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ABSTRACT

Recent stratigraphic studies in three widely separated localities in southeastern Idaho and western Utah have revealed a startling continuity of both individual rock units and of rock sequences over a distance of some 300 mi parallel to the strike of a late Precambrian and Cambrian depositional trough. Between 15,000 and 25,000 ft of beds were deposited in the axis of the trough, whereas only 1000 to 3300 ft of correlative rocks were laid down on the shelf to the east. In several areas a diamictite is present near the base of the sequence; this is underlain locally and overlain generally by argillites containing lenticular limestones and dolomites; these in turn are succeeded by quartzitic rocks containing a thick grayish-red to maroon unit—the Mutual Formation. In each area the sequence includes, at the top, quartzites typical of the basal Cambrian. Deposition in the basin was essentially continuous from late Precambrian into Cambrian time but was interrupted by uplift and erosion on the shelf. The hinge line of the ancient seaway is inferred to have coincided roughly with the present "Wasatch line," but erosion prior to deposition of the Tintic Quartzite has removed most of the data needed to establish this with certainty.

Rocks in each of the three areas described here in detail are regarded as allochthonous and appear to have been thrust eastward during the Sevier orogeny. A precise reconstruction of the sedimentary basin must therefore await not only additional stratigraphic studies in such areas as the Promontory Range of Utah and the Bannock and Malad Ranges of southern Idaho, but also final resolution of the structural events.

INTRODUCTION

Geologic mapping and stratigraphic studies in three widely separated areas of the northeastern part of the Great Basin have shown that both individual stratigraphic units and gross rock sequences of late Precambrian and Cambrian age exhibit remarkable continuity over the 300-mi distance from southeastern Idaho to central Utah (Fig. 1). The sequences are 15,000 to 25,000 ft thick where most complete and appear to record continuous sedimentation from late Precambrian into Cambrian time. All three areas are within the deformed part of the Sevier orogenic belt and are presumed to have been transported eastward several tens of miles from their original sites of deposition. However, because correlative rocks in shelf sections to the east are thin or absent and the rates of thickening and of original facies change are unknown, the precise amount of telescoping by tectonic transport remains uncertain.

The purpose of this paper is to name, describe, and correlate the thickest and least complicated sections of these rocks, in the hope that the units and sequences defined in these areas can be recognized in other areas where exposures are limited or where structural complexity makes it impossible to work out a complete stratigraphic section.

Authors are listed alphabetically; responsibility is shared jointly for sections on correlation, age, paleogeography, and structure, but is carried individually for stratigraphic description of specific areas.

The rocks of the Pocatello, Idaho, area now assigned to the Precambrian were first described by Anderson (1928) and included in the Cambrian; Ludlum (1942) was the first

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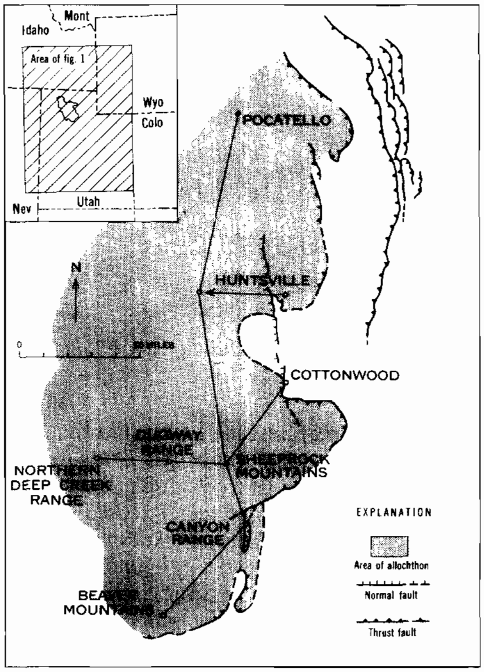

Figure 1. Index map showing location and tectonic setting of stratigraphic sections described.

to recognize that some of them are Precambrian. Similar rocks in the area near Huntsville, Utah, were first recognized by Blackwelder (1910) and were mapped in reconnaissance and described briefly by Eardley (1944). The earliest and most significant synthesis of younger Precambrian rocks in northern Utah was that of Eardley and Hatch (1940); more recent summaries include those of Cohenour (1959) and Condie (1966, 1969). Precambrian rocks in the Beaver Mountains were originally assigned to the Ordovician and Silurian(?) by Butler (*in* Butler and others, 1910, p. 511) because he failed to recognize the thrust fault which separated them from the immediately underlying lower Paleozoic rocks. The presence of a thick Precambrian section in this area was noted by D.M. Lemmon, W. C. Jeffs, and others, during mapping following World War II, and the rocks are assigned to the Precambrian on the geologic map of southwestern Utah (Hintze, 1963).

Stratigraphic studies of the older rocks in the Pocatello area were started in 1961 by F. E. Schaeffer during preparation of a geologic map of Bannock County, Idaho, for the Idaho Bureau of Mines and Geology. Schaeffer was the first to distinguish the major subdivisions within the Precambrian rocks of this area and to recognize that they could be traced over the adjoining parts of southeastern Idaho. These subdivisions were used in mapping the Pocatello and Michaud 15-minute quadrangles by D. E. Trimble from 1962 to 1965 (Trimble and Schaeffer, 1965) and in more recent mapping of the Michaud and Pocatello 15-minute quadrangles.

Geologic mapping at a scale of 1:24,000 in the Huntsville area by Crittenden largely between 1964 and 1966 led to definition of the Huntsville sequence (Crittenden, 1967) in a little-deformed area in the Browns Hole quadrangle. Mapping designed to establish the stratigraphy of the lower diamictite-bearing units is continuing in structurally complex areas near Willard Peak, northwest of Huntsville.

Stratigraphic relations in the shelf area were established during mapping in the Cottonwood district east of Salt Lake City by the U.S. Geological Survey between 1940 and 1960 (Calkins and Butler, 1943; Crittenden, 1965a, 1965b).

Stratigraphic studies in the Beaver Mountains were completed by Woodward during 1966 (Woodward, 1968).

POCATELLO AREA, IDAHO

The rocks of the Pocatello area, southeastern Idaho, appear to be typical of the conformable depositional sequence of upper Precambrian and lowermost Cambrian rocks of the eastern part of the Great Basin. Inasmuch as they constitute the thickest known section of those rocks and because the units defined here can be recognized over a wide area, they may well serve as a standard for much of southeastern Idaho. More than 25,000 ft of dominantly quartzitic rocks, of which more than 20,000 ft probably are Precambrian, underlie Middle Cambrian limestones. Lower Cambrian fossils have not been discovered in this area but were found in correlative rocks in the Portneuf Range (Oriel, 1965). The rocks below the Cambrian carbonates formerly assigned to the Brigham Formation (Anderson, 1928; Ludlum, 1942, 1943) are divided into six formational units, four of which are Precambrian. New names are introduced here for three of these and for the two Cambrian units.

POCATELLO FORMATION

The lowest and oldest rocks in the Pocatello area comprise clastic, volcanic, and carbonate rocks of probable marine origin that were designated the Pocatello Formation by Ludlum (1942). That term is retained here, and the formation is divided into four members, a lower member, mainly argillite; a diamictite[1] member, a volcanic member; and an upper member, also dominantly argillite. The type section of the Pocatello Formation is a composite of those of the individual members, defined below.

The lower member of the Pocatello Formation consists of black, thinly laminated, slaty argillite, phyllitic siltite, and brown quartzite. A thickness of about 700 ft is observed, but the total thickness is uncertain because the base is not exposed. The type section of the lower member is designated as the section from the canyon bottom to near the top of the west slope of a small canyon just north of the Portneuf River, in the S½ sec. 15, and N½ sec. 22, T. 7 S., R. 35 E., about 7 mi southeast of Pocatello (A-B, Fig. 2).

These slaty rocks are overlain conformably by several thousand feet of diamictite-bearing rocks, here named the Scout Mountain Member, with excellent exposures on the summit of and on the ridge approximately 2 mi north and south of Scout Mountain in Tps. 8 and 9 S., R. 35 E., about 15 mi south-southeast of Pocatello (Fig. 2). Owing to severe faulting, a complete section is not present either at the type locality on Scout Mountain, or elsewhere. The reference section for this unit is therefore designated as a composite of three partial sections as follows: (1) from the crest, down the west slope of the ridge immediately northeast of Portneuf in the SW¼ sec. 15, T. 7 S., R. 35 E. (C-C′, Fig. 2); (2) from the base, up the west slope to the crest of the corresponding ridge immediately south of the river, in the W½ sec. 27, T. 7 S., R. 35 E., (C′-C′′, Fig. 2); (3) up part of the west slope of the same ridge about a mile south in the NW¼ sec. 34, T. 7 S., R. 35 E. (C′′-D, Fig. 2). Sections C-C′ and C′-C′′ could not be matched, and an unknown, but probably small, amount of section is believed to be missing. The following is a generalized description of these composite sections. The Scout Mountain Member has at the base 65 ft of limestone, locally recrystallized to dense marble. This is succeeded by 100 ft of medium-grained gray quartzite with much interbedded siltstone at the top. This, in turn, is overlain by the main body of the member, consisting of intercalated diamictite and quartzite. It is several thousand feet thick including the intercalated volcanics (see below). Above this thick unit, but still within the Scout Mountain Member are as much as 1200 ft of quartzite and minor argillite, 150 to 350 ft of cobble conglomerate, an additional 100 to 300 ft of quartzite, an upper bed of diamictite, on the order of 100 ft thick, a distinctive 2-ft bed of laminated dolomite, 100 to 800 ft of quartzite with small amounts of argillite, and a 15-ft bed of limestone, designated the top of the member.

