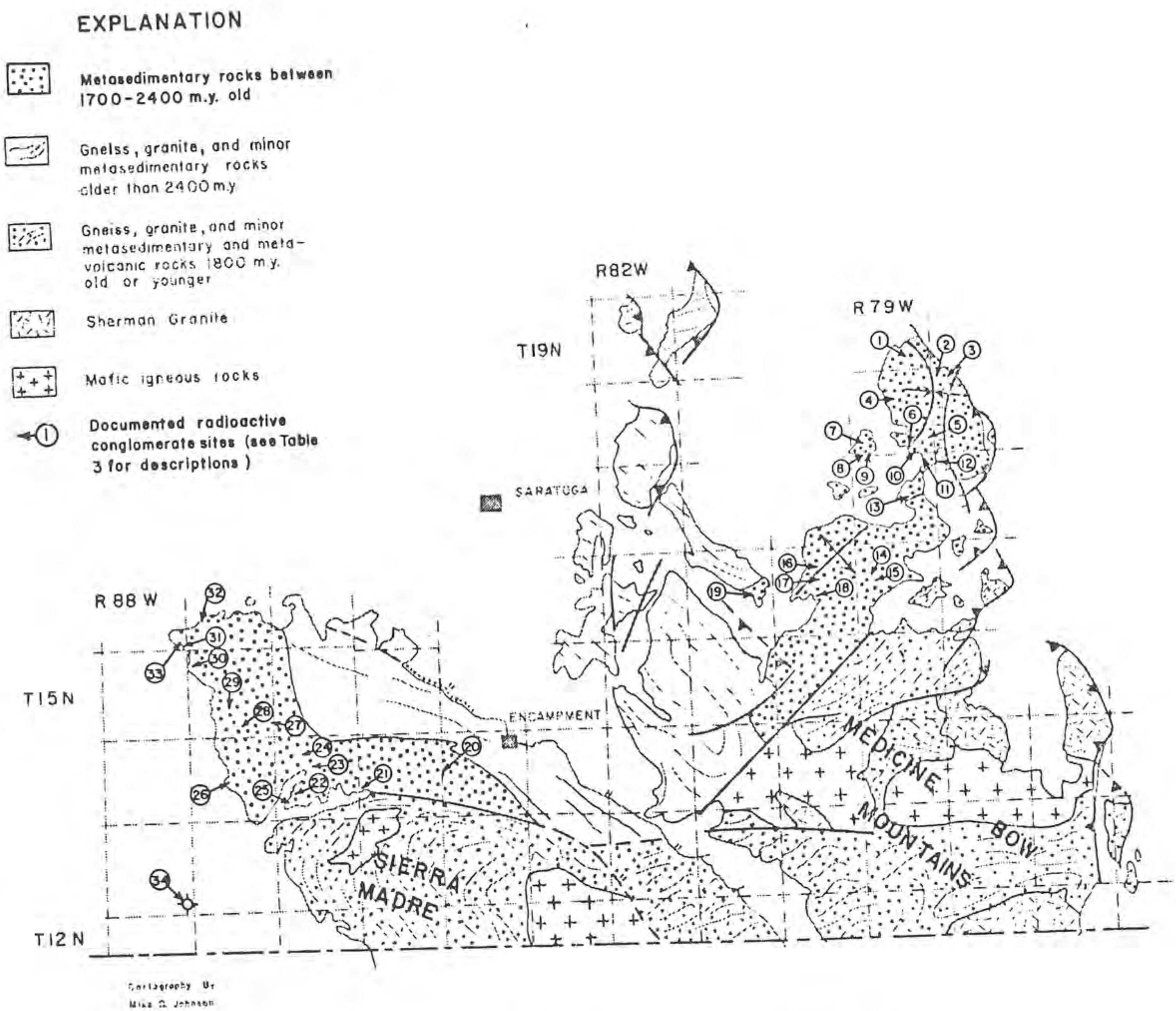


Figure 3. Locations of Precambrian radioactive conglomerate occurrences in the Sierra Madre and Medicine Bow Mountains, southeastern Wyoming

metavolcanic rock in the lower Phantom Lake Group which crops out outside the study area near Crater Lake (Figure 3, sample site 10). This unit includes metavolcanic schists (metatuffs?) and mafic agglomerate. Scintillometer readings of surface radioactivity show values up to five times background (Lanthier, oral communication). These rocks are not necessarily of economic interest in themselves but it is possible that units of this type in the lower Phantom Lake Group were a source for detrital uranium in the overlying radioactive conglomerates.

The second major radioactive unit is the conglomerate that occurs near the base of the upper Phantom Lake Group. In the western part of the study area, this conglomerate has a medium-grained, micaceous, arkosic matrix and contains pebbles of quartz, quartzite, mafic schist, and felsic metavolcanics. The clasts in this outcrop are not concentrated at the lower contact of the paraconglomerate but become more abundant higher in the section. This suggests that the conglomerate was deposited on unconsolidated sands (Palonen, 1973). Scintillometer readings on this outcrop (Figure 3, sample sites 18 and 19) are highest in the coarsest layers and reach values up to six times background (Table 3). Extensive radioactive quartz-pebble conglomerates in the northern Medicine Bows, north of the study area near the town of Arlington, may also be part of the upper Phantom Lake Group. However, the exact stratigraphic position of these conglomerates is poorly understood. Scintillometer readings of surface radioactivity in these conglomerates shows readings of up to 24 times background (Figure 3, sample sites 2, 3, and 6).

The third major radioactive unit in the Medicine Bow Mountains is the radioactive conglomerate member of the Magnolia Formation. This unit crops out in the core of the anticline near Arrastre Lake (Figure 3, sample site 16), and along the North Fork of Rock Creek (Figure 3, sample sites 12 and 13). Scintillometer readings show that surface radioactivity is more than five times background near Arrastre Lake and more than four times background along the North Fork of Rock Creek (Table 3). A heavy-mineral separate from the conglomerate near Arrastre Lake shows much higher radioactivity than the whole-rock samples (Table 3), and this indicates that the uranium in these rocks is concentrated in the heavy mineral fraction.

Table 3. Radioactive occurrences in Precambrian metasediments of the Sierra Madre and Medicine Bow Mountains, southeastern Wyoming (modified from Whalen, 1954; Houston and others, 1968; Graff and Houston, 1977; Houston and others, 1977; Karlstrom, 1977; and Lanthier, 1978).

SITE NUMBER	UNIT	LITHOLOGY	LOCATION	MAXIMUM SCINTILLOMETER READING, (COUNTS PER SECOND)	RADIOACTIVITY RELATIVE TO LOCAL BACKGROUND	URANIUM (PPM)	THORIUM (PPM)
1	Lower Phantom Lake Group	Feldspathic quartzite	Overland Creek area, northern Medicine Bow Mountains, SW¼, Sec.26, T.19N., R.79W.	No data	2X	7	Not detected
2	Upper Phantom Lake Group	Quartz-pebble conglomerate	Onemile Creek area, northern Medicine Bow Mountains, S½, NW¼, Sec.6, T.18N., R.78W.	40,000 1 sample	18X-22X 2 samples	128-141* 3 samples	262-377* 2 samples.
3	Upper Phantom Lake Group	Quartz-pebble conglomerate	Onemile Creek area, northern Medicine Bow Mountains, SE¼, NW¼, Sec.5, T.18N., R.78W.	30,000 1 sample	20X 1 sample	80-109* 2 samples	916* 1 sample
4	Lower Phantom Lake Group	Coarse-grained, arkosic, quartz-pebble conglomerate	Rock Creek area, northern Medicine Bow Mountains, SW¼, Sec.10, T.18N., R.79W.	No data	3X	3.2	Not detected
5	Magnolia Formation	Arkosic quartz-pebble conglomerate	Rock Creek area, northern Medicine Bow Mountains, C, Sec.25, T.18N., R.79W.	No data	7X	Not detected	Not detected
6	Upper Phantom Lake Group	Muscovite schist	Crater Lake area, northern Medicine Bow Mountains, NW¼, Sec.35, T.18N., R.79W.	No data	5X	Not detected	Not detected
7	Lower Phantom Lake Group	Pebbly quartzite	Medicine Bow River area, northern Medicine Bow Mountains, ?SE¼, Sec.30, T.18N., R.79W.	No data	2.5X	Not detected	Not detected
8	Lower Phantom Lake Group	Hematitic quartz vein	Medicine Bow River area, northern Medicine Bow Mountains, E½, Sec.31, T.18N., R.79W.	No data	1.5X	7	Not detected

Table 3, continued

SITE NUMBER	UNIT	LITHOLOGY	LOCATION	MAXIMUM SCINTILLOMETER READINGS, (COUNTS PER SECOND)	RADIOACTIVITY RELATIVE TO LOCAL BACKGROUND	URANIUM (PPM)	THORIUM (PPM)
9	Lower Phantom Lake Group	Hematitic quartz vein	Medicine Bow River area, northern Medicine Bow Mountains, SW¼, Sec.32, T.18N., R.79W.	No data	1.5X	10	Not detected
10	Lower Phantom Lake Group	Mafic tuff and mafic agglomerate	Near Crater Lake, Medicine Bow Mountains, SW¼, Sec.35, T.18N., R.79W.	20,000	No data	No data	No data
11	Magnolia Formation	Arkosic quartz-pebble conglomerate	Deep Creek area, Medicine Bow Mountains, N½, Sec.2, T.17N., R.79W.	No data	3X	Not detected	Not detected
12	Magnolia Formation	Arkosic quartz-pebble conglomerate	North Fork Rock Creek, Medicine Bow Mountains, S½, NW¼, Sec.6, T.17N., R.78W.	No data	5X 1 sample	150 1 sample	Not detected
13	Magnolia Formation	Arkosic, quartz-pebble conglomerate	North Fork Rock Creek, Medicine Bow Mountains, SW¼, NW¼, Sec.22, T.17N., R.79W.	20,000 1 sample	2X-6X 5 samples	0.5-11.2 5 samples	Not detected
14	Medicine Peak Quartzite	Sheared granite	Lewis Lake area, Medicine Bow Mountains, SW¼, SE¼, Sec.8, T.16N., R.79W.	No data	10X	Not detected	Not detected
15	Lookout Schist	Sulphide veinlet in granite	Lewis Lake area, Medicine Bow Mountains, NW¼, Sec.17, T.16N., R.79W.	No data	20X	Not detected	Not detected
16	Magnolia Formation	Arkosic quartz-pebble conglomerate	Arrastre Lake area, Medicine Bow Mountains, NW¼, Sec.10, T.16N., R.80W.	22,000 1 sample	2X-6X 9 samples	2.8-8.4 9 samples	20-38 9 samples
		Heavy mineral separate from conglomerate	"	No data	No data	89	Not detected

