Uppermost Precambrian and Lowest Cambrian Rocks in Southeastern Idaho

GEOLOGICAL SURVEY PROFESSIONAL PAPER 394

Uppermost Precambrian and Lowest Cambrian Rocks in Southeastern Idaho

By STEVEN S. ORIEL *and* FRANK C. ARMSTRONG

With contributions to early Middle Cambrian faunal zones

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Contrasts in rock sequences in the Bancroft, Soda Springs, and Preston quadrangles require new units for, and modified usages of, the names Brigham, Langston, and Ute

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[Plates are in pocket]

UPPERMOST PRECAMBRIAN AND LOWEST CAMBRIAN ROCKS IN SOUTHEASTERN IDAHO

By Steven S. Oriel and Frank C. Armstrong

ABSTRACT

The lowest rocks exposed in the Portneuf Range within the Bancroft quadrangle and in the Bear River Range within the Soda Springs quadrangle differ markedly in both composition and unit sequence from place to place. The former inconsistent application of the names Brigham Quartzite, Langston Limestone, Ute Limestone, and Blacksmith Limestone to comparable rocks in nearby areas has masked these marked and significant differences.

Three subdivisions of the Brigham Quartzite in the Bancroft quadrangle are recognized and named here. The lowest, the Kasiska Quartzite Member, is more than 1,600 feet thick and consists of light-gray and tan and partly purplish-red poorly sorted partly conglomeratic quartzite and thin layers of argillite and quartzitic siltstone; the unit is unfossiliferous and is assigned a late Precambrian age. The middle unit, the Windy Pass Argillite Member, is about 760 feet thick and is composed mainly of greenish-gray and gray silty and sandy argillite, abundantly interbedded and interlaminated with gray and pale-pink quartzite; although equivocal worm tracks and tubes were observed, the member is assigned a Precambrian(?) age. The highest subdivision, the Sedgwick Peak Quartzite Member, is 300 feet thick and consists of tan and light-green fine to very fine grained quartzite interbedded with thin units of argillite and siltstone; an Early Cambrian age assignment is based on *Olenellus* fragments in the middle of the member.

Although the three members of the Brigham in the Bancroft quadrangle can be recognized in nearby sections in the Portneuf Range, they are not evident in adjoining ranges. Local differences in composition in the upper part of the Brigham exposed in the Soda Springs quadrangle suggest marked local facies changes. Moreover, the presence of a lens of limestone with trilobites of the Middle Cambrian *Albertella* zone 150 feet below the top of the Brigham indicates that the top of the quartzite becomes younger eastward, confirming inferred eastward marine transgression.

Earlier usages of the term "Brigham" have not been consistent in nearby areas. Adopted here are usage of the Brigham in an inclusive sense and a Precambrian and Cambrian age assignment. The Brigham may be raised to group status in other areas where divisible. The presence of clearly evident rock-stratigraphic subdivisions of the Brigham in nearby areas and their absence from the Bancroft, Soda Springs, and Preston quadrangles and other considerations suggest that the eastern Bear River Range exposures may have accumulated near the eastern margin of, rather than well within, the Brigham depositional basin.

Above the Brigham in the Bancroft quadrangle are several distinctive rock units here assigned to new formations. The lowest, the Twin Knobs Formation, is about 600 feet thick and is divisible into three informal members. The lowest, 300–400 feet thick, consists of interbedded brown calcareous sandstone, green and gray quartzite, and mainly medium to dark-gray partly coarsely crystalline, partly subaphanitic, and partly oolitic limestone. The middle member, about 20 feet thick but absent from some sections, consists of green claystone. The upper member, 200–300 feet thick, consists of prominent ledges of *Girvanella*-bearing limestone. The Twin Knobs Formation is assigned, on the basis of stratigraphic position and regional relations, to the *Albertella* zone of the Middle Cambrian.

The Twin Knobs is overlain by about 500 feet of argillaceous rock here named the Lead Bell Shale. Dark-gray to black claystone interbedded with siltstone and sandstone is dominant in the lower part. Green and tan claystone interbedded with thin layers of limestone is dominant in the upper part. Trilobites from the lower and middle parts of the Lead Bell Shale are assigned to the *Glossopleura* zone; those from the upper part, to the *Bathyuriscus-Elrathina* zone of Middle Cambrian.

Above the Lead Bell Shale is a 500-foot-thick unit here named the Bancroft Limestone. It consists dominantly of thin-bedded mainly silty but partly oolitic and *Girvanella*-bearing limestone that contains thin green claystone partings in the lower part. The Bancroft contains trilobites of the Middle Cambrian *Bathyuriscus-Elrathina* zone and is overlain by thick-bedded to massive ledges assigned to the Blacksmith Limestone.

Above the Brigham Quartzite and below thick-bedded limestones assigned to the Blacksmith in the Soda Springs quadrangle are three different sequences of rock. The sequence near Nelson Creek is divisible into two units. The lower unit, about 450 feet thick and assigned to the Langston Formation, consists of two parts. The lower 50 feet is thin-bedded finely crystalline limestone; the upper 400 feet is thick-bedded tan-weathering coarsely crystalline dolomite. The upper unit, about 250 feet thick and assigned to the Ute Limestone, consists of three parts. The lowest is characterized by red and pink partly oolitic and partly silty limestone interbedded with thin layers of claystone and siltstone; the middle, by a 25-foot ledge of white-weathering finely crystalline limestone; and the upper, by mainly tan-weathering gray finely crystalline limestone.