The typical diamictite is a massive dark purplish- to greenish-black rock consisting of pebble- to boulder-size clasts in a voluminous fine-grained matrix characterized by angular sand-size grains. The clasts are rounded to angular, up to 3 ft in diameter, and of diverse lithologies, including quartzite, granite, dolomite or limestone, mafic igneous rocks, and argillite. This rock is believed to be partly of glacial origin because of its massive character, the anomalous angularity of the sand-size grains, the abnormally large ratio of fine matrix to clasts, and the presence of large clasts that are faceted or striated. It is also suspected to be of submarine origin because it is interstratified with several thousand feet of quartzite, and with several thin beds of limestone and dolomite presumed to have been of marine origin.

Metavolcanic rocks, herein designated the Bannock Volcanic Member, form a wedge at least 1000 ft thick that interfingers with the diamictites of the Scout Mountain Member. This volcanic unit was first designated the Bannock Volcanic Formation by Anderson (1928, p. 3), who defined it as including all the exposed rocks below his Black Rock Limestone and inferred that it might be Cambrian. It was later restricted by Ludlum (1942, 1943) to exclude most of the sedimentary rocks and was assigned to the Precambrian. Both volcanic flows and breccias are present; the massive rocks show a wide range of porphyritic textures, and include both vesicular and amygdaloidal types. Fragmental textures ranging from coarse volcanic breccia to

[1] Diamictite: A nonsorted sedimentary rock consisting of sand and/or larger particles in a muddy matrix (modified *from* Flint and others, 1960).

tuff can also be recognized readily, although all are fairly typical "greenstones" showing weak schistosity, and consisting largely of albite, chlorite, epidote, and calcite.

Exposures here designated the type section of the Bannock Volcanic Member are located on the west slopes of Chinks Peak in secs. 32 and 33, T. 6 S., R. 35 E., about 4 mi east-southeast of Pocatello (E-F, Fig. 2).

The upper member of the Pocatello Form-

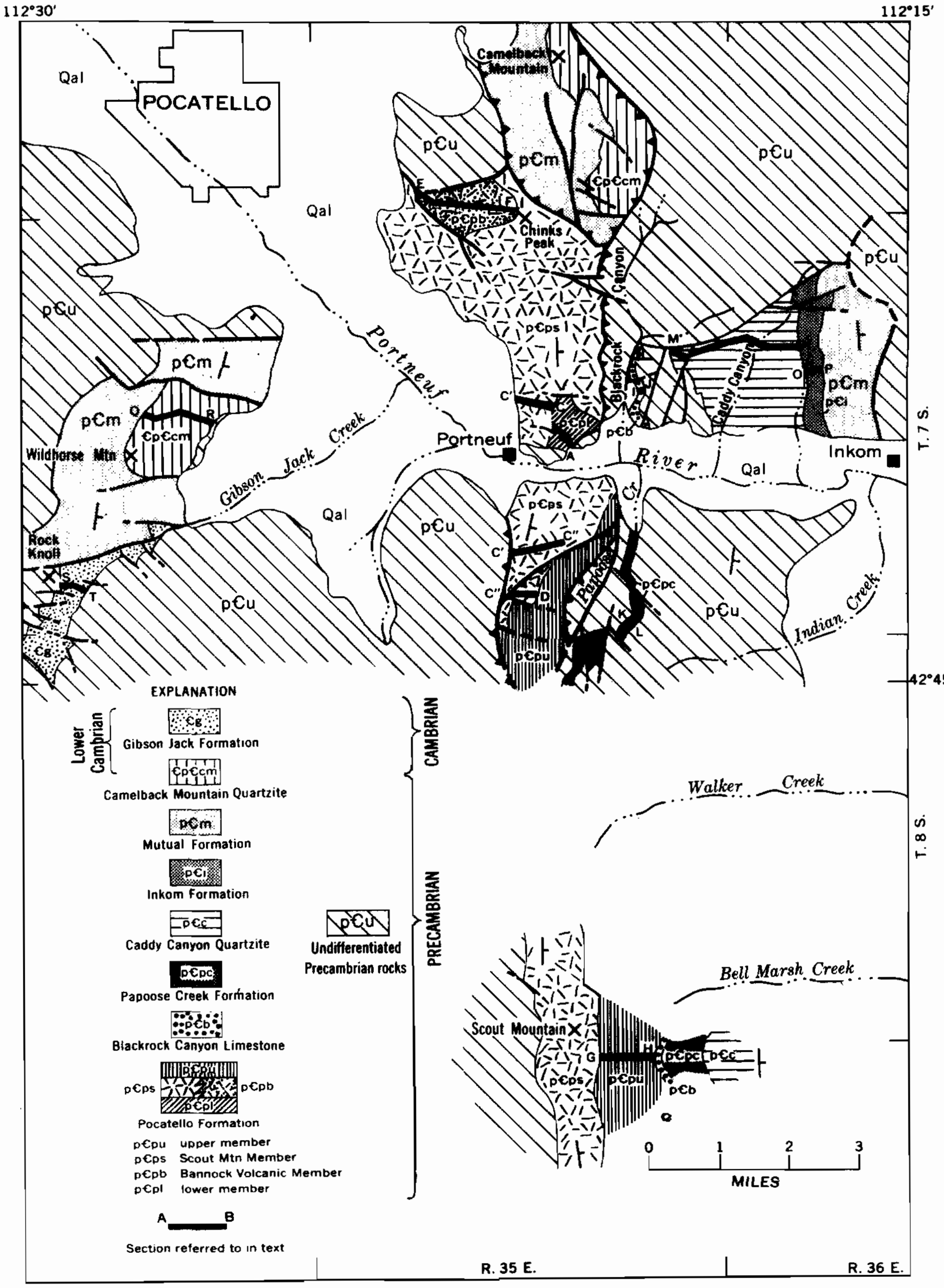

Figure 2. Map of area near Pocatello, Idaho, showing location of type sections for newly described Precambrian and Cambrian units.

tion consists of nearly 2000 ft of black, thinly laminated phyllitic to slaty argillite that contains much interbedded quartzite in the upper half. As thus defined, it corresponds essentially to Ludlum's (1942) "varved slate series." The type section is designated as extending across the top of a narrow saddle about a mile southeast of Scout Mountain in sec. 2, T. 9 S., R. 35 E. (G-H, Fig. 2).

Blackrock Canyon Limestone

The thickest carbonate unit of the Precambrian section in the Pocatello area consists of several hundred feet of fine-grained gray limestone interbedded with quartzite and minor variegated argillite. This limestone unit was originally named the Black Rock Limestone by Anderson (1928, p. 4); it was later designated the Blackrock Limestone by Ludlum (1942, p. 92–93), but is here renamed the Blackrock Canyon Limestone because the name "Blackrock" is preempted. The type section is on the east side of lower Blackrock Canyon in sec. 14, T. 7 S., R. 35 E., about 7.5 mi southeast of Pocatello (I-J, Fig. 2).

Brigham Quartzite of Anderson and Ludlum

The 15,000-ft interval of detrital rocks, consisting mainly of quartzite, between the underlying Blackrock Canyon Limestone and the lowest carbonate rocks of Cambrian age, was assigned to the Brigham Quartzite by both Anderson (1928) and Ludlum (1942). However, the term is not used at Pocatello in this report because this interval is thick and contains several distinctive lithologic units, and because the term has been used in several different ways in adjoining parts of Utah and Idaho (*see* Huntsville area, Utah, this paper). In recent mapping of the Pocatello quadrangle (Trimble, unpub. data), this interval is divided into six new formations; the lower four are believed to be Precambrian, the upper two are presumed to include Cambrian rocks.

Papoose Creek Formation. Overlying the Blackrock Canyon Limestone in the Pocatello area are about 1800 ft of distinctively, irregularly bedded, mottled gray and brown siltite and very fine-grained quartzite, here designated the Papoose Creek Formation. The name is taken from exposures in Papoose Creek, the type locality south of the Portneuf River about 5 mi southeast of Pocatello, Idaho (Fig. 2). The type section (K-L, Fig. 2) is in sec. 35, T. 7 S., R. 35 E., and secs. 2 and 3, T. 8 S., R. 35 E., in the headwaters and just east of the canyon of Papoose Creek where the formation is a little more than 600 ft thick. The Papoose Creek Formation is poorly exposed in most places and must be recognized by float. The beds of siltite or quartzite, commonly 1 to 3 mm thick, form alternating layers of light gray and light to dark brown that are undulating, broken, and slightly offset in many places. This deformation of the bedding is probably penecontemporaneous and characterizes the formation. The lower contact is drawn at the top of the highest carbonate of the underlying Blackrock Canyon Limestone. Locally, the Papoose Creek appears to overlie conformably the Blackrock Canyon Limestone, but great variations in thickness suggest that the contact may be a disconformity. The formation is presumed to be marine.

Caddy Canyon Quartzite. The Papoose Creek Formation is overlain by several thousand feet of vitreous quartzite here named the Caddy Canyon Quartzite. The type section is in Caddy Canyon, north of the Portneuf River in sec. 13, T. 7 S., R. 35 E., and sec. 18, T. 7 S., R. 36 E., about 8 mi southeast of Pocatello (M-N, Fig. 2). The base of the formation is exposed on the west side of a spur west of the mouth of Caddy Canyon in sec. 24, T. 7 S., R. 35 E.; the upper contact is exposed on the ridge east of the canyon in sec. 7, T. 7 S., R. 36 E. The formation is widely exposed as smooth slopes and ledges. The lower part of the Caddy Canyon Quartzite is mostly white- to tan-weathering, light-colored vitreous orthoquartzite that contains some interbedded greenish argillite or siltite. In places, especially in the lowermost part, there are many interbeds, some rather thick, of irregularly bedded, fine-grained quartzite and siltite much like that of the conformably underlying Papoose Creek Formation. The lower contact is placed at the base of the lowermost light-colored quartzite in the transitional sequence between the predominantly silty Papoose Creek Formation and the light-colored orthoquartzite of the Caddy Canyon Quartzite. Somewhat above the middle of the Caddy Canyon, and overlying the light-colored quartzite, there is at many places about 50 ft of dolomite or, less commonly, limestone. Above the dolomite or limestone, the quartzite and argillite beds that constitute the upper part of the formation commonly are pinkish, purplish, or maroon. In the uppermost few hundred feet of the Caddy Canyon are several interbeds of greenish argillite and siltite.