Table 3, continued

SITE NUMBER	UNIT	LITHOLOGY	LOCATION	MAXIMUM SCINTILLOMETER READING, (COUNTS PER SECOND)	RADIOACTIVITY RELATIVE TO LOCAL BACKGROUND)	URANIUM (PPM)	THORIUM (PPM)
17	Magnolia Formation	Quartz vein	Arrastre Lake area, Medicine Bow Mountains, SW¼, Sec.10, T.16N., R.80W.	No data	No data	31	Not detected
18	Upper Phantom Lake Group	Paraconglomerate (amphibolite matrix)	Headwaters of South Brush Creek, Medicine Bow Mountains, NW¼, Sec.21, T.16N., R.80W.	No data	2X-3X	Not detected	Not detected
19	Upper Phantom Lake Group?	Arkosic, quartz-pebble conglomerate (? paraconglomerate)	South Brush Creek area, Medicine Bow Mountains, NW¼, Sec.23, T.16N., R.81W.	25,000	5X-6X	No data	No data
20	Magnolia Formation	Quartz-pebble conglomerate	Bottle Creek area, Sierra Madre, SE¼, Sec.13, T.14N., R.85W.	No data	3X 2 samples	3.0-6.0* 74 samples	39* 1 sample
21	Cascade Quartzite	Quartz-pebble conglomerate	Rambler mine area, Sierra Madre, NE¼, Sec.25, T.14N., R.86W.	No data	No data	Not detected	Not detected
22	Cascade Quartzite	Quartzite	Haggerty Creek area, Sierra Madre, NE¼, Sec.30, T.14N., R.86W.	No data	No data	Not detected	Not detected
23	Magnolia Formation	Quartzite and phyllite (mine dump)	Ferris-Hagerty mine area, Sierra Madre, NW¼, Sec.16, T.14N., R.86W.	No data	No data	Not detected	Not detected
24	Upper Phantom Lake Group	Quartz-pebble conglomerate	North Spring Creek Lake area, Sierra Madre, NE¼, Sec.8, T.14N., R.86W.	No data	No data	4.3	Not detected
25	Copperton Quartztie	Quartzite	Haggarty Creek area, Sierra Madre, NW¼, Sec.31, T.14N., R.86W.	No data	No data	Not detected	Not detected

Table 3, continued

SITE NUMBER	UNIT	LITHOLOGY	LOCATION	MAXIMUM SCINTILLOMETER READING, (COUNTS PER SECOND)	RADIOACTIVITY RELATIVE TO LOCAL BACKGROUND	URANIUM (PPM)	THORIUM (PPM)
26	Vagner Formation	Quartz-pebble conglomerate	Big Sandstone Creek area, Sierra Madre, NW¼, Sec.21, T.14N., R.87W.	No data	No data	0.8	Not detected
27	Upper Phantom Lake Group	Quartz-pebble conglomerate	Headwaters of East Fork of Savery Creek, Sierra Madre, SE¼, Sec.25, T.15N., R.87W.	No data	4X-6X	No data	No data
28	Magnolia Formation	Quartz-pebble conglomerate	Headwaters of a Deep Creek tributary, Sierra Madre, N½, Sec.34, T.15N., R.87W.	No data	2X-4X	Not detected	Not detected
29	Magnolia Formation	Quartz-pebble conglomerate	Dexter Peak area, western Sierra Madre, SE¼, SE¼, Sec.21, T.15N., R.87W.	No data	12X-22X 2 samples	3.0-131* 5 samples	16-664* 3 samples
30	Upper Phantom Lake Group	Quartz-pebble conglomerate	East Savery Creek area, Sierra Madre, NW¼, Sec.7, T.15N., R.87W.	No data	4X-5X	Not detected	Not detected
31	Upper Phantom Lake Group	Quartz-pebble conglomerate	Deep Gulch area, western Sierra Madre, NW¼, SE¼, Sec.36, T.16N., R.88W.	No data	16X 1 sample	27.5-37* 2 samples	718* 1 sample
32	Lower Phantom Lake Group	Quartz-pebble conglomerate	North Fork Savery Creek, western Sierra Madre, SE¼, Sec.19, T.16N., R.87W.	No data	5X	Not detected	Not detected
33	Lower Phantom Lake Group	Quartz-rich gneiss	Deep Gulch area, western Sierra Madre, NW¼, SW¼, Sec.36, T.16N., R.88W.	No data	3X	Not detected	Not detected
34	?	Quartz-pebble conglomerate	Core from Battle Mountain State No. 1 well, west of Sierra Madre outcrops, Sec.36, T.13N., R.88W.	No data	No data	No data	No data

*Analyses by U.S. Geological Survey; analysts: H.T. Millard, Jr.; C.M. Ellis; C. McFee; D.M. Hopkins; W.H. Ficlin.

The radioactive conglomerates in the upper Phantom Lake Group and the Magnolia Formation have many characteristics in common with uranium-bearing rocks in the Huronian Supergroup of Canada as described by Roscoe (1969) and Robertson (1976). In both areas, the rocks contain radioactive minerals and pyrite and are considered to be fluvial deposits. However, the conglomerates in the Medicine Bow Mountains are relatively immature, poorly to moderately sorted, arkosic conglomerates whereas high-grade uranium ore zones in the Huronian Supergroup tend to be mature, well sorted, quartz-pebble conglomerates. Thus, it appears unlikely that the radioactive units seen so far in the Medicine Bow Mountains are directly analogous to ore zones in the Huronian Supergroup. It is possible that the conglomerates in the Phantom Lake and Deep Lake groups represent a more proximal facies of fluvial deposition than do conglomerates in the Huronian Supergroup.

There are several indications that oxidation of surface outcrops in the Medicine Bow Mountains has leached pyrite and uranium from the radioactive conglomerate units. First, pyrite grains are only locally preserved in the conglomerates, having been partly or completely altered to iron oxides. Second, abundant holes and cube-shaped casts filled with iron oxide are scattered throughout the matrix of the conglomerates and attest to original abundance of pyrite greatly exceeding present abundance.

Uranium has also been leached from surface outcrops in the Medicine Bow Mountains. Miller, and others (1977) analyzed the radon content of ground water in the Arrastre Lake (Plate 2, sec. 9, T. 16 N., R. 80 W.) area and compared those data with the uranium content of surface rocks, ground water, and bog material. Radon is a short-half-life (3.8 days) daughter product of uranium 238. It cannot migrate long distances in water and is a positive indication of nearby uranium. Miller, and others (1977) found that the radon content of waters in the Arrastre Lake area was several orders of magnitude greater than could be accounted for by decay of surface uranium 238. They concluded that subsurface rocks contain far more uranium than surface rocks.

Before proceeding, it may also be worth noting that above-background radiation (10-20x) has locally been observed in both the Medicine Peak Quartzite (Figure 3, sample site 14) and in the Lookout Schist (Figure 3, sample site 15).

In the Sierra Madre, radioactive units are not only reported in the upper and lower Phantom Lake Group and Magnolia Formation, but also are reported in rocks now mapped as the Cascade Quartzite, Vagner Formation, and Copperton Quartzite (Whalen, 1954; Graff and Houston, 1977) (Table 3). In the latter three cases, the radioactive occurrences are isolated occurrences and probably not typical of these formations. Quartzite in the Cascade and Copperton quartzites are reportedly radioactive on the east side of Haggerty Creek (Figure 3, sample sites 22 and 25, respectively). A second radioactive occurrence in the Cascade Quartzite is reported north of Battle Lake (Figure 3, sample site 21). A quartz-pebble conglomerate in the Vagner Formation is radioactive in the headwaters of Big Sandstone Creek (Figure 3, sample site 26).

As in the Medicine Bow Mountains, the most commonly radioactive conglomerates in the Sierra Madre are found in the upper Phantom Lake Group and the Magnolia Formation of the Deep Lake Group. These quartz-pebble conglomerates occur as channels of well sorted, well rounded, quartz and chert-pebble clasts. These conglomerate lenses occur in sericitic quartzite layers low in the Phantom Lake and Deep Lake Groups. Pyrite, sometimes as pseudo-rounded grains, is present in amounts ranging from a few tenths to about 10 percent; however, in most outcrops darkly stained, porous zones may respresent weathered areas of concentrations of pyrite. These weathered zones often contain voids which are the casts of weathered-out pyrite grains.

Single outcrops of sericitic quartzite are as great as 30 meters in thickness with channels of conglomerate scattered laterally and vertically throughout the exposure. Highly stained zones, brown to yellow in color, often indicate areas of pyrite and other heavy mineral concentrations.