The sequence near Egbert Canyon is also divisible into two units. The lower, about 450 feet thick and formerly assigned to the Langston, consists of two parts. The lower part is 150 feet

of shaly claystone, black at the base and olive green higher, and contains *Glossopleura*-zone trilobites; the upper part, 300 feet thick, is mainly thin bedded finely crystalline gray and partly oolitic limestone with numerous olive claystone partings. The upper unit, about 480 feet thick and tentatively assigned to the Ute, consists of tan-, pink-, and red-weathering thin-bedded partly silty and partly oolitic limestone with claystone and siltstone partings.

The sequence southeast of Eightmile Creek is also divisible into two units. The lower, about 330 feet thick, consists dominantly of claystone and siltstone in one section but includes thin quartzite beds in another; although formerly assigned to the Langston, the unit more likely represents the Lead Bell Shale. The upper unit, incompletely exposed, consists of thin-bedded gray finely crystalline partly oolitic limestone with pink, tan, and red siltstone partings; although formerly assigned to the Ute, it may represent the Bancroft Limestone.

A review of previously described nearby sections and their relations to the foregoing demonstrates the inadequacies of the inconsistently used terms Langston, Ute, and Spence, for these terms not only have masked rock composition but have also limited recognition of the applicability of Palmer's (1960) concept of an outer detrital belt, a middle carbonate belt, and an inner detrital belt. The Lead Bell Shale, which represents the other detrital belt, grades into and intertongues eastward with carbonate rock. A lower tongue of the shale, the Spence Tongue of the Lead Bell Shale, separates the Twin Knobs Formation and its eastern counterpart, the Naomi Peak Tongue, from higher limestones. A higher tongue, here named the Cub Tongue of the Lead Bell Shale, is considered a member of the Ute Limestone on the east and contains claystone formerly incorrectly designated the Spence Shale Member of the Ute Limestone. Between the two tongues are limestone on the west, here designated the High Creek Limestone and representing the outer part of the middle carbonate belt, and dolomite on the east, here redefined the Langston Dolomite and representing the inner part of the middle carbonate belt. The inner detrital belt is represented by Brigham Quartzite and, farther east, by Flathead Sandstone, whose top becomes younger eastward. The Bancroft Limestone is similar in composition to parts of the Ute Limestone that overlie the Cub Tongue of the Lead Bell Shale.

Although the name Blacksmith has been applied to dolomite on the southeast and to thick-bedded limestone elsewhere and although the base of the Blacksmith may not be mapped consistently, no change is proposed here. The Blacksmith is overlain by shale in the Bloomington Formation marking another marine transgression.

INTRODUCTION

Major contrasts have been encountered in the rock types and lithologic sequences of the lowest sedimentary rocks exposed in the various quadrangles that we mapped at several scales in southeastern Idaho. These contrasts in rock sequence have made it difficult to use available stratigraphic units with any degree of consistency and in a meaningful way. An implication is that the units Brigham Quartzite, Langston Limestone, and Ute Limestone, as currently understood, may not be entirely adequate for the needs of geologists working in the region.

The contrasts in rock sequence, not only from one quadrangle to another but even within a single quadrangle, indicate moderately complex and abrupt facies changes. These changes could indeed have been predicted, for the Cambrian throughout the Cordilleran region has long been known to exhibit complex facies relations which are attributed to extensive marine transgressions and regressions.

The new mapping by the U.S. Geological Survey has required recognition of some new local units for the clarification of complex structures. This new stratigraphic information will undoubtedly be of value to future syntheses of upper Precambrian and Cambrian stratigraphy of the northern Rocky Mountains. An additional aim of this report is to stimulate the collection of additional data in nearby areas in a critical and objective manner by sweeping away some of the nomenclatural constraints under which geologists have worked in the past; we hope we are not imposing others.

An attempt is made, through the organization of this report, to present objective data before discussing the conclusions based upon them. First, the rock sequence in the Bancroft area is described; then, the sequences in parts of the Soda Springs area. Previously described sections from nearby areas, some of which we have examined but none of which we have remeasured, are then compared with those measured during this study. The implications of all these data to regional relations and to stratigraphic nomenclature are then considered. Readers unconcerned with details may find our principal recommendations on rock-stratigraphic nomenclature on pages 32–38 and a summary of regional relations in figure 5.

AREAS STUDIED

Problems discussed here arose during geologic mapping of the Soda Springs (Armstrong, 1969), Bancroft (Oriel, 1968), and Preston (Oriel and Platt, 1968) quadrangles (fig. 1), Caribou, Bannock, Franklin, and Bear Lake Counties, Idaho. These quadrangles include the northern part of the Bear River Range on the east and the south-central part of the Portneuf Range on the west (fig. 2); the ranges are separated by Gem Valley which is thought to be a broad, deep graben (Mabey and Armstrong, 1962; Oriel, Mabey, and Armstrong, 1965), filled in part by Pleistocene basalt and Pleistocene lacustrine sediments (Bright, 1963).

Both the northern part of the Bear River Range and the Portneuf Range are complexly faulted homoclines of eastward-dipping Paleozoic strata. The lowest rocks in the sequence have been assigned to the Brigham