Inkom Formation. The Caddy Canyon Quartzite is overlain by 800 to 1000 ft (locally as much as 2300 ft) of very fine-grained detrital rocks here named the Inkom Formation. In the Pocatello area these rocks are characteristically greenish, although locally as much as 200 ft of grayish-red or dusty-red argillite is present at the top. The name is taken from the small town of Inkom, Idaho, and the type section is in a small canyon north of the Portneuf River about a mile west. The lower part of the Inkom is mainly greenish phyllite. This grades upward into greenish-gray to light olive-gray argillite or slate, siltite, and very fine-grained quartzite. The unit also contains a few beds of conglomerate or impure micaceous quartzite. The lower contact of the Inkom is placed at the top of the highest quartzite of the Caddy Canyon Quartzite, although some beds of argillite like the Inkom are present below it. The top is placed at the base of massive quartzite ledges of the overlying Mutual Formation and is generally quite sharp.

Mutual Formation. The Inkom Formation is overlain by a massive 3000 ft quartzite unit whose characteristic grayish-red color (5R 4/2)[2] contrasts strongly with that of the underlying greenish argillite. This unit is correlated with the type Mutual Formation southeast of Salt Lake City, Utah (Crittenden and others, 1952) on the basis of its characteristic lithology, color, and position. In the Pocatello area, the quartzites of the Mutual are coarse-grained, pebbly or conglomeratic, and persistently cross-bedded. The color ranges from light grayish-red (5R 5/2) to dark grayish-red (5R 3/2) or purplish-black (5RP 2/1). In addition to quartzite, the unit contains relatively thin but distinctive beds of argillite, one of which is more than 200 ft thick. Most of the argillite is dusky-red to very dark red; locally, it may be olive drab (5Y 5/2) or greenish-gray (5GY 6/1). The basal contact is placed at a conspicuous and abrupt change from argillite to quartzite; in most places greenish-red quartzite overlies the Inkom Formation. The Mutual Formation is present in all of the basin sequences and is the youngest unit that one can be sure is entirely of Precambrian age.

Camelback Mountain Quartzite. The Mutual Formation of the Pocatello area is overlain by as much as 3500 ft of light-colored vitreous orthoquartzite that is lithologically similar to the Cambrian Tintic Quartzite of the Tintic district of Utah and the Prospect Mountain Quartzite (restricted) of the northern part of the Great Basin. This orthoquartzite is here designated the Camelback Mountain Quartzite for exposures on Camelback Mountain east of Pocatello, Idaho (Fig. 2). This section is severely faulted, however, and a section on the east slope of Wild Horse Mountain in secs. 22 and 23, T. 7 S., R. 34 E., about 4.5 mi south-southwest of Pocatello (O-R, Fig. 2) is designated an alternate type section. This formation generally forms smooth slopes. It is composed of thick-bedded to massive, locally cross-bedded, medium-grained vitreous orthoquartzite that weathers white, tan, brown, and brownish-gray. It is mostly white at the base. The Camelback Mountain Quartzite lacks the reddish hues found in older units and contains little argillite or phyllite. The basal contact is conformable and transitional with the underlying Mutual Formation. Locally, the base is marked by a pebble conglomerate, 5 to 15 ft thick, that contains light colored pebbles as much as 1.5 in. in diameter in a pinkish quartzitic matrix. No fossils have been found in the Camelback Mountain Quartzite, but Cambrian fossils occur about 300 ft above the base of the overlying unit. The Camelback Mountain is therefore assigned a Precambrian and Early Cambrian age. It is considered to be of marine origin.

Gibson Jack Formation. The uppermost clastic unit at Pocatello is composed of more than 1000 ft of argillaceous siltstone and shaly argillite with interbeds of quartzite and sandstone that is here named the Gibson Jack Formation. The name is taken from exposures on Gibson Jack Creek south of the Portneuf River about 5 mi south of Pocatello. The type locality is at the head of Gibson Jack Creek in sec. 33, T. 7 S., R. 34 E., about 8 mi south-southwest of Pocatello (S-T,

[2] Numerical designations derived from the Rock Color Chart (Goddard and others, 1948) are given for the Mutual Formation, because color is a distinctive and characterizing feature of this unit. Adjective designations are used throughout the remainder of the report.

Fig. 2). The formation consists of argillaceous siltstone and papery-weathering argillite with minor interbeds of sandstone or quartzite. The lower part is mostly tan, olive, or gray-green; the upper part is mainly pale yellowish-brown. A 100-ft bed of light gray medium-grained quartzite is present about 350 ft above the base and other beds are present near the top. Two or more beds of thin-bedded argillaceous limestone, tens of feet thick, also occur near the top, but they seldom crop out. The basal contact of the Gibson Jack Formation is placed at the base of the first thick siltstone or argillite; although this leaves some argillaceous beds in the underlying Camelback Mountain Quartzite, they are commonly thin.

The upper contact is placed at the base of the first thick limestone or dolomite lithologically equivalent to the Langston or Ute Formations of Walcott (1908b). The only fossil found to date in the Gibson Jack Formation is the Cambrian arthropod *Naroia*, which was found about 300 ft above the base. The only other occurrence of this rare form is in Middle Cambrian rocks in British Columbia (A. R. Palmer, 1968, written commun.), but its actual range is unknown. Therefore, because the Early Cambrian *Olenellus* was reported by Oriel (1965) in beds believed to be equivalent to or slightly higher than the Gibson Jack, this formation is assigned an Early Cambrian age.

HUNTSVILLE AREA, UTAH

General Features

About 13,000 ft of younger Precambrian and basal Cambrian rocks are exposed east and northeast of Huntsville, Utah. This section, which has been divided into seven formational units, should serve as a standard for northwestern Utah as the Pocatello section does for southeastern Idaho.

The existence of a thick section of younger Precambrian rocks near Huntsville was recognized by Blackwelder as early as 1910. Indeed, its presence there and its absence near Ogden, where the basal Cambrian quartzite (Tintic) rests directly on crystalline basement, was the basis for his identification of the Willard thrust. The general character of these rocks and their structural relations were further elaborated by Eardley and Hatch (1940), and Eardley (1944). Although younger Precambrian rocks are present both east and west of Huntsville, the present description will be restricted to the rocks that crop out to the northeast and east (Fig. 3). As a consequence, the lowest units of the more complete section at Pocatello—argillite and the diamictites of the Scout Mountain Member of the Pocatello Formation—are absent from this section. Previous work (Eardley and Hatch, 1940) has shown that diamictites (Fig. 4) are present above the Willard thrust between Willard Peak and Brigham City, and recent mapping by Crittenden indicates that they occur 2000 to 3000 ft below the lowest rocks exposed east of Huntsville, but their exact stratigraphic relations are still being studied.

The sequence of Precambrian and basal Cambrian rocks east of Huntsville will be described briefly, beginning with the oldest and continuing to the base of the carbonate units which here are of Middle Cambrian age. The lowest units are well exposed in the foothills and along the lower reaches of both the South Fork and Middle Fork of the Ogden River east and northeast of Huntsville.

Maple Canyon Formation

The name Maple Canyon Formation is here given to about 1000 to 1500 ft of clastic rocks which are divided into three informal members on the basis of lithology. The name is taken from Maple Canyon about 6 mi east of Huntsville, Utah, and the type locality is near the mouth of the canyon, beginning in the north half of sec. 9, T. 6 N., R. 2 E. (A-B, Fig. 3).

The lowest unit, designated the argillite member, consists of about 500 ft of olive drab to locally gray, thin-bedded, silty argillite or siltstone which contains one or more beds of greenish-gray arkosic sandstone. This unit is exposed at several places along the foothills northwest from Maple Canyon, and in each place it is the lowest unit of Precambrian rocks exposed on this side of the valley. Although the rocks in the Huntsville area as a whole are little metamorphosed, this unit is typically phyllitic and commonly shows small-scale crenulations and folds usually at an angle to the bedding (Fig. 5); locally these rocks show well-defined schistosity.