Radioactive quartz-pebble zones in the lower Phantom Lake Group are reported along the North Fork of Savery Creek (Figure 3, sample site 32) and in the Deep Gulch area (Figure 3, sample site 33) of the western Sierra Madre. Upper Phantom Lake Group conglomerates are radioactive in the North Spring Creek Lake area (Figure 3, sample site 24), in the vicinity of the East Fork of Savery Creek (Figure 3, sample sites 27 and 30), and in the Deep Gulch area (Figure 3, sample site 31).

Radioactive occurrences in the Magnolia Formation have been reported in the Bottle Creek area (Figure 3, sample site 20), at the Ferris-Hagerty mine

(Figure 3, sample site 23), at the headwaters of a Deep Creek tributary (Figure 3, sample site 28), and in the Dexter Peak area (Figure 3, sample site 29).

DEPOSITIONAL ENVIRONMENTS OF RADIOACTIVE CONGLOMERATES

The basal beds of the upper Phantom Lake Group, including the radioactive sericitic quartzite with conglomerate beds and the overlying quartzite with fining-upward sets, are fluvial (Table 4). Much more information must be obtained on primary structure, paleocurrent direction, and petrography before a sedimentological model can be proposed, but these basal beds have features like those described by Minter (1976) for the gold-uranium Vaal Reef Placer and associated beds of South Africa and by McGowen and Groat (1971) for the Cambrian(?) distal facies Van Horn Sandstone of West Texas, and by McDowell (1957), Roscoe, (1969), and Robertson (1976) for the Blind River uranium-bearing quartz-pebble conglomerates of Canada.

Minter (1976) interprets the Vaal Reef as a braided drainage system deposited unconformably on a gently sloping paleosurface. The Vaal Reef ore body is a light gray, pebbly, siliceous quartzite with a bimodal size-frequency distribution (Minter, 1976, p. 165). According to Minter, it contains every combination of sand-sized and pebble-sized material varying from a few inches of siliceous quartzite to consecutive layers of conglomerate, pebbly quartzite, conglomerate, siliceous quartzite, and quartzite developed in channels. The beds that underlie the Vaal Reef are coarse-grained siliceous to argillaceous quartzites with minor, thin, shale partings (Minter, 1976, p. 162). The beds that overlie the Vaal Reef are largely argillaceous quartzite. The Vaal Reef is thus a conglomeratic unit (a few inches to a few feet thick), largely confined by coarse-grained quartzite. Minter has made thousands of observations of the Vaal Reef and associated rocks, a good part underground, and from his comprehensive data bank, he has developed a model that describes the genesis of the Vaal Reef Placer. It is much too early to attempt this kind of interpretation for the units of the Sierra Madre and Medicine Bow Mountains; however, we will present the information collected to date, and the reader will see a similarity to the Vaal Reef and associated rocks.

In the Arlington or Onemile Creek locality northeast of the Medicine Bow Mountains study area, some limited information is available from surface studies of the radioactive coarse-grained sericitic quartzite unit and from study of cores made available by the Exxon Company. Maximum thickness of the radioactive unit measured in subsurface is 130 meters. The unit is essentially sericitic, coarse-grained quartzite with pebble layers. The pebble layers range from beds with the thickness of a single pebble to compound zones approximately three meters thick that include pyritic quartz-pebble conglomerate, fine-grained pyritic quartzite, and coarse-grained pyritic quartzite, in varying combinations. There are four compound zones from 0.5 to 3 meters thick. In addition there are eleven other pyritic quartz-pebble layers less than 0.5 meters thick scattered through the 130 meter section. As noted above, the entire section has radioactivity above background for the area, but the most radioactive units are the conglomerate layers. These conglomerate layers are several orders of magnitude more radioactive in subsurface samples (at depths below 35 meters) than they are on the surface, and they contain abundant pyrite (up to 20 percent from visual estimates) which is almost entirely leached from surface samples.

Clearly because both uranium minerals and pyrite have been largely removed from the surface, useful information on the occurrence of these minerals must come from the subsurface. Subsurface samples show that the most intense radioactivity is characteristically at the base of conglomerate layers suggesting that there is a concentration of uranium- and thorium-bearing minerals at the base of channels. Study of cores also shows that pyrite is more abundant in conglomerate layers, but it does not appear to be concentrated at the base of the layer. Some pyrite appears rounded in hand specimens, but most occurs as euhedral grains; some with vugs. The pyrite may have been redistributed -- it is certainly largely recrystallized.

The pyritic quartz-pebble conglomerate layers are trimodal and consist of a major clay-silt-sized fraction, sand-sized fraction, and pebble-sized fraction. The silt-sized fraction is largely sericite, the sand-sized fraction is largely quartz with subordinate feldspar, and the rounded pebbles consist chiefly of vein quartz, quartzite, altered felsic volcanic rocks(?), and some altered feldspar(?) of possible pegmatite origin.

The source of the clasts in the radioactive unit is not known. A few paleocurrent measurements have been made on cross-bedding sets in quartzite above the radioactive unit, and they indicate a source to the north or north-northeast (Karlstrom, 1977). These measurements are not statistically valid, and they are not from rocks within the radioactive unit proper. However, field observations of the size of clasts within the conglomerate of the radioactive unit indicate that the coarsest fraction is found in the northernmost outcrop; so the available evidence although not conclusive, suggests a north to north-northeast source.

We suggest that pyritic, quartz-pebble conglomerate units with radioactive minerals concentrated at their base, fining-upward sets containing quartzite with trough cross-bedding, "rounded" pyrite, and thick channel-like units similar to those described by Minter (1976, p. 165-166) in the Vaal Reef of South Africa, imply a fluvial origin for the conglomerate and its associate pyrite and radioactive minerals. As stated above, the best guess is that these conglomerates were deposited in braided streams, but their exact depositional environment or source is presently unknown.

In the Sierra Madre the radioactive unit in the upper Phantom Lake Group is also considered to be fluvial, and is succeeded by fine-grained quartzites that grade upward into rocks that were probably argillites; an overall fining-upward section (cycle 1) that might be interpreted as a transgressive sequence of some type. There is no evidence to ascertain whether the upper part of the cycle is non-marine or marine. The sequence above cycle 1 grades from quartzite to marble; again suggesting a second transgressive sequence (cycle 2). The marble may indicate a marine origin for the upper part of this unit. In the western Sierra Madre, beds above these two cycles were probably also deposited in cycles, but they are generally finer grained and contain a larger proportion of rocks that were originally argillite. This suggests deposition at some distance from source and a possible marine origin for some of these rocks (Table 4). The origin of the metavolcanic rocks and associated paraconglomerate of the eastern Sierra Madre is uncertain. Features of some metavolcanic rocks (pillows) suggest a marine environment of deposition, but the paraconglomerate may be nonmarine (see Graff, 1978 , for a detailed discussion of these rocks).

In the Medicine Bow Mountains, there are several clues to the provenance and depositional environment of the basal conglomerate of the Magnolia Formation. This radioactive conglomerate is characterized by poorly sorted quartz-pebbles and rock fragments in an arkosic matrix. The rock fragments are mainly quartzite and phyllite which are similar to micaceous quartzite and phyllite units in the underlying Phantom Lake Group. No metavolcanic rock fragments were observed. Thus, the radioactive conglomerates appear to have been derived from a not-too-distant source, transported a short distance, and deposited unconformably on the upper Phantom Lake Group. The coarse grain sizes, poor sorting, distinct horizons (or channels) of clasts, and trough cross-bedding all suggest deposition by fluvial currents in a fairly high-energy flow regime. The pebbles and rock fragments can be interpreted as stream gravels that were deposited in migrating channels of a river system, and the few trough cross-beds may have formed by migrating dunes. The prevalence of horizontal stratification, rarity of trough cross-bedding, and coarse grain sizes suggest high current flow velocities (Harms, and others, 1975).

In the Sierra Madre, the basal uraniferous conglomerate of the Magnolia Formation is also coarse-grained with some trough cross-bedding. Like the quartz-pebble conglomerate at this horizon in the Medicine Bow Mountains, the basal conglomerate is believed to be of fluvial origin.

RELATIONSHIP OF REGIONAL STRUCTURE TO THE DISTRIBUTION OF RADIOACTIVE CONGLOMERATES

Background information on the structure of the Medicine Bow Mountains is in Houston, and others (1968, p. 101-135) and in Houston, Schuster, and Ebbett (1975, p. 6-25) for the Sierra Madre. Karlstrom (1977, p. 70-110) gives detailed information on the structure of the metasedimentary rocks of the Medicine Bow Mountains in the area from the confluence of Little Brush Creek and South Brush Creek to the heads of Trail Creek and the Middle Fork of Rock Creek (Plate 2). Details of Sierra Madre structure (Plate 1) are in Graff (1978).

This review of the structure of these two ranges will be confined to regional features that may control the distribution of radioactive conglomerates. In the Medicine Bow Mountains, outcrops of the Phantom Lake Group west of the confluence of Little Brush Creek and South Brush Creek constitute as east-plunging syncline (Plate 2; sec. 24, T. 16 N., R. 81 W.). The radioactive unit at the base of the upper Phantom Lake Group probably is located in the trough of this syncline. A major northeast-striking fault with southeast side down is extrapolated into this area and is believed to strike roughly parallel to Little Brush Creek. East of this fault a north-northeast-plunging anticline is exposed which has upper Phantom Lake Group rocks in its core and Deep Lake Group rocks up to Cascade Quartzite in the nose of the structure (Plate 2; secs. 2, 10, 16, T. 16 N., R. 80 W.). The radioactive unit at the base of the Magnolia Formation has been mapped on the east side of this anticline and is missing on the west side. If the radioactive unit represents a braided river system, it may trend north-northeast, parallel to paleocurrent directions measured in the associated quartzite (Karlstrom, 1977). Although the width of such a paleo-river system is not known, the radioactive unit should be expected in the subsurface east of the surface outcrop. Another braided river system may occur in the subsurface on the northwest flank of the anticline, but there is no surface evidence for such a system. Inasmuch as rocks of the Phantom Lake Group are in the core of the anticline, the radioactive unit in the upper Phantom Lake Group may be found by drilling. The radioactive unit of the upper Phantom Lake Group if present, might be encountered at shallow depth by drilling in the South Brush Creek area. The southeast flank of the anticline is bound by a northeast-striking thrust fault that brings rocks of the Libby Creek Group over this structure. Rocks of the Phantom Lake Group and the Deep Lake Group may be in the subsurface east of this fault but any interpretation of their distribution would be highly speculative.