The middle member of the Maple Canyon Formation is informally designated the green arkose member. It consists of 500 to 1000 ft of relatively thick-bedded, massive, very fine-

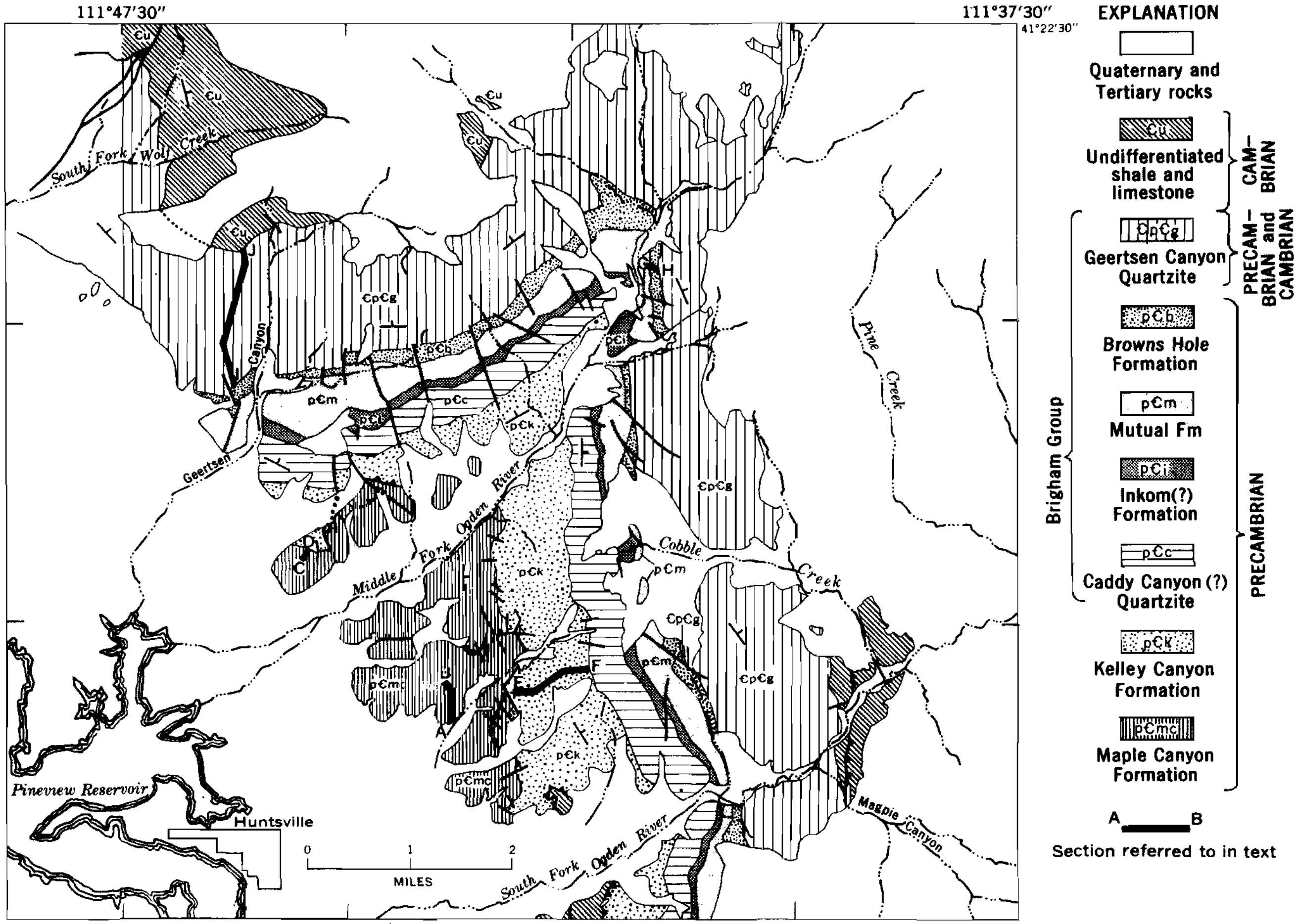

Figure 3. Map of area near Huntsville, Utah, showing location of type sections for newly described Precambrian and Cambrian units.

Figure 4. Diamictite consisting of subrounded to subangular clasts of quartzite, granitic rocks, and carbonates in a black fine-grained matrix. Exposures are in Willard thrust sheet north of Willard Peak, Utah.

grained arkosic sandstone. On fresh fractures, this rock is a very pale greenish-gray, but this color is commonly obscured by weathering and, at a distance, the unit forms rounded ledges that are dark gray or brown. Individual beds range from 1 to 2.5 ft in thickness and are separated by thin partings of siltstone or thin-bedded argillite. The more massive beds are distinguished from quartzites in other parts of the section by their remarkably perfect sorting, and by the abundance of K-feldspar, which makes up as much as 40 percent of some stained slabs. As a result of the feldspar content, this unit tends to be less quartzitic in character than other parts of the section. The feldspar content is variable, however, with some areas containing lenticular bodies of well-cemented vitreous and pebbly quartzite as much as 200 ft thick.

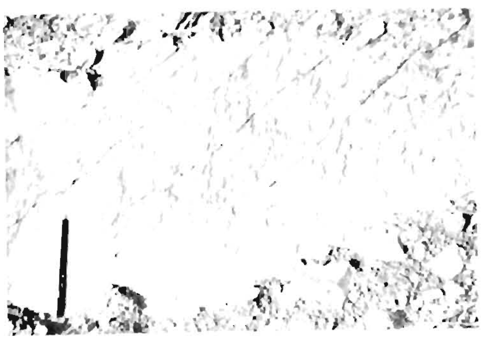

Figure 5. Argillite member of Maple Canyon Formation near Huntsville, Utah. Crenulated bedding is nearly vertical, parallel to pen; schistosity dips 30° to left.

The uppermost member of the Maple Canyon Formation is designated the conglomerate member. It consists of two conglomerates or, locally, quartzites and an intervening argillite. The member as a whole ranges from 60 to 500 ft in thickness but in the type area immediately north of Maple Canyon, averages about 200 ft. Much better exposures are present on the top of a rounded hill just north of the mouth of the middle fork of Ogden River (C-D, Fig. 3) and this is designated a reference section for this member. The lowermost conglomerate consists of 50 to 200 ft of white to light gray, conglomeratic quartzite. Clasts range from pebble to small cobble in size and consist mainly of white quartz, or white, gray to pale pink quartzite. Pale green quartzite containing chromian mica (x-ray fluorescence) is a sparse but significant constituent. These distinctive clasts closely resemble the green quartzites near Park Valley in the Raft River Range of Utah (Felix, 1956). Similar clasts are present also in the tillites of Antelope Island and in the Dutch Peak Tillite of Cohenour (1959) in the Sheeprock Mountains of Utah.

The two conglomerates are separated by 10 to 100 ft of olive drab laminated argillite. This unit is not well exposed and commonly must be mapped by its silver-gray-weathering flakes in the soil. The upper part of the conglomerate member commonly consists of a white, coarse-grained rock that ranges from quartzite to conglomerate. In places it is only 50 ft thick and consists entirely of pebble to small cobble conglomerate; in other places it is as much as 200 ft thick and consists almost entirely of quartzite with only a few pebbles at the base. In a few places the matrix, instead of being light colored vitreous quartzite, grades into a dark gray, tan-weathering, friable, impure sandstone or graywacke whose anomalous appearance is vaguely reminiscent of a diamictite. This leads to the suspicion that this clastic member may be correlative with the uppermost thin unit of diamictite in the Scout Mountain Member of the Pocatello Formation, which occupies a corresponding position immediately below laminated dolomites at Pocatello (Fig. 6).

Kelley Canyon Formation

The conglomerate member of the Maple Canyon Formation is overlain by a domi-

Figure 6. Tan-weathering laminated dolomite at base of Kelley Canyon Formation, near Huntsville, Utah.

nantly argillaceous unit to which the new name Kelley Canyon Formation is here given. The type section is located in the head of Kelley Canyon (E-F, Fig. 3) in the south half of sec. 3, T. 6 N., R. 2 E., about 3.5 mi east of Huntsville. Although argillaceous rocks predominate, the unit contains much interbedded quartzite in the upper portion and grades into the overlying quartzite. The formation is distinctive in that it contains the only limestones and dolomites known within the Precambrian rocks in this area.

The Kelley Canyon Formation begins at the base with a persistent 10-ft bed of thinly laminated, tan-weathering, fine-grained dolomite. The laminae are commonly about 1 mm thick but tend to be cyclic, giving the appearance of bedding 1 to 2 cm thick. Locally, individual laminae consist of chert, giving the rock a distinctive ribbed appearance (Fig. 6). Although the unit is poorly exposed in general, its presence can usually be verified by large and persistent dolomite blocks in the float. The dolomite is overlain by lavender-gray, purplish-gray or olive drab shale and siltstone locally containing thin beds of greenish fine-grained sandstone. Like the argillite at the base of the Maple Canyon Formation, these units are commonly phyllitic.

The middle part of the formation consists of gray to lavender-gray argillite enclosing several lenticular bodies of thin-bedded pinkish-gray silty limestone. The gray color, absence of laminae, and intercalations with shale distinguish these carbonate units from the dolomite at the base of the unit. Although they are not persistent enough to map everywhere, these limestones occur at the same horizon as the Blackrock Canyon Limestone of the Pocatello area, and it is possible that they represent the distal end of a tongue of this formation.

Above the thin-bedded limestones, the argillites of the Kelley Canyon Formation are largely olive drab- or tan-weathering and contain increasing amounts of thin- to medium-bedded quartzite. The top of the formation is poorly defined and cannot always be identified with certainty. In many places, however, it is marked by a zone of very thin-bedded white quartzite (.25 to .75 in. in thickness) with intervening wavy laminae of red-weathering shale and silt.

Brigham Group

History and definition—The term Brigham Formation was first applied by Walcott (1908a, 1908b), to a 2000-ft thickness of massive quartzites and sandstones in the Wasatch Range immediately east of Brigham City, Utah. Unfortunately, he did not give a precise locality or measured section, nor show the unit on a map. More importantly, for problems of the Precambrian, the base was completely undefined. As a consequence, two strongly contrasting usages of the term Brigham have evolved. Most authors working in southern Idaho (for example, Mansfield, 1920, 1927, 1929; Anderson, 1928; Ludlum, 1942, 1943; and Bright, 1960), have used the term Brigham in an inclusive sense for the entire sequence of dominantly quartzitic rocks below the Cambrian carbonates. Another group, working mainly in northern Utah (for example, Eardley and Hatch, 1940; Lochman-Balk, 1955; Williams, 1958; and Stokes, 1963), used the term in a restricted sense for only the uppermost 2000 to 5000 ft of light colored quartzites that were presumed to be Cambrian.