To the northeast within the outcrop area of the Deep Lake Group, the anticlinal axis changes strike from north-northeast to east (Plate 2; sec. 31, T. 17 N., R. 79 W.). The anticline is limited on the north by a major fault (the Jeff Lake fault) downthrown on the south side, and the anticline is limited on the south by rocks of the Libby Creek Group thrust over the older rocks of the anticline.

East of Deep Lake, the anticlinal axis changes to a northeast strike once again, and this strike remains constant to Rock Creek (Plate 2; sec. 18, T. 17 N., R. 78 W.) where the structure is disrupted by a series of north-striking faults that parallel Rock Creek. Erosion does not cut deeply enough to expose radioactive conglomerate of either the Deep Lake Group or Phantom Lake Group. However, on the upthrown side of the Jeff Lake fault, older rocks are exposed in a number of areas in a block marked by the Medicine Bow River on the west and Rock Creek on the east, and by Deep Creek on the north and by the Jeff Lake fault on the south. Outcrops within this block are uncommon, but the structure is probably a series of anticlines and synclines disrupted by faults that parallel the fold axes and are upthrown on the north side (Plate 2; northern part of study area). This block or domain can be divided into two parts by considering rocks east and west of a north-striking fault that is located west of Corral Lake, the Corral Lake fault (Plate 2; sec. 21, T. 17 N., R. 79 W.). West of the Corral Lake fault, the Cascade Quartzite is exposed although there are no surface exposures of radioactive conglomerate. If the radioactive conglomerate of the Magnolia Formation that is exposed east of Arrastre Lake is projected north-northeast (parallel to paleocurrent indicators), it might be found by drilling in the area east of the Medicine Bow River. East of the Corral Lake fault, radioactive conglomerate is exposed at four localities, near the head of the North Fork of the Rock Creek where radioactive conglomerate of the Magnolia Formation is exposed on the south limb of an anticline (Plate 2; sec. 22, T. 17 N., T. 79 W.); on the south side of Deep Creek where radioactive conglomerate of the Magnolia Formation is exposed on the north limb of a syncline (Plate 2; sec. 2, T. 17 N., R. 79 W.); and at one locality west of Rock Creek where radioactive conglomerate is exposed on the south limb of the same syncline (Plate 2; sec. 6, T. 17 N., R. 78 W.). These surface exposures show that radioactive conglomerate of the Magnolia Formation should be expected in the subsurface in much of this eastern area; unfortunately there is not sufficient information on paleocurrent directions to establish a reliable trend for a braided river system. Paleocurrent measurements (Karlstrom, 1977, pl. 11) are difficult to obtain in the conglomerate of the Magnolia Formation and those obtained in the quartzite above the conglomerate are quite variable; a south-southwest trend for a braided river system is suggested, however, from work to date. If this trend is correct, there are probably two river systems in the area, one near the headwaters of the North Fork of Rock Creek (Plate 2; sec. 22, T. 17 N., R. 79 W.), and another in the vicinity of Rock Creek, north of the study area. There is no information on radioactive conglomerate of the upper Phantom Lake Group, but it could occur within this area.

North of the study area, mapping is largely reconnaissance and all formations may have to be revised. For example, a radioactive unit mapped on Onemile Creek (Figure 3, sample sites 2 and 3) is exposed in the trough of a syncline with its northwest limb overturned. It is mapped as the basal radioactive unit of the upper Phantom Lake Group. However, there has been no recent mapping between Onemile Creek and Rock Creek. Therefore, it is possible that the overturned north limb of the syncline extends to an area south of the confluence of Deep Creek and Rock Creek and would thus be coincident with radioactive units mapped as basal Deep Lake Group or the Magnolia Formation of Karlstrom (1977). If these units are continuous, the radioactive unit on Onemile Creek might represent the base of the Magnolia Formation rather than the base of the upper Phantom Lake Group. We prefer the former interpretation, however, because hornblende schists and gneiss layers overlie the radioactive conglomerates on Onemile Creek. These rock types have not been found interbedded with metasedimentary rocks that are stratigraphically above the Magnolia Formation, but they are present in units of the Phantom Lake Group that overlie the radioactive conglomerate of the Sierra Madre.

If the above interpretation is correct, drilling in the axis of the syncline mapped west of Rock Creek and the axis of the same syncline extrapolated east of Rock Creek might encounter two radioactive beds; one at the base of the Magnolia Formation and another at the base of the upper Phantom Lake Group. Inasmuch as we have no reliable information on paleocurrents, no recommendations can be made on exact drill site locations. If a hole were drilled in the axis of the syncline west of Rock Creek, depth to basal

Magnolia would be approximately 130 meters, but depth to the base of the upper Phantom Lake Group might be 3,000 meters or more.

In general, mapping east of Rock Creek and north of approximately the southern margin of T. 18 N. (Figure 1), is outdated and mostly reconnaissance. Further mapping will be required to evaluate the economic potential of this area.

Sierra Madre structure has never been well understood because primary structures, used for top and bottom criteria in metasedimentary rock, have been difficult to find. Cross-bedding, channels, and graded bedding have been found in local areas by geologists who have studied the metasedimentary rocks (Short, 1958; Ebbett; 1970; Divis, 1976; Houston and Ebbett, 1977; and Graff, 1978), but they are often missing or destroyed in key areas where they are needed to establish a stratigraphic succession or interpret the structure. Therefore, it is not surprising that a different structural interpretation has been proposed by every geologist who has described the metasedimentary succession.

From the areas east and west of the Encampment River where the easternmost exposures of metasedimentary rocks are found, west to the limit of outcrop of metasedimentary rocks, the great majority of beds in the metasedimentary succession top south. There is good evidence for folding, however, in rocks exposed in the western Sierra Madre; notably west of Haggerty Creek (Plate 1; sec. 19, T. 14 N., R. 86 W.) and in the entire northwest area of outcrop of metasedimentary rocks (Plate 1). In this report, we interpret metasedimentary rocks of the central and eastern Sierra Madre (east of Haggerty Creek) as not isoclinally folded, but instead as disrupted by east-striking thrust faults, and further we interpret the stratigraphic succession exposed in the western Sierra Madre between Jack Creek (Plate 1; sec. 32, T. 14 N., R. 86 W.) and Deep Creek (Plate 1; sec. 4, T. 14 N., R. 87 W.) as a normal succession interrupted only by minor folds.

In sec. 25, T. 15 N., R. 87 W., radioactive conglomerate is present near the base of the metasedimentary succession (Plate 1). This radioactive conglomerate probably lies unconformably on an Archean basement of felsic gneiss and older metasedimentary rocks, but the actual unconformity is not exposed. This radioactive conglomerate is mapped as the basal bed of the upper Phantom Lake Group. West of the head of Deep Creek (Plate 1; sec. 21, T. 15 N., R. 87 W.), another radioactive conglomerate is exposed that is correlated with the radioactive conglomerate at the base of the Magnolia Formation of Karlstrom (1977). This radioactive conglomerate probably also lies unconformably on older rocks, but again the actual unconformity is not exposed.

The East Fork of Savery Creek is a convenient line to separate the Sierra Madre into two parts (Plate 1; sec. 17, T. 15 N., R. 87 W.). We will discuss the structure of the metasedimentary rocks south and east of the East Fork of Savery Creek first. South of the East Fork of Savery Creek, a series of southwest-plunging folds is developed in the Magnolia Formation and overlying beds (Plate 1). These folds die out down-section in the upper Phantom Lake Group metasedimentary rocks. The folds are best developed in metasedimentary rocks having a high proportion of phyllite and slate, and they may represent detachment of younger metasedimentary rocks from older rocks with the phyllite or slate layers acting as detachment planes. These folds have not been mapped east of Haggerty Creek (Plate 1; sec. 19, T. 14 N., R. 86 W.). In that area most beds dip south and with few exceptions, they also top south. There is local evidence of folding in the rocks east of Haggerty Creek, however, they are minor folds with amplitudes of several meters. There are also a few isolated quartzites with primary structure suggesting top north. Inasmuch as we have not been able to verify major folds in this area, the uncommon reversals are considered to be parts of minor folds developed in response to the same stress field that caused the development of thrust faults.

From west to east the exposed metasedimentary succession (probably representing the north limb of a west-plunging synclinorium) is reduced from about 13,000 meters to about 3,000 meters; in fact, it tapers to a feather edge on the east bank of the Encampment River (Plate 1, eastern side). This is accomplished by thrust faults that move younger rocks over older. These thrust faults dip south, are commonly marked by thick sills of diabase, and clearly have greater displacement to the east than they have to the west. There may also be a wedge effect because Archean basement is thought to be in fault contact with quartzites of the upper

Phantom Lake Group from South Spring Creek (Plate 1; sec. 36, T. 15 N., R. 86 W.) east to the limit of outcrop. The Archean basement may be thrust over upper Phantom Lake Group metasedimentary rocks along fault planes that dip north. There is a major fault within the basement which follows the East Fork of Savery Creek and turns southeast at about sec. 24, T. 15 N., R. 87 W. (Plate 1). This fault brings hornblende gneiss of possible volcanic origin against quartzite in sec. 14, T. 15 N., R. 87 W. (Plate 1). Where this fault turns southeast, it brings northeast-striking basement gneiss against northwest-striking basement rocks (Plate 1; sec. 23, T. 15 N., R. 87 W.). This fault continues southeast to South Spring Creek Lake where it is offset by another fault that strikes northeast (Plate 1; sec. 11, T. 14 N., R. 86 W.). It may be the same fault that brings Archean basement over upper Phantom Lake Group rocks in the eastern Sierra Madre.