As a result of these persistent conflicts, the term "Brigham" is here raised to group rank, and this term is recommended for use wherever the units here defined or others of formational rank can be recognized. In areas where exposures are inadequate or structural complications are too severe to permit subdivision, the term Brigham Quartzite can be used in an inclusive sense for rocks within the same stratigraphic limits defined below for the Brigham Group. Thus far, these formational units have been recognized by

Trimble near Pocatello, by Schaeffer in much of Bannock County, Idaho, and by Crittenden near Huntsville, Utah. Reconnaissance suggests that at least some of the lithologies characteristic of these units can be distinguished in intervening areas also, as near Preston, Idaho (Bright, 1960). Detailed study of such areas will be required to determine which of the formational units described here are present.

In the Huntsville area, the Brigham Group is here defined as comprising approximately 7000 ft of beds, largely quartzite, in the interval between the top of the Kelley Canyon Formation and the base of the lowest carbonatic or pelitic rocks of Cambrian age. It thus includes the Caddy Canyon(?) Quartzite, Inkom(?), Mutual, and Browns Hole Formations and Geertsen Canyon Quartzite. Two of these units (Caddy Canyon and Inkom) are named elsewhere in this report for rocks in the Pocatello area; the Mutual Formation was described in the Cottonwood area near Salt Lake City (Crittenden and others, 1952); the remaining two units are defined below for the first time.

The best exposed and least faulted section of the Brigham Group in northeastern Utah is on the north wall of the Middle Fork of Ogden River, beginning at the base of the Caddy Canyon(?) Quartzite near the southeast corner of sec. 21, T. 7 N., R. 2 E., and extending northwest to the base of Cambrian limestones exposed near the head of Geertsen Canyon in section 18. This stratigraphic section is here designated the principal reference section for the Brigham Group. Redefinition of the Brigham in terms of this reference section is necessary because reconnaissance mapping at Walcott's presumed type locality along U.S. Highway 89–91, 2 mi east of Brigham City, has shown that the lower 5000 ft of the Brigham Group, as here defined, is cut out by a north-striking fault which places beds near the base of the Geertsen Canyon Quartzite in fault contact with beds near the top of the Kelley Canyon Formation. The newly designated reference section is about 18 mi southeast along the regional strike from the type locality, but the units have already been mapped at 1:24,000 scale over some 12 mi of the intervening distance. Although many normal faults are present in the area between the two sections, there appear to be no significant thrust faults.

Caddy Canyon(?) Quartzite

The lowest formation of the Brigham Group in the Huntsville area is a brown- to tan-weathering, impure quartzite tentatively correlated with the Caddy Canyon Quartzite of the Pocatello area. The lower contact is gradational, the slope-forming argillites of the underlying Kelley Canyon Formation giving way upward through an interval of a few tens of feet, or locally as much as 100 to 200 ft, to cliff-forming quartzite ledges. Near the base, argillite and thin-bedded fine-grained quartzite make up nearly half of the formation; near the top, however, argillaceous rocks are limited to partings a few inches to a few feet thick. Similarly, quartzite ledges near the base are impure and weather to shades of brown, whereas those near the top are increasingly pure, form steep cliffs, and weather light gray or tan. The upper contact is very sharp, and generally is marked by a topographic bench exposing gently wavy bedding surfaces, from which the overlying less resistant shale has been stripped. The Caddy Canyon(?) Quartzite thickens systematically from about 1500 ft in the South Fork of Ogden River to 2500 ft in the area north of Huntsville.

Inkom(?) Formation

Above the massive cliff-forming quartzites is a bench- or slope-forming argillite unit 360 to 450 ft thick. The upper half is dominantly grayish-red; the lower half is olive drab to light green. This unit is tentatively correlated with the Inkom Formation of the Pocatello area on the basis of stratigraphic position and general character. Although the Inkom at its type area is thicker and is dominantly green, the lithology is essentially identical, and the larger proportion of grayish-red rocks here is thought to represent a decrease in the reducing capacity of the environment, suggesting that perhaps the Huntsville section was deposited in shallower water.

Mutual Formation

One of the most distinctive units in the Precambrian rocks of northern Utah is the strikingly colored grayish-red quartzite which can be recognized widely from the Beaver Mountains, Utah, on the south, to Pocatello, Idaho, on the north. This unit was designated the Mutual Formation by Crittenden and others (1952) in the Cottonwood area near Salt Lake City. It consists dominantly of grayish-red to pale purplish or pale pink coarse-grained, locally pebbly or feldspathic quartzite with abundant cross-bedding. In this area, as in the type locality, it contains local lenticular interbeds of argillite, most of which are the same distinctive grayish-red or pale purplish-red as the surrounding quartzite. Mapping northwest of Huntsville has shown that this unit is intercalated locally with both basalt and rhyolitic tuff.

Browns Hole Formation

The unit here designated by the new name Browns Hole Formation consists of two lithologically distinctive members, a lower member characterized by volcanics and an upper member of terra cotta quartzite. The type section is along the middle fork of Ogden River on slopes northwest of Browns Hole, near the center of sec. 14, T. 7 N., R. 2 E., Browns Hole quadrangle (G-H, Fig. 3). Still better exposures are present high on the north slopes of the middle fork extending along strike about 2 mi southwestward from the northeast corner of section 10 into Geertsen Canyon. This formation has no lithologic counterpart at Pocatello or in the Beaver Mountains.

The volcanic member is a slope-forming unit 182 to 460 ft thick. Although characterized by volcanics, it also includes fine-grained sediments ranging from shale to thin-bedded quartzite. The volcanics observed in greatest abundance are basalt, either gray, massive, and fine-grained, or vesicular and amygdaloidal. In places, black to red scoriaceous rocks of boulder size weather out from the finer matrix. Locally, volcanic fragments show a wide range in composition, and include porphyritic types with stony or vitrophyric-appearing groundmass. Both the massive and fragmental rocks are reworked along strike as rounded cobbles and boulders which diminish in abundance southward and finally give way in the South Fork of the Ogden River to a zone of brown thin-bedded quartzite and argillite containing only traces of volcanic material.

The upper member of the Browns Hole Formation throughout the Huntsville area is a distinctive terra cotta colored, medium- to fine-grained quartzite 100 to 150 ft thick. It is distinguished by its uniformity of grain size, the presence of well rounded, locally frosted grains, and widespread small- to large-scale cross-bedding. Locally, the weathered unit is friable and strongly resembles the Jurassic Nugget Sandstone of the Wasatch Mountains near Salt Lake City. The presence of frosted grains suggests an eolian environment, but bedding features indicate that final deposition may have taken place in shallow water.

The range of Rb Sr ratios in the basalt is too small to permit adequate whole-rock dating, even though the rocks are remarkably fresh in many places. It is hoped that a combination of this basalt and the rhyolitic tuff discovered recently in the underlying Mutual Formation may provide the necessary range in composition. The age of this unit, like that of all of those below, is presumed to be Precambrian.

Geertsen Canyon Quartzite

The basalt and quartzite of the Browns Hole Formation are overlain with apparent conformity by a very thick, light colored conglomeratic quartzite unit that is here given the new name Geertsen Canyon Quartzite. Rocks with this lithology underlie fossiliferous Cambrian shale or carbonates throughout the intermountain region of western Utah and much of eastern Nevada. In each area, however, a different name has been applied: in Nevada and western Utah they are generally called the Prospect Mountain Quartzite; in central Utah they are commonly referred to as the Tintic Quartzite; in much of northern Utah and southern Idaho, including the Huntsville area, these rocks have been referred to as the Brigham Quartzite. However, because of the conflicting and more inclusive use of the term "Brigham" in much of northeastern Utah and southeastern Idaho, the formation is here given a new name.

The type section of the Geertsen Canyon Quartzite is on the ridge west of Geertsen Canyon, 5 mi north of Huntsville in sections 18 and 19, of T. 7 N., R. 2 E. (I-J, Fig. 3). In this area the formation rests with apparent conformity on the terra cotta quartzite member of the Browns Hole Formation and is overlain with apparent conformity by brown-weathering dolomite of the Langston Dolomite. The total thickness in this area is approximately 4200 ft, divided into a lower member about 1200 ft thick that is dominantly arkosic, and an upper member about 3000 ft thick that is dominantly quartzitic. The two are separated by a persistent zone of conglomerate lenses.

The lower member of the Geertsen Canyon Quartzite has at the base 300 to 400 ft of very coarse-grained arkose containing fragments of salmon-colored microcline and pale greenish-weathered plagioclase up to a half inch in size; both the grain size and feldspar content diminish upward, however, and the remaining 800 ft or so of this member is white- or tan-weathering quartzite.

The contact between the lower and upper members of the Geertsen Canyon is drawn at a persistent zone of cobble conglomerates. Where best developed, the conglomerate occurs as a single bed 8 to 10 ft thick of 2- to 4-in. clasts mainly of reddish-coated vein quartz or quartzite, occasionally of gray quartzite or red jasper. In many areas, however, conglomerate beds a few feet thick are found throughout a stratigraphic interval 100 to 200 ft thick. The upper member of the Geertsen Canyon Quartzite is typical of basal Cambrian quartzites throughout the intermountain area. It consists predominantly of pale buff to white or pale-pink quartzite locally streaked pale red or pale purple. In general, it is coarse grained with scattered pebbles up to an inch in diameter, particularly along bedding planes, throughout the unit. Locally, at the top of this member is an interval about 375 ft thick in which the quartzites are marked by persistent *Scolithus* and in which the interbedded argillites show abundant fucoidal structures, occasional trilobite tracks, and sparse unidentifiable phosphatic fragments. It seems probable, although not yet demonstrable, that this part of the unit is equivalent to rocks in the Portneuf Range called the "quartzite of Sedgewick Peak" by Oriel (1965), which have yielded an olenellid trilobite, and hence are of Early Cambrian age.