The distribution of the basal radioactive conglomerate of the upper Phantom Lake Group is controlled largely by structure. Outcrops are such that the conglomerate cannot be traced for a significant distance northwest or southeast of its outcrop area in sec. 25, T. 15 N., R. 87 W. (Plate 1). The conglomerate should be cut out by a fault to the northwest, however, and it probably does not extend too far to the southeast because certainly from South Spring Creek eastward, it is probably cut out by faults bringing the Archean basement over upper Deep Lake Group metasedimentary rocks (Plate 1; sec. 36, T. 15 N., R. 86 W.).

The radioactive conglomerate at the base of the Magnolia Formation is exposed in the axes of two southeast-plunging synclines and probably extends under cover in an anticlinal axis located in sec. 28, T. 15 N., R. 87 W. (Plate 1). The radioactive conglomerate has been traced in a linear outcrop of the Magnolia Formation southeast to sec. 2, T. 14 N., R. 87 W. (Plate 1). The radioactive conglomerate may pinch out east of this locality, or it may be removed by faults. Radioactive conglomerate reappears in the Magnolia Formation in the eastern Sierra Madre between Cow Creek and Bottle Creek (Plate 1; sec. 14, T. 14 N., R. 85 W.). This conglomerate is not like the basal conglomerate in the folds to the west. It is cleaner (contains less sericite), finer grained, and much less radioactive. It resembles conglomerate higher in the Magnolia Formation. Perhaps the lower part of the no primary structure can be found in the biotite gneiss, it has a layered aspect that suggests the unit was derived from sedimentary rocks or volcano-sedimentary rocks. The radioactive unit of sec. 36 can be traced for about five kilometers northeast, but in the NE 1/4, sec. 30, T. 16 N., R. 87 W., the radioactive unit lies on quartzite (Plate 1). The radioactive unit therefore, probably lies on successively younger rocks to the east, and is therefore clearly unconformable. The structural relationship might be as suggested in Figure 4.

Inspection of Plate 1 shows that the structure suggested above is disrupted by later faults, and also shows that key areas are yet to be mapped. The above interpretation is simply a working hypothesis, at present, but it may be significant that the radioactive unit exposed on Onemile Creek in the Medicine Bow Mountains shows a relationship to underlying rocks remarkably similar to that suggested above (Figure 4).

It is now possible to suggest other localities where the radioactive unit may be found in the northwest Sierra Madre. The first, simplest, and least economically attractive hypothesis, is to suggest that the radioactive units pinch out at about their northeast mapped limit. This does not seem probable because both radioactive units have at least, average thickness at their northeast limit. Certainly the two radioactive units might extend under cover for some distance to the southwest, because both units are near maximum thickness at their southwest limit. In other words, we do not expect these radioactive units to terminate abruptly.

The northernmost radioactive unit is probably cut out by a northwest-striking fault extrapolated into this area (Figure 4). This fault is upthrown on the northeast and would bring older rocks in contact with the radicactive unit near the point where the conglomerate is exposed in the NW 1/4, sec. 29, T. 16 N., R. 87 W. (Plate 1).

The radioactive unit on the northwest limb of the syncline might be found near the contact with gneiss by careful mapping to the northeast of the last known exposure. An interesting possibility, however, is that this radioactive unit lies on younger units to the northeast in the same manner that the northernmost radioactive unit does. Under such circumstances it might be expected in a quite different stratigraphic position on both the north and

Magnolia Formation is removed by faults in this area, or the unit may simply thin and change character.

North of the East Fork of Savery Creek (Plate 1; sec. 17, T. 15 N., R. 87 W.), mapping of metasedimentary rocks is reconnaissance level, and there are sizeable gaps even in the reconnaissance mapping. This is an extremely interesting area, however, because thick beds of radioactive sericitic quartzite and associated radioactive conglomerate have been found in several areas and may occur at other localities.

Divide Peak is near the axis of an overturned syncline (Plate 1; sec. 3, T. 15 N., R. 87 W.). The axis of the syncline strikes northeast, from the East Fork of Savery Creek to Divide Peak and then gradually changes strike to the east and southeast (Plate 1). The northern limb of the syncline is overturned, and here the radioactive unit at the base of the upper Phantom Lake Group lies unconformably on biotite gneiss. The biotite gneiss complex of the lower Phantom Lake Group contains local layers of quartzite and has many quartz-rich layers that are probably metasediments; it is cut by a pink granite best exposed in sec. 1, T. 15 N., R. 88 W. (Plate 1). The radioactive unit has been mapped over a distance of two and four-tenths kilometers. Detailed mapping has not been undertaken but the radioactive unit has not been traced to the northeast beyond sec. 6, T. 15 N., R. 87 W. (Plate 1). The radioactive unit extends under cover to the southwest (Plate 1). Before we can consider the possible distribution of this radioactive unit in other parts of the syncline, exposures of metasedimentary rocks north and northwest of the syncline must be discussed.

The overturned northwest limb of the syncline is thought to be repeated in sec. 36, T. 16 N., R. 88 W. (Plate 1). Here a radioactive unit nearly identical to that exposed on the northwest limb of the syncline is present (Figure 3, sample site 31). This radioactive unit in sec. 36 lies unconformably on biotite gneiss of the lower Phantom Lake Group that is very similar to that at the base of the radioactive unit in the northwest limb of the syncline. The biotite gneiss of section 36 is undoubtedly partly paragneiss; near the contact with the radioactive unit it contains highly deformed but identifable clasts of granite and various metamorphic rocks. There gneisses of sedimentary origin grade into biotite gneiss and although

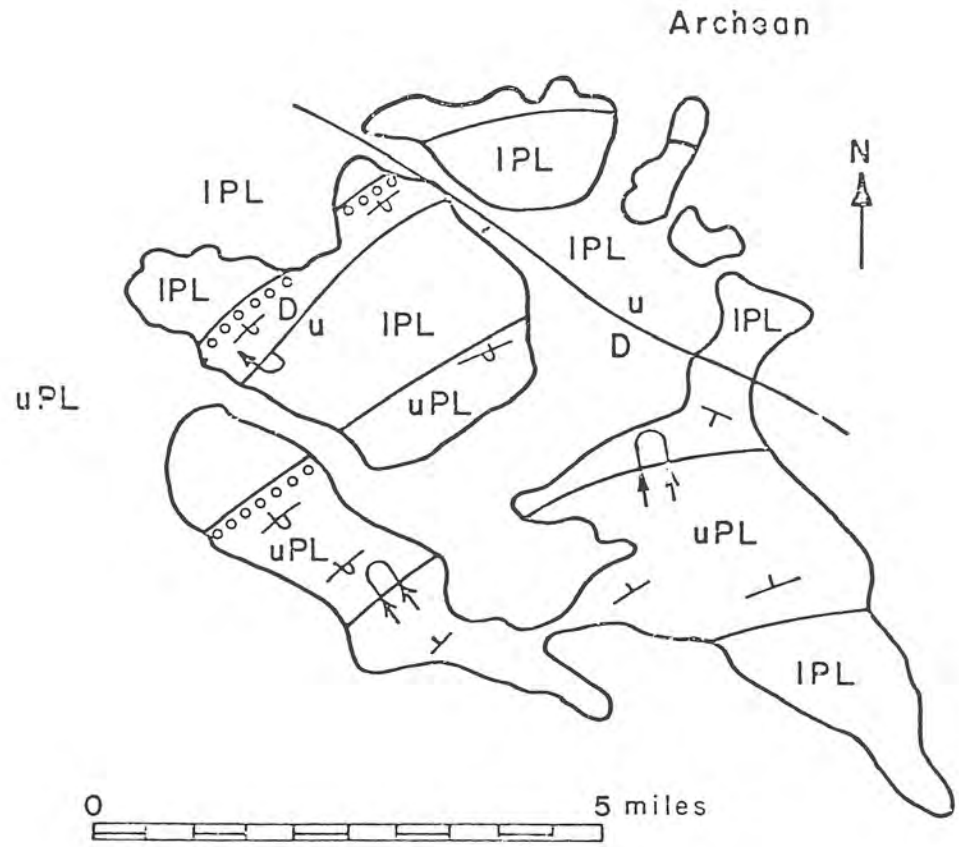


Figure 4. Tentative interpretation of structure at the northwest border of the Sierra Madre, southwestern Wyoming

south limb of the syncline.

REFERENCES

Bateman, J. D., 1958, Uranium-bearing auriferous reefs at Jacobina, Brazil: Econ. Geol., v. 53, p. 417-425.

Blackwelder, Eliot, 1926, Precambrian geology of the Medicine Bow Mountains: Geol. Soc. America Bull., v. 37, p. 615-658.

__________, 1935, Precambrian rocks of Utah and Wyoming: Utah Academy of Sciences, Arts and Letters, v. 22, p. 153-157.

Carey, S. W., and Ahmad, N., 1961, Glacial marine sedimentation: in Geology of the Arctic: Univ. of Toronto Press, Toronto, Ont., Canada, p. 865-894.

Cloud, P. E., 1968 Atmospheric and hydrospheric evolution on the primative earth: Science, v. 160, p. 729-736.

Davidson, C. F., 1953, The gold-uranium ores of the Witwatersrand; Mining Mag., v. 88, no. 2, p. 73-85.

Divis, A. F., 1976, Geology and geochemistry of Sierra Madre Range, Wyoming: Colorado School of Mines Quarterly, v. 71, no. 3, 127 p.

Ebbett, B. E., 1970, Geologic maps of the Singer Peak, Encampment, Red Mountain, and Bridger Peak quadrangles: Geol. Survey of Wyoming Open-File Maps, scale 1:24,000.

Engel, A. E. J., 1963, Geologic evolution of North America: Science, v. 140, p. 143-152.

Graff, P. J., 1978, Geology of the lower part of the Early Proterozoic Snowy Range Supergroup, Sierra Madre, Wyoming -- with chapters on Proterozoic regional tectonics and uraniferous quartz-pebble conglomerates: unpublished Ph.D. thesis, Univ. of Wyoming, 92 p.

Graff, P. J., and Houston, R. S., 1977, Radioactive conglomerate in Proterozoic (Precambrian X) metasedimentary rocks of the Sierra Madre, Wyoming: U.S. Geol. Survey Open-File Report 77-830, 7 p.

Harms, J. C., Southard, J. B., Spearing, D. R., and Walder, R. G., 1975, Depositional environments as interpreted from primary sedimentary structures and stratification sequences: Soc. Econ. Paleontologists and Mineralogists Short Course No. 2, 161 p.

Hills, F. A., Gast, P. W., Houston, R. S., and Swainbank, Ian, 1968, Precambrian geochronology of the Medicine Bow Mountains of southeastern Wyoming: Geol. Soc. America Bull., v. 79 p. 1757-1784.

Houston, R. S., and others, 1968, A regional study of rocks of Precambrian age in that part of the Medicine Bow Mountains lying in southeastern Wyoming -- with a chapter on the relationship between Precambrian and Laramide structure: Geol. Survey of Wyoming Memoir 1, 167 p.

Houston, R. S., Schuster, J. E., and Ebbett, B. E., 1975, Preliminary report on the distribution of copper and platinum group metals in mafic igneous rocks of the Sierra Madre, Wyoming: U.S. Geol. Surv. Open-File Report 75-85, 129 p.

Houston, R. S., and Ebbett, B. E., 1977, Geologic map of the Sierra Madre and western Medicine Bow Mountains, southeastern Wyoming: U.S. Geol. Survey Map MF-827.

Houston, R. S., Graff, P. J., Karlstrom, K. E., and Root, F. K., 1977, Preliminary report on radioactive conglomerate of middle Precambrian age in the Sierra Madre and Medicine Bow Mountains of southeastern Wyoming: U.S. Geol. Survey Open-File Report 77-574, 31 p.

Joubin, F. R., 1954, Uranium deposits of the Algoma District, Ontario: Canadian Inst. Mining Transactions, v. LVII, p. 431-437.

Karlstrom, K. E., 1977, Geology of the Proterozoic Deep Lake Group, Central Medicine Bow Mountains, Wyoming: unpublished M.S. thesis, Univ. of Wyoming, 116 p.

Knight, S. H., 1968, Precambrian stromatolites, bioherms, and reefs in the lower half of the Nash Formation, Medicine Bow Mountains, Wyoming: Contrib. to Geology, v. 7, no. 2, p. 73-116.

Lanthier, L. R., 1978, Stratigraphy and structure of the lower part of the Libby Creek Group, central Medicine Bow Mountains, Wyoming: unpublished M.S. thesis, Univ. of Wyoming, 30p.

Miller, W. R., Houston, R. S., Karlstrom, K. E., Hopkins, D. M., and Fickin, W. H., 1977, Geological and geochemical investigations of uranium occurrences in the Arrastre Lake area of the Medicine Bow Mountains, Wyoming: U.S. Geol. Survey Open-File Report 77-92, 30 p.

Minter, W. E. L., 1976, Detrital gold, uranium, and pyrite concentrations related to sedimentology in the Precambrian Vaal Reef Placer, Witwatersrand, South Africa: Econ. Geol., v. 71, p. 157-177.

McDowell, J. P., 1957, The sedimentary petrology of the Mississagi Quartzite in the Blind River area: Ontario Dept. Mines Geological Circ. No. 6, 31 p.

McGowen, J. H., and Groat, C. G., 1971, Van Horn Sandstone, West Texas: an alluvial fan model for mineral exploration: Texas Bur. of Econ. Geol. Report Inv. 72, 57 p.

Palonen, P. A., 1973, Paleogeography of the Mississagi Formation and Lower Huronian cyclicity, in Huronian stratigraphy and sedimentation: Geol. Assoc. Canada, Special Paper No. 12, p. 157-168.

Robertson, J. A., 1976, The Blind River uranium deposits: the ores and their setting: Ontario Division of Mines Misc. Paper 65, 45 p.

Roscoe, S. M., 1969, Huronian rocks and uraniferous conglomerates in the Canadian Shield: Geol. Surv. Canada Paper 68-40, 205 p.

Short, Ben L., 1958, A geologic and petrographic study of the Ferris-Haggerty Mining area, Carbon County, Wyoming: unpublished M. S. thesis, Univ. of Wyoming, 138 p.

Stanton, R. L., 1972, Ore petrology: McGraw-Hill Book Company, p. 564-565.

Sylvester, G. H., 1973, Depositional environment of diamictites in the Headquarters Formation, Medicine Bow Mountains, southeastern Wyoming: unpublished M.S. thesis, Univ. of Wyoming, 84 p.

Van Hise, Charles and Leith, C. K., 1909, Precambrian geology of North America: U.S. Geol. Survey Monograph 52, 641 p.

Whalen, J. F., 1954, Preliminary reconnaissance report: U.S. Atomic Energy Comm., DCB-RRD-1372-1375-1374.

Wilson, B. D., 1975, The origin of slaty cleavage and associated structures, Precambrian Lookout Schist, Medicine Bow Mountains, Wyoming: unpublished M.S. thesis, Univ. of Wyoming, 83 p.

Winkler, H. G. F., 1976, Petrogenesis of metamorphic rocks (4th ed.): Springer-Verlag, New York, Heidelberg, Berlin, 334 p.

Young, G. M., 1970, An extensive Early Proterozoic glaciation in North America: Palaeogeography, Palacoclimatology, Palaeoecology, v. 7, p. 85-101.