In terms of general position and lithology, the Geertsen Canyon Quartzite is presumed to correlate approximately with the Camelback Mountain Quartzite of Pocatello and with the Prospect Mountain Quartzite (restricted) of the Beaver Mountains. It is assigned a Precambrian and Early(?) Cambrian age.

BEAVER MOUNTAINS, UTAH

About 9000 ft of younger Precambrian and lowermost Cambrian strata are present in the Beaver Mountains (Fig. 1). The uppermost formation is the Prospect Mountain Quartzite (restricted, *of* Woodward, 1968) which generally has been considered to be Lower Cambrian; however, the Precambrian-Cambrian boundary within the Beaver Mountains cannot be located precisely (Woodward, 1968).

Beneath the Prospect Mountain Quartzite (restricted) are seven units, tentatively considered Precambrian; these have been informally numbered 1 through 7, beginning with the oldest. This concordant section is correlated with the younger Precambrian and Cambrian sections near Pocatello and Huntsville on the basis of remarkable lithologic similarities in both individual units and in the over-all sequence (Fig. 7). The following brief descriptions begin at the base; more complete descriptions are given by Woodward (1967).

Unit 1 consists of medium- to coarse-grained, thick-bedded, light gray, cross-bedded quartzite. Although the base of the unit is not exposed, 970 ft were measured. This unit appears to be correlative with the upper part of the upper member of the Pocatello Formation.

Overlying this quartzite unit is about 1300 ft of interbedded quartzite, slate, argillite and marble of unit 2. The lower 500 ft consists of thin-bedded gray quartzite with intercalated red and green slate laminae and thin-bedded quartzose marble. A thin zone of intraformational edge-wise quartzite conglomerate occurs near the top of this sequence. Overlying it is a 25-ft cliff formed by very thick-bedded quartzose calcite marble. Above the cliff-making marble, the unit consists of thinly interbedded tan, olive-green, and greenish-gray slate, argillite, and quartzite with minor quartzose marble that decreases in abundance upward. The marble beds, mostly occurring in the lower part of the unit, probably represent tongues of the Blackrock Canyon Limestone of the Pocatello area. The upper part of unit 2 may be correlative with the Papoose Creek Formation.

Unit 3 consists of 260 ft of quartzite with minor green slate near the top. The lower part of the unit is thick-bedded, medium- to coarse-grained, whitish and light gray quartzite. About 50 ft below the top of the unit there is an abrupt upward change from light gray quartzite to dark brown quartzite containing subrounded white quartz pebbles up to 2 cm in diameter. The top of the unit is formed by a 15-ft green slate interval and 10 ft of overlying very thick-bedded, medium- to coarse-grained, dark gray quartzite. This unit appears to be lithologically correlative with the much thicker Caddy Canyon Quartzite of the Pocatello region.

Unit 4 consists of 530 ft of olive-green slate and argillite with minor thinly intercalated fine- to medium-grained green quartzite. The quartzite is impure, containing abundant chlorite and sericite matrix. This greenish unit is the lithologic equivalent of the Inkom Formation of the Pocatello area.

Units 5, 6, and 7 of the Beaver Mountains appear to be lithologically correlative with the rocks assigned to the Mutual Formation in the Pocatello and Huntsville areas. Unit 5 contains 760 ft of thick-bedded, reddish-brown, medium-grained to conglomeratic quartzite. Well-rounded white quartz pebbles up to 3 cm in diameter occur sparsely in the lower beds and become more abundant near the top of the unit, forming thin conglomeratic layers. Unit 6 consists of approximately 150 ft of interbedded maroon slate, argillite, and thick-bedded, coarse-grained to gritty quartzite. A composite section of unit 7 measures 1175 ft and is composed of purple conglomeratic quartzite with minor purple and silver slate and argillite laminae. The quartzite is medium- to very coarse-grained and contains abundant but thin gritty and conglomeratic zones with pebbles of white and clear quartz or, rarely, jasper up to 1 cm in diameter. Beds are thin near the base of this unit but become thicker upward.

The purple quartzite of unit 7 is overlain with a concordant but sharp contact by pinkish and tan quartzite characteristic of the Prospect Mountain Quartzite (restricted). This unit consists of thick to very thick-bedded, coarse-grained to conglomeratic quartzite; the lowest beds are poorly sorted and gritty, becoming conglomeratic about 20 ft above the base of the formation. This conglomeratic zone is 20 ft thick and contains pink and tan subrounded quartz pebbles up to 2 cm in diameter. In the succeeding 200 ft, pebble-size clasts are scattered, only locally becoming abundant enough to form thin conglomerate layers. Still higher, pebbles are scarce and the rock is more uniformly coarse grained or gritty. Pink feldspar clasts, principally microcline, are common in the lower part of the formation and constitute up to 10 percent of some specimens. The thickness of the Prospect Mountain Quartzite (restricted) cannot be measured precisely because of faults in the section, but it appears to be at least 4000 ft thick.

OTHER AREAS IN UTAH

Dugway Range

A 12,000-ft sequence of younger Precambrian and basal Cambrian rocks in the Dugway Range, Utah, described by Staatz and Carr (1964), contains rocks equivalent to a large part of the sections previously described at Pocatello, Huntsville, and the Beaver Mountains. Although Staatz and Carr assigned these rocks to the Prospect Mountain Quartzite, which they designated Lower Cambrian, they pointed out (1964, p. 16) that the lower part was probably of Precambrian age. The close lithologic similarity between the rocks in the Dugway Range and those of Pocatello were pointed out to Trimble by W. J. Carr and later confirmed in the field.

The oldest units exposed in the section at Dugway (Fig. 8) are dominantly light colored to pinkish-tan, rusty weathering quartzite interbedded with considerable olive-drab or tan micaceous shale (units 1 through 6 *of* Staatz and Carr, 1964). Except for the presence of a 150-ft pebbly conglomerate (unit 6), this section bears a considerable resemblance to parts of the Caddy Canyon Quartzite of the Pocatello and Huntsville areas and perhaps part of the underlying Kelley Canyon Formation of Huntsville. The succeeding unit at Dugway (unit 7 *of* Staatz and Carr) consists of 600 ft of olive-tan, thinly laminated shale and siltstone which is virtually indistinguishable from the greenish Inkom Formation at Pocatello. This unit in turn is overlain by 1600 ft of coarse-grained "violet" to grayish-red conglomeratic quartzite that resembles in both character and position the Mutual Formation of all three of the areas previously described. The Mutual equivalents at Dugway are overlain by approximately 4500 ft of white or tan quartzite (unit 8 *of* Staatz and Carr, 1964) that appears to be correlative with the Camelback Mountain Quartzite of the Pocatello area, the Geertsen

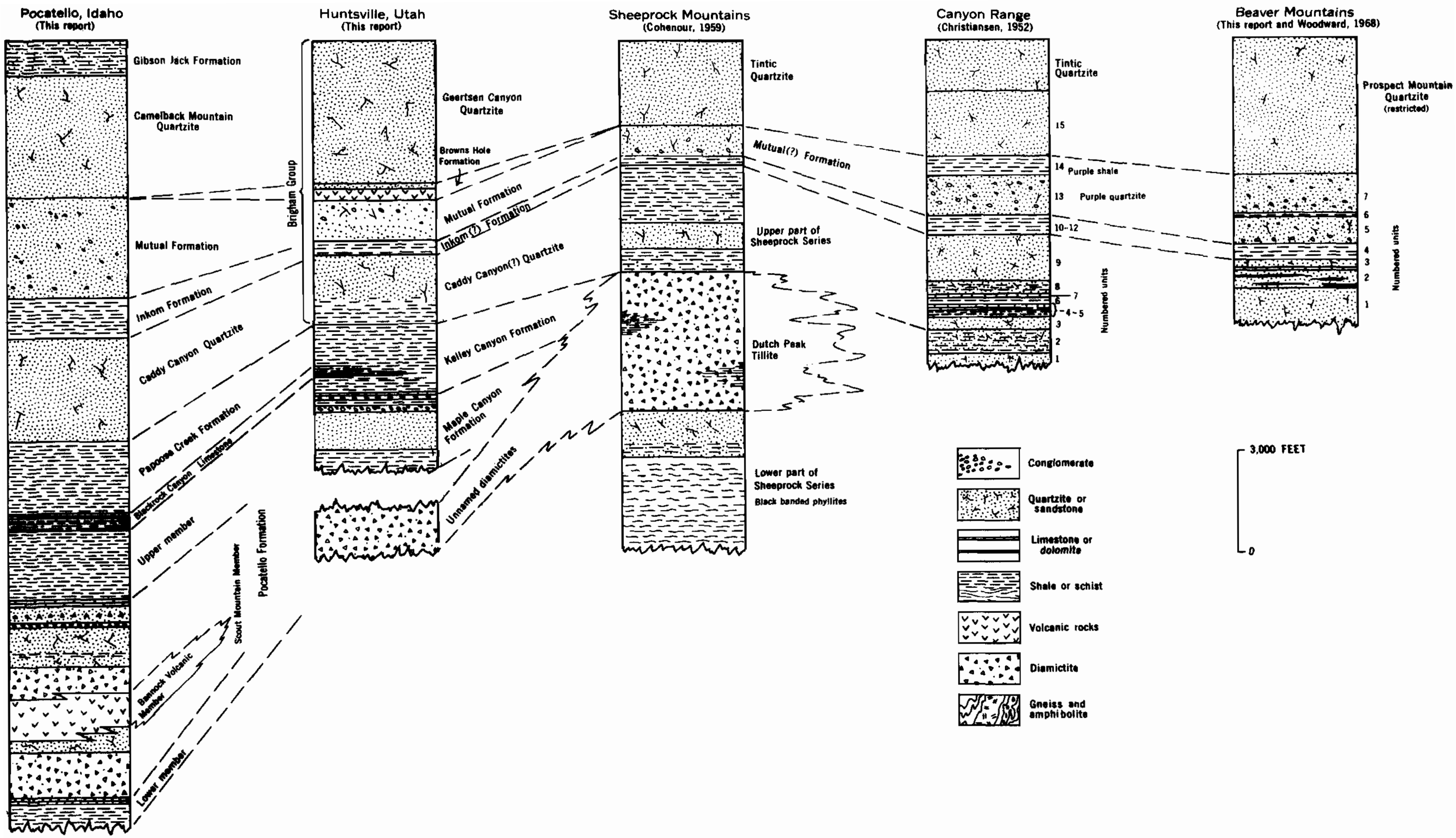

Figure 7. North-south correlation of younger Precambrian and basal Cambrian rocks from Pocatello, Idaho, to Beaver Mountains, Utah.