OFR 78-3

MEDICINE BOW MOUNTAINS

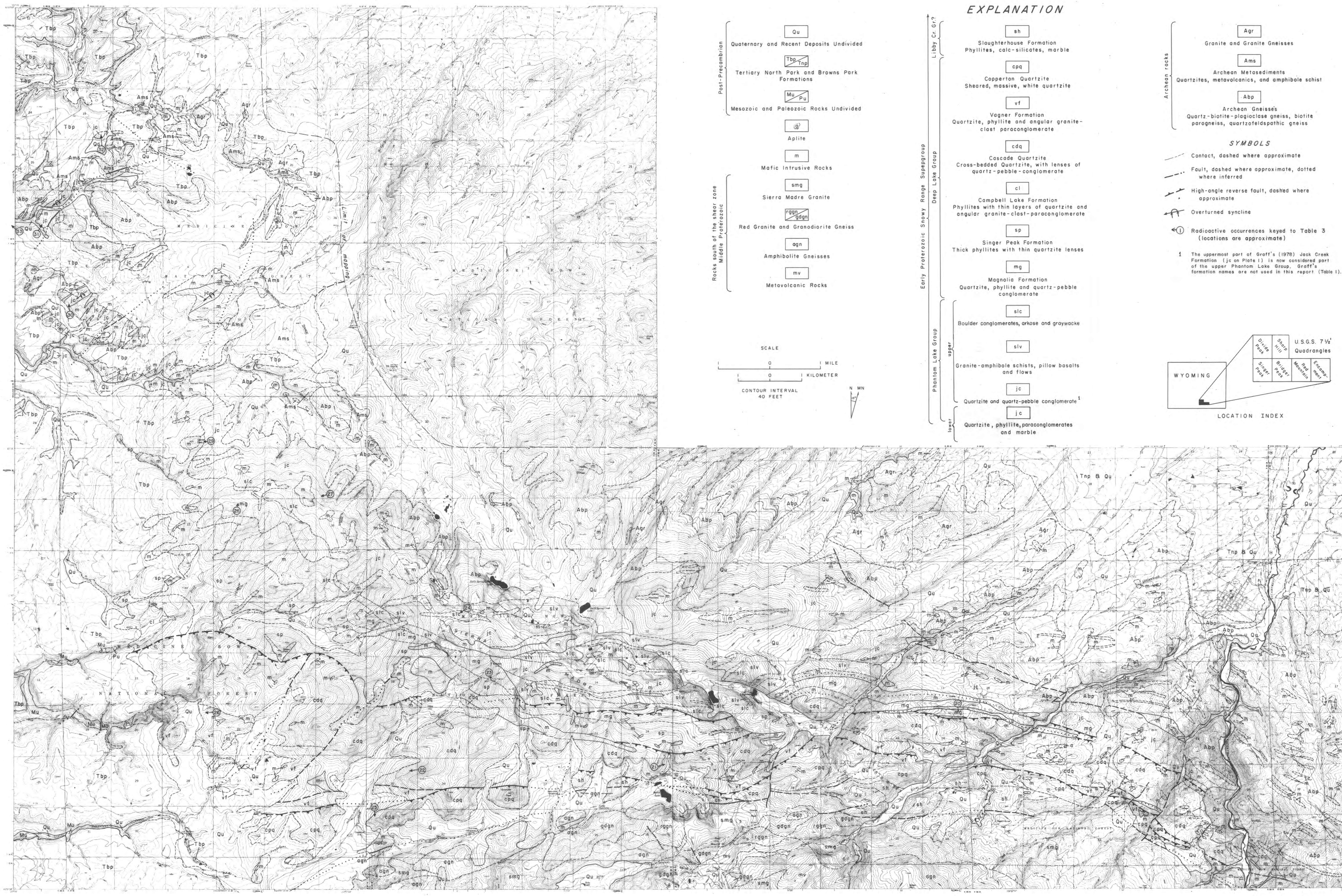
GROUP	FORMATION	LITHOLOGY	PRIMARY FEATURES	SOURCE	DEPOSITIONAL ENVIRONMENT	THICKNESS (M)
LIBBY CREEK GROUP	FRENCH SLATE	GRAY SLATE	THIN QUARTZITE LAYERS	?	MARINE	600
	TOWNER GREENSTONE	CHLORITE SCHIST	RELICT IGNEOUS TEXTURES	?	?	0-480
	NASH FORMATION	LENTICULAR PHYLLITE METADOLOMITE	GRAPHITIC LAYERS STROMATOLITES	?	MARINE SHALLOW MARINE	1900
	SUGARLOAF QUARTZITE	MASSIVE QUARTZITE	CROSS-BEDS, RIPPLE MARKS	?	MARINE	0-580
	LOOKOUT SCHIST	LAMINATED SCHIST WITH QUARTZITE LAYERS	SOLE MARKINGS CLASTIC DIKES CROSS-BEDDING	?	MARINE, TURBIDITES	365
	MEDICINE PEAK QUARTZITE	QUARTZITE: CONGLOMERATE	FINING UPWARD SEQUENCES	ENE	FLUVIAL AND SHALLOW MARINE	1585
		QUARTZ-PEBBLE CONGLOMERATE; QUARTZITE	MASSIVE		PRO-DELTAIC?	
		QUARTZITE	TABULAR CROSS-BEDS		NEAR SHORE MARINE	
	HEART FORMATION	QUARTZITE PHYLLITE QUARTZITE	MASSIVE LAMINATED MASSIVE, CROSS-BEDS	NE	SHALLOW MARINE MARINE SHALLOW MARINE; FLUVIAL	650
	HEADQUARTERS FORMATION	PHYLLITE	VARVES?	NNE	GLACIAL OR GLACIO-MARINE	650
		ARKOSIC QUARTZITE PARACONGLOMERATE	CROSS-BEDS DROPSTONES			
			UNCONFORMITY			
DEEP LAKE GROUP	ROCK KNOLL FORMATION	CONGLOMERATE; QUARTZITE QUARTZITE; PHYLLITIC QUARTZITE QUARTZITE	CHANNELS SLATE PARTINGS; RIPPLE MARKS PLANAR CROSS-BEDS	ESE	FLUVIAL SHALLOW MARINE SHALLOW MARINE	380
	VAGNER FORMATION	PHYLLITIC QUARTZITE	RIPPLE MARKS; CROSS-BEDS	ENE	GLACIAL OR GLACIO-MARINE	120-400
		MARBLE	SILICEOUS AND CALCAREOUS LAYERS			
		PARACONGLOMERATE	DROPSTONES			
			UNCONFORMITY			
	CASCADE QUARTZITE	PEBBLY, ARKOSIC QUARTZITE PEBBLY QUARTZITE	BLACK CHERT PEBBLES; TABULAR AND TROUGH CROSS-BEDS	ENE	FLUVIAL	150-1530
		QUARTZITE	MASSIVE			
	CAMPBELL LAKE FORMATION	QUARTZ-RICH PHYLLITE	FAINT STRATIFICATION	NE	MARINE?	75
		PARACONGLOMERATE			GLACIAL?	
	LINDSEY QUARTZITE	MEDIUM-GRAINED QUARTZITE	TROUGH CROSS-BEDS	?	FLUVIAL; FLUVIAL DELTAIC	440
	MAGNOLIA FORMATION	COARSE-GRAINED QUARTZITE	TROUGH CROSS-BEDS	NNE	FLUVIAL	570
		QUARTZ-GRANULE CONGLOMERATE	NOT OBSERVED	?	FLUVIAL	
		RADIOACTIVE QUARTZ-PEBBLE CONGLOMERATE	POOR SORTING, PLANAR BEDS	?	FLUVIAL	
			UNCONFORMITY			
PHANTOM LAKE GROUP	UPPER	PHYLLITE, BASALT, AND PARACONGLOMERATE	NOT OBSERVED		SUBAERIAL?	1500-2000
		MICACEOUS QUARTZITE PHYLLITE QUARTZITE	TROUGH CROSS-BEDS NOT OBSERVED TABULAR CROSS-BEDS	NE	SHALLOW MARINE?	
		QUARTZITE AND RADIOACTIVE QUARTZ-PEBBLE CONGLOMERATE	TROUGH CROSS-BEDS GRADED BEDS CHANNELS	? NNE	FLUVIAL	
	LOWER	VOLCANOCLASTIC METAGRAYWACKE, METAFLOWS, METATUFFS	NOT OBSERVED		SUBAERIAL?	800
		QUARTZITE, QUARTZ-PEBBLE CONGLOMERATE, PARACONGLOMERATE	TROUGH CROSS-BEDS CHANNELS		FLUVIAL	

SIERRA MADRE

GROUP	FORMATION	LITHOLOGY	PRIMARY FEATURES	SOURCE DIRECTION	DEPOSITIONAL ENVIRONMENT	THICKNESS (M)
LIBBY CREEK GROUP	LIBBY CREEK GROUP NOT PRESENT					
			SHEAR ZONE			
DEEP LAKE GROUP	SLAUGHTERHOUSE FORMATION	CALCAREOUS PHYLLITE; METADOLOMITE	NOT OBSERVED	?	MARINE	500
	COPPERTON QUARTZITE	MASSIVE SHEARED QUARTZITE; MINOR PHYLLITE	NOT OBSERVED	?	SHALLOW MARINE?	1400
	VAGNER FORMATION	PHYLLITE, QUARTZITE, MARBLE	RARE CROSS-BEDS	NE?	GLACIO-MARINE	600
		PARACONGLOMERATE	CHANNELS			
			UNCONFORMITY			
	CASCADE QUARTZITE	PEBBLE ARKOSIC QUARTZITE QUARTZ-ARENITE QUARTZ-PEBBLE CONGLOMERATE	TROUGH CROSS-BEDS CHANNELS	NE	FLUVIAL	2100
	CAMPBELL LAKE FORMATION	GREEN PHYLLITE, THIN QUARTZITE PARACONGLOMERATE	RARE CROSS-BEDS	?	GLACIO-MARINE	200
	SINGER PEAK FORMATION	THICK GREEN PHYLLITE, GREEN PHYLLITE WITH THIN, INTERBEDDED QUARTZITE	NOT OBSERVED	?	MARINE	1100
	MAGNOLIA FORMATION	ARKOSIC QUARTZITE, THIN PHYLLITE, QUARTZ GRANULE AND RADIOACTIVE QUARTZ-PEBBLE CONGLOMERATE	TROUGH CROSS-BEDS GRADED BEDS CHANNELS	NE	FLUVIAL	400
			UNCONFORMITY			
PHANTOM LAKE GROUP	UPPER (WEST)	PHYLLITE, SLATE	NOT OBSERVED	?	MARINE	1250
		PHYLLITE, QUARTZITE MARBLE AND QUARTZITE PARACONGLOMERATE (SCHIST)	NOT OBSERVED PLANAR CROSS-BEDS TURBIDITES			
		QUARTZITE AND RADIOACTIVE QUARTZ-PEBBLE CONGLOMERATE	TROUGH CROSS-BEDS GRADED BEDS CHANNELS	?	FLUVIAL	
	LOWER	VOLCANOCLASTIC METAGRAYWACKE, METAFLOWS, METATUFFS	NOT OBSERVED	?	SUBAERIAL?	2000+
		QUARTZITE	TABULAR CROSS-BEDS; RIPPLE MARKS	?	SHALLOW MARINE?	
		QUARTZ-PEBBLE CONGLOMERATE, PARACONGLOMERATE	TROUGH CROSS-BEDS CHANNELS	?	FLUVIAL	

Table 4. Depositional environments of the Phantom Lake, Deep Lake, and Libby Creek groups in the Sierra Madre and Medicine Bow Mountains, southeastern Wyoming.

PLATE 1



EXPLANATION

Post-Precambrian

Qu — Quaternary and Recent Deposits Undivided

Tbp / Tnp — Tertiary North Park and Browns Park Formations

Mu / Pu — Mesozoic and Paleozoic Rocks Undivided

ap — Aplite

m — Mafic Intrusive Rocks

Rocks south of the shear zone — Middle Proterozoic

smg — Sierra Madre Granite

rggn / gdgn — Red Granite and Granodiorite Gneiss

agn — Amphibolite Gneisses

mv — Metavolcanic Rocks

Early Proterozoic Snowy Range Supergroup

Libby Cr. Gr.?

sh — Sloughterhouse Formation: Phyllites, calc-silicates, marble

Deep Lake Group

cpq — Copperton Quartzite: Sheared, massive, white quartzite

vf — Vagner Formation: Quartzite, phyllite and angular granite-clast paraconglomerate

cdq — Cascade Quartzite: Cross-bedded Quartzite, with lenses of quartz-pebble-conglomerate

cl — Campbell Lake Formation: Phyllites with thin layers of quartzite and angular granite-clast-paraconglomerate

sp — Singer Peak Formation: Thick phyllites with thin quartzite lenses

mg — Magnolia Formation: Quartzite, phyllite and quartz-pebble conglomerate

Phantom Lake Group — upper

slc — Boulder conglomerates, arkose and graywacke

slv — Granite-amphibole schists, pillow basalts and flows

jc — Quartzite and quartz-pebble conglomerate[1]

Phantom Lake Group — lower

jc — Quartzite, phyllite, paraconglomerates and marble

Archean rocks

Agr — Granite and Granite Gneisses

Ams — Archean Metasediments: Quartzites, metavolcanics, and amphibole schist

Abp — Archean Gneisses: Quartz-biotite-plagioclase gneiss, biotite paragneiss, quartzofeldspathic gneiss

SYMBOLS

Contact, dashed where approximate

Fault, dashed where approximate, dotted where inferred

High-angle reverse fault, dashed where approximate

Overturned syncline

Radioactive occurrences keyed to Table 3 (locations are approximate)

1 The uppermost part of Graff's (1978) Jack Creek Formation (jc on Plate 1) is now considered part of the upper Phantom Lake Group. Graff's formation names are not used in this report (Table 1).

SCALE 1 MILE; 1 KILOMETER

CONTOUR INTERVAL 40 FEET

U.S.G.S. 7½' Quadrangles

WYOMING

LOCATION INDEX

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

GEOLOGIC MAP OF THE CENTRAL AND NORTHWESTERN SIERRA MADRE, WYOMING

PAUL GRAFF

MAY 1978

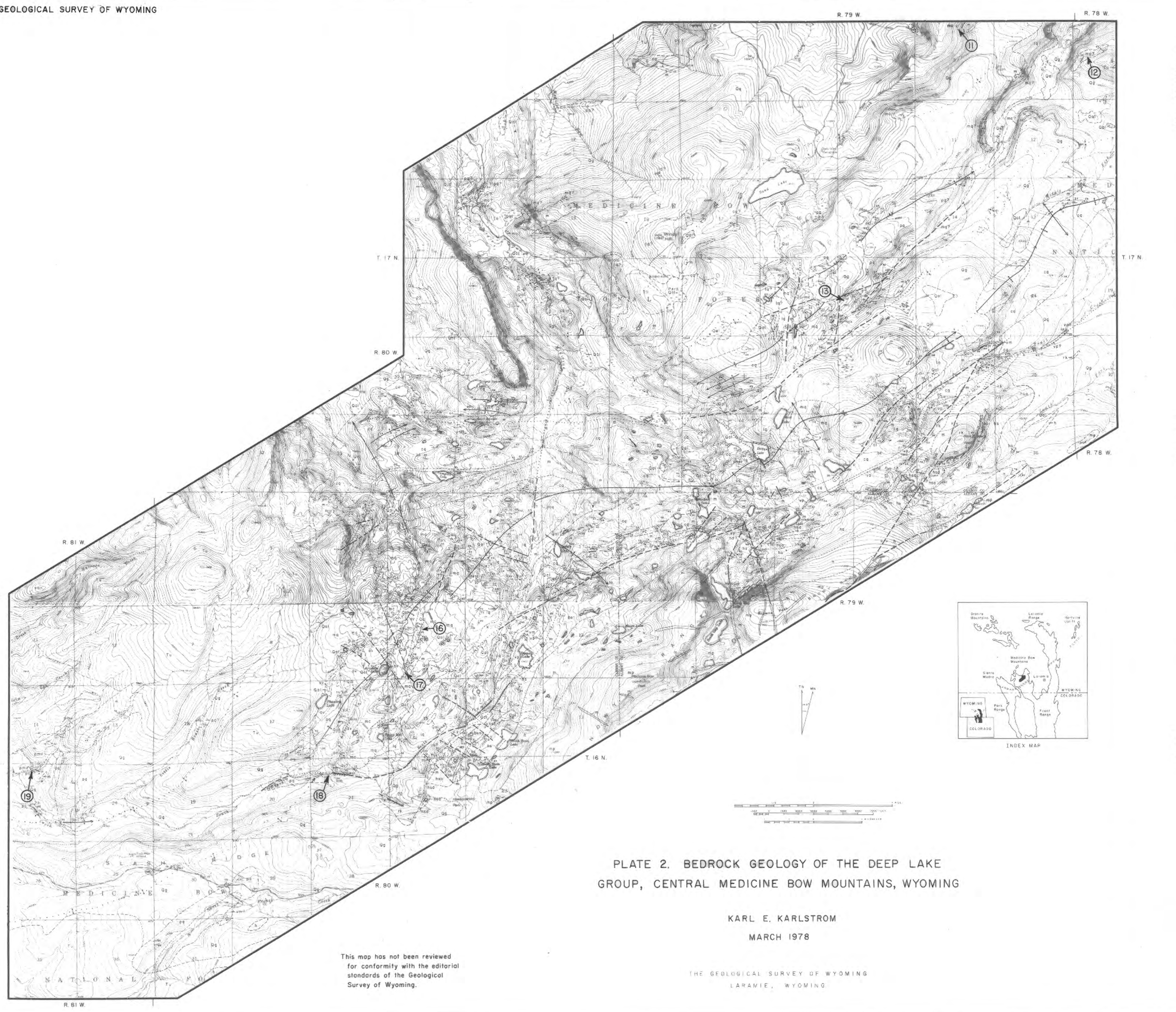


PLATE 2. BEDROCK GEOLOGY OF THE DEEP LAKE GROUP, CENTRAL MEDICINE BOW MOUNTAINS, WYOMING

KARL E. KARLSTROM

MARCH 1978

THE GEOLOGICAL SURVEY OF WYOMING

LARAMIE, WYOMING

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

EXPLANATION

POST-PRECAMBRIAN

Qls / Qal / Qg — QUATERNARY DEPOSITS

Qls - Landslide deposits

Qal - Alluvial deposits

Qg - Glacial deposits undivided

UNCONFORMITY

Tu — TERTIARY DEPOSITS UNDIVIDED

Includes Ferris, Hanna, Wind River, White River, and North Park Formations

UNCONFORMITY

PROTEROZOIC

m — MAFIC IGNEOUS ROCK

Includes mafic sills and dikes ranging from massive gabbro and diabase to foliated amphibolite. Degree of metamorphism higher in rocks to northeast and southwest and lowest in the central area.

Lower Libby Creek Group

ls / mp / h — LOWER LIBBY CREEK GROUP

ls - Lookout Schist - mainly laminated schist

mp - Medicine Peak Quartzite - massive quartzite

h - Heart Formation - mainly quartzite

hs / hsa / hsd — HEADQUARTERS FORMATION

hs - Dominantly chlorite schist and phyllite

hsa - Arkosic units interbedded with phyllite

hsd - Diamictite or paraconglomerate units

UNCONFORMITY

Deep Lake Group

rk — ROCK KNOLL FORMATION

Fine-grained quartzite with interbedded phyllite and some quartzite pebble conglomerate; local ripple marks and cross-bedding. Phyllitic partings form green weathered surfaces.

vp / vm / vc — VAGNER FORMATION

vp - Phyllitic quartzite

vm - Siliceous marble with layers of marble and silica

vc - Paraconglomerate, matrix is arkose, clasts are granite, quartzite, phyllite, basalt, and vein quartz

UNCONFORMITY

cq — CASCADE QUARTZITE

Medium grained quartzarenite with well-rounded, well sorted pebbles of quartz and black chert. Pebbles form distinct channels locally, contains large scale trough cross bedding.

cl — CAMPBELL LAKE FORMATION

Paraconglomerate overlain by quartz rich phyllite. Matrix of paraconglomerate is subarkose, clasts are granite, phyllite, quartzite and basalt.

lq — LINDSEY QUARTZITE

Fine to medium-grained quartzite with well developed small scale trough cross-bedding and local thin phyllitic partings.

mq / mc — MAGNOLIA FORMATION

mq - Very coarse-grained quartzite with large scale trough cross-bedding

mc - Poorly sorted conglomerate, locally radioactive. Matrix is arkose, clasts are quartzite, quartz, and phyllite

Phantom Lake Group[1]

av / pq — UPPER PHANTOM LAKE GROUP

av - Massive metabasalt, amygdaloidal metabasalt, volcanic conglomerate, garnet, schist, and phyllite.

pq - Mainly medium-grained quartzite with large scale tabular cross-bedding, smaller scale trough cross-bedding, and some climbing ripples. Phyllite and calcareous phyllite appear locally; radioactive at base.

pc / pmv — LOWER PHANTOM LAKE GROUP

pc - Paraconglomerate. Matrix is phyllitic, clasts are phyllite, quartzite, quartz, rhyolite, and gabbro.

pmv - Metavolcanics with minor sheared quartzite.

ARCHEAN

gqm — ARCHEAN ROCKS

gqm - Granite and quartz monzonite

SYMBOLS

Areas of outcrop (dark colors)

Contact; dashed where approximate. Approximate contacts inferred from outcrop pattern

Poorly defined contact, relations obscured by Quaternary deposits

Lithologic transition within formation

Fault, dashed where inferred, dotted where concealed; U - upthrown block, D - downthrown block

Shear zone; contains cataclastic rock

Plunging anticline; shows approximate trace of axial plane and plunge of fold axis; dotted where covered

Plunging syncline; shows approximate trace of axial plane and plunge of fold axis; dotted where covered

Assymetrical anticline, double arrows on steeper limb; dotted where covered

Overturned anticline, shows trend and plunge of fold axis, dotted where covered

Dip and strike of bedding

Dip and strike of overturned bedding

Strike of vertical bedding

Questionable dip and strike of bedding

Dip and strike of foliation

Foliation with minor fold axis lineation

Strike of vertical foliation

Trend and plunge of minor fold axis

Other lineations: c - crenulation, p - stretched pebble, m - aligned minerals, s - slickenside

Direction of stratigraphic top

Trend of adit

Mine

Small prospect

Radioactive occurrence keyed to Table 3 (locations are approximate)

1 The four members of the Phantom Lake Formation of Karlstrom (1977) are subdivided to approximate the upper and lower parts of the Phantom Lake Group as defined in this report.