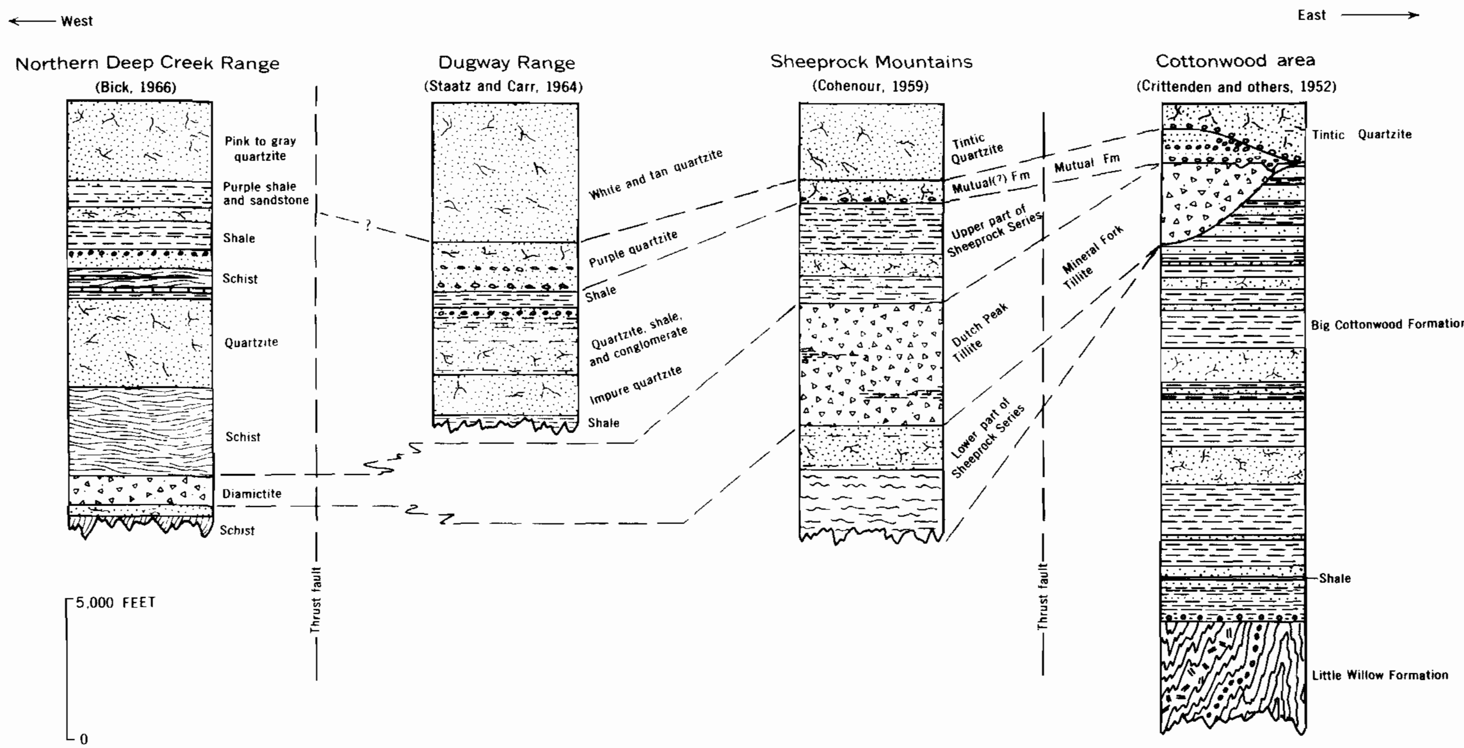

Figure 8. East-west correlation of younger Precambrian and basal Cambrian rocks in western Utah.

Canyon Quartzite of Huntsville, and the Prospect Mountain Quartzite (restricted) in the Beaver Mountains.

Sheeprock Mountains

A 15,000-ft section of younger Precambrian and basal Cambrian rocks described by Cohenour (1959) in the Sheeprock Mountains of central Utah also contains lithologic equivalents of the rocks recognized at Pocatello and Huntsville (Fig. 7). The lower part of the section, designated the Sheeprock Group by Harris (1958, p. 6) and the Sheeprock Series by Cohenour (1959, p. 17), contains a lower "black-banded phyllite" 2690 ft thick that together with about 1470 ft of dark slate, conglomerate, and graywacke, probably is correlative with the lower member of the Pocatello Formation. This is overlain by a diamictite unit, called the Dutch Peak Tillite by Cohenour (1959, p. 19), which correlates in both character and stratigraphic relations with the diamictite-bearing Scout Mountain Member of the Pocatello Formation. More recent mapping in the southern Sheeprock Mountains by H. T. Morris and R. W. Kopf (1968, oral commun.) indicates that diamictites in that area intertongue with normal marine sedimentary rocks as they do at Pocatello. Above the Dutch Peak Tillite is the upper part of the Sheeprock Series, which consists of olive-green or tan shale and a white quartzite. These suggest the lithology of the upper member of the Pocatello Formation and the Papoose Creek Formation at Pocatello and of the Kelley Canyon Formation at Huntsville, although the limestone tongues are apparently absent. The Mutual Formation in the Sheeprock Mountains is thin (900 ft) compared with other trough sections, but this may be local, inasmuch as Groff (1959, p. 25) reports a 3000-ft section on the slopes of Sabie Mountain immediately to the east. A small angular discordance reported by Cohenour at the base of the Mutual shows that the effects of epeirogenic movements that strongly modified the section in the shelf areas to the east (Fig. 8) also were effective locally within the basin. A 2500-ft section of white, pale gray, or tan quartzite, called Tintic Quartzite by Cohenour (1959), appears to be correlative with the Camelback Mountain Quartzite of Pocatello and the Geertsen Canyon Quartzite of Huntsville. As in other parts of the trough (Fig. 7), there is no evidence of a stratigraphic break between the Mutual and Tintic, and sedimentation appears to have been nearly continuous from Precambrian to Cambrian time.

Canyon Range

A 9900-ft section of younger Precambrian rocks described by Christiansen (1952) in the Canyon Range (Fig. 1) also exhibits the same sequence and many of the same units recognized to the north and south (Fig. 7). At the base, Christiansen's units 1 through 3 occupy the stratigraphic position of the upper member of the Pocatello Formation in Idaho; units 4 and 5 may represent a distal tongue of the Blackrock Canyon Limestone of Pocatello and equivalents at Huntsville inasmuch as they resemble it in both character and position. Units 9, 10 through 12, and 13 are correlated, respectively, with the Caddy Canyon Quartzite, Inkom Formation, and Mutual Formation, recognized in the Pocatello, Huntsville, and Beaver sections. Christiansen's unit 15 and the conformably overlying quartzite, which he referred to as the Tintic Quartzite, are the equivalents of the Camelback Mountain Quartzite and Geertsen Canyon Quartzite of southern Idaho and Huntsville, and the Prospect Mountain Quartzite of the Beaver Mountains and probably contain the same continuous record of deposition from Precambrian to Cambrian time.

Antelope Island

The thin but highly significant sequence of younger Precambrian rocks on Antelope Island (Fig. 1) near the eastern edge of Great Salt Lake was described by Eardley and Hatch in 1940. The crystalline basement is overlain by a few tens of feet of diamictite, a thin shale, and a laminated limestone that closely resembles the laminated dolomite immediately above the diamictite in the Pocatello section. This is overlain unconformably by a thick cobble and pebble conglomerate that is typical in every respect of the basal Cambrian throughout all of northern Utah. This unit has been examined repeatedly by one of the authors (Crittenden) and also by R. J. Roberts, H. T. Morris and E. W. Tooker, who agree that Eardley and Hatch's original identification as Tintic Quartzite was correct, and that Larsen's (1957) correlation with the

Mutual Formation (shown also on the Geologic Map of northwestern Utah; *see* Stokes, 1963), is in error.

CORRELATION WITHIN SEDIMENTARY BASIN

The remarkable similarity of both individual stratigraphic units and of rock sequences in a north-south direction is evident from the preceding descriptions. Correlation in this direction (Fig. 7), therefore, presents few problems. The key horizons are: (1) the distinctive and persistent purple to grayish-red quartzite of the Mutual Formation, which characteristically overlies greenish pelitic rocks of the Inkom Formation; (2) the impure silty carbonates of the Blackrock Canyon Limestone, thin equivalents of which reappear at Huntsville, in the Beaver Mountains, and the Canyon Range; (3) a few feet of tan-weathering laminated dolomite that occurs with remarkable persistence just above a thin conglomerate at both Pocatello and Huntsville; and (4) the lithologically distinct and genetically significant diamictites.

The unique character and the probable glacial origin of the diamictites in Utah was recognized near the turn of the century by Blackwelder (1910) and Hintze (1913). These are black boulder-bearing beds containing several unusual lithologies. The most distinctive is a massive rock (Fig. 4) consisting of clasts ranging from boulder to small pebble size in a muddy matrix. It is remarkable for its persistent black color (resulting from an abundance of both carbon and pyrite), faceted and striated cobble-size clasts, anomalously angular character of sand-size fragments, and absence of bedding through many tens of feet. A second characteristic rock is boulder phyllite in which boulder- to cobble-size clasts are spaced at intervals of a few feet to a few hundred feet (one or two per outcrop) in thin-bedded black (carbonaceous) mudstones which have been sheared to phyllite. A third characteristic lithology is medium-bedded, coarse-grained, greenish-gray arkosic quartzite or graywacke. These rocks occur through about 5000 ft of section at Pocatello, are present along strike below the sequence at Huntsville, and intertongue through 4000 ft of beds in the Sheeprock area (Cohenour, 1959). These relations suggest deposition in a subsiding marine trough by glacial tongues, which in some areas dumped till directly, in others yielded ice-rafted clasts, and in many other areas yielded only the reworked or redistributed products of a complex depositional process like that described by Frakes and Crowell (1969, p. 1027–1029) for Paleozoic glaciation in South America.

East-west correlation (Fig. 8) across the assumed trend of the depositional basin can be established with confidence only as far west as the Dugway Range. Farther west, correlation with sections in easternmost Nevada and along the Utah-Nevada line (northern Deep Creek Range, Schell Creek Range, Pilot Range; Fig. 1) have been suggested by Woodward (1968), but variation within individual sections, together with a lack of key beds, makes these correlations much more tenuous than those within the basin.

Correlation eastward from the basin sections of Pocatello and Huntsville to the Cottonwood area, which appears to represent a shelf environment, can be established with considerable confidence (Fig. 8). The basal Cambrian quartzites are identical lithologically but thin from some 4000 ft in the axis of the trough to less than 1000 ft on the shelf. Moreover, the Tintic Quartzite in both the Cottonwood areas and in the autochthon near Ogden appears to represent only the upper member of the Geertsen Canyon Quartzite at Huntsville; the lower member is cut out along the low-angle unconformity. Locally, in the Cottonwood area, the entire Mutual Formation also has been cut out by this unconformity, and the Tintic Quartzite rests directly on the diamictite-bearing rocks, there designated the Mineral Fork Tillite (Crittenden and others, 1952).

A second angular unconformity is locally present in the shelf section at the base of the Mutual Formation. As a result, coarse boulder conglomerate at the base of the Mutual rests directly on the Mineral Fork Tillite—the equivalent of the lower part of the thick basin sequence at Pocatello. The thickness of beds cut out by this unconformity amounts to nearly 10,000 ft.

REGIONAL CORRELATION AND AGE

All of the rocks here described lie within the Big Cottonwood subprovince of younger Precambrian rocks as defined by Condie (1969). However, without detailed mapping and stratigraphic studies of the kind here reported, correlation both within that subprovince and with adjoining provinces was considered tenuous (Condie, 1969, p. 83 and 86).

Recognizing the unique lithologic character of the diamictites, whether or not they are of glacial origin, it is now possible to subdivide the major younger Precambrian sequences of western North America, even though strict temporal equivalence cannot be demonstrated. Thick prediamictite sequences which may be in part temporal equivalents, include the Purcell Series of British Columbia, the Belt Supergroup of Montana and Idaho, and the Big Cottonwood Formation of Utah. Diamictites are recognized in all or parts of the Toby Conglomerate of British Columbia (Walker, 1926), the Scout Mountain Member of the Pocatello Formation, the Mineral Fork Tillite, and the Dutch Peak Tillite of Cohenour (1959) in Utah (Fig. 3), and the Kingston Peak Formation in southern California (Hewett, 1956, p. 27). Thick post-diamictite sequences include the remainder of the Windermere Group of British Columbia, the Brigham Group and its equivalents here described near Pocatello, Idaho, near Huntsville, and in the Beaver Mountain sections in Utah. Temporal equivalence of the diamictites is strengthened by their close association with volcanic rocks in the Pocatello section (Bannock Volcanic Member), in Washington (Leola Volcanics), and in British Columbia (Irene Volcanics), a relation pointed out by Yates (1968) and others.

The age span of each of the rock sequences described above has not been determined in the eastern Great Basin. The entire sequence is obviously bracketed between the underlying crystalline rocks, which are dated as 2.3 b.y. in the eastern Uinta Mountains (Hansen, 1963, and 1965, p. 31) and 1.6 b.y. in the Farmington area between Salt Lake City and Ogden (Giletti and Gast, 1961) and the basal Cambrian with which the uppermost units are gradational in the basin sections. If the correlations suggested above are valid, the dates established for Belt rocks in Montana, Idaho, and British Columbia (Obradovich and Peterman, 1968) imply that the Big Cottonwood Formation is between 1 to 1.5 b.y. old. The bulk of the rocks in the Pocatello and Huntsville sections should be the same age as the Windermere, that is, between 570 and 700 m.y. (*see* Leech, *in* Lowdon, 1961, p. 6), inasmuch as all three groups of rocks have a diamictite at the base and appear to have been deposited continuously, or at least without detectable tectonic disturbance, into Cambrian time.

PALEOGEOGRAPHY AND TECTONIC RELATIONS

The sequence of rocks at Pocatello, together with that present, although not yet completely mapped, at Huntsville, suggests the following generalized sequence of events in the eastern Great Basin, in very late Precambrian time.

1. Accumulation of a thick series of black argillaceous sediments containing thin tongues of dolomite or limestone which thicken westward. The shoreline during this time probably lay close to the present site of the Wasatch line; the axis of the trough was at least 40 mi farther west, possibly close to the Nevada line. The presence of black (carbonaceous) pyritic mudstones or shales in the lower member of the Pocatello Formation and at Huntsville suggests relatively deep quiet water and euxinic bottom conditions.

2. This depositional basin was invaded periodically from an unknown eastern source by tongues and sheets of ice which deposited diamictites, at times directly from ice, at times by ice-rafting of boulders beyond the glacial limits. Reworking and redeposition by slumping and turbidity currents is also probable (Condie, 1966, 1969). An episode of volcanism intervened in the Pocatello area during this same interval.

3. Normal marine sedimentation then resumed, including the deposition of tongues of carbonate intercalated with silt-size clastics whose green or purple color and scarcity of carbon or pyrite suggests normal rather than euxinic bottom conditions.

4. Gradually, the supply of sand-size debris increased, leading to accumulation of the quartzitic sequences that characterize the Brigham Group. Deposition appears to have been continuous into the Cambrian in parts of the basin, but the presence of volcanics and eolian sands in the Browns Hole Formation of the Huntsville sequence suggests that terrestrial conditions existed, at least temporarily, perhaps representing a slowing in the rate of basin subsidence.

5. The abundant cross-bedding and "pebbled" bedding surfaces that characterize the

upper parts of the Geertsen Canyon Quartzite indicate that shallow water conditions persisted into Cambrian time throughout the area.

Although a complete reconstruction of late Precambrian to Early Cambrian paleogeography is impossible, the preceding framework is sufficient to help clarify certain tectonic relations, particularly in northern Utah. That the thick Precambrian sequences of Huntsville and the northern Wasatch are allochthonous and are derived from the west, was evidently suspected by Blackwelder (Eardley, 1944, p. 849), and was one of two structural alternatives considered by Eardley and Hatch in 1940 (p. 867-872). More recently, Eardley (1968, 1969) has proposed that the Huntsville sequence is autochthonous, having been deposited in a trough on the east side of a late Precambrian uplift, which is marked by the very thin Antelope Island sequence.

The following evidence, drawn from the preceding discussion, is believed by the writers to support the concept of eastward thrusting. (1) The startling similarity of the Huntsville, Pocatello, Sheeprock, and Beaver Mountain sections implies that they all accumulated in the axis of a subsiding trough in which deposition was nearly continuous from Precambrian into Cambrian time: (2) The Antelope Island section, like that in the Cottonwood area near Salt Lake City, indicates intermittent uplift, with the result that only equivalents of the lowermost (diamictite) and uppermost (Tintic Quartzite) parts of the Pocatello and Huntsville sequence is present in these areas. The vastly thicker and more complete Huntsville section must have been deposited well to the west of Antelope Island. Thick sections of younger Precambrian rocks exposed on Promontory Point, Fremont Island, and Little Mountain are believed by Crittenden to be part of the Huntsville sequence, and presumably came from still farther west. (3) Accumulation of the Huntsville sequence at its present location in an embayment *east* of Antelope Island and east of the extensive exposures of the Farmington Canyon Complex in the Ogden area is unlikely because the late Precambrian uplift proposed by Eardley, and recorded by the profound unconformity exposed in those areas, would have yielded abundant conglomerates and coarse gneissic clasts which are conspicuously absent in the Huntsville sequence, and which, had they been present, would have caused this sequence to contrast strongly with the rocks at Pocatello. Similarly, uplift and stripping of the entire Huntsville sequence from the Antelope Island-Farmington area during Early Cambrian should have been recorded by an abundance of Huntsville-type clasts in the Geertsen Canyon Quartzite. These also are conspicuously lacking.

The logical alternative is that thick younger Precambrian sequences were never deposited at Antelope Island, and that the Huntsville sequence has been thrust eastward *over* the Antelope Island section. This conclusion is strongly reinforced by evidence from other parts of the stratigraphic column (Rigo, 1968; Crittenden, 1961; Armstrong, 1968). Although the 40-mi transport of the frontal edges of the thrust plates proposed in 1961 still appears reasonable, stratigraphic and structural relations in areas such as the Raft River Range (Felix, 1956; Compton, 1969) suggest that much greater distances are possible. A more complete reconstruction of the paleogeography of late Precambrian rocks must await solution of these and related structural problems.

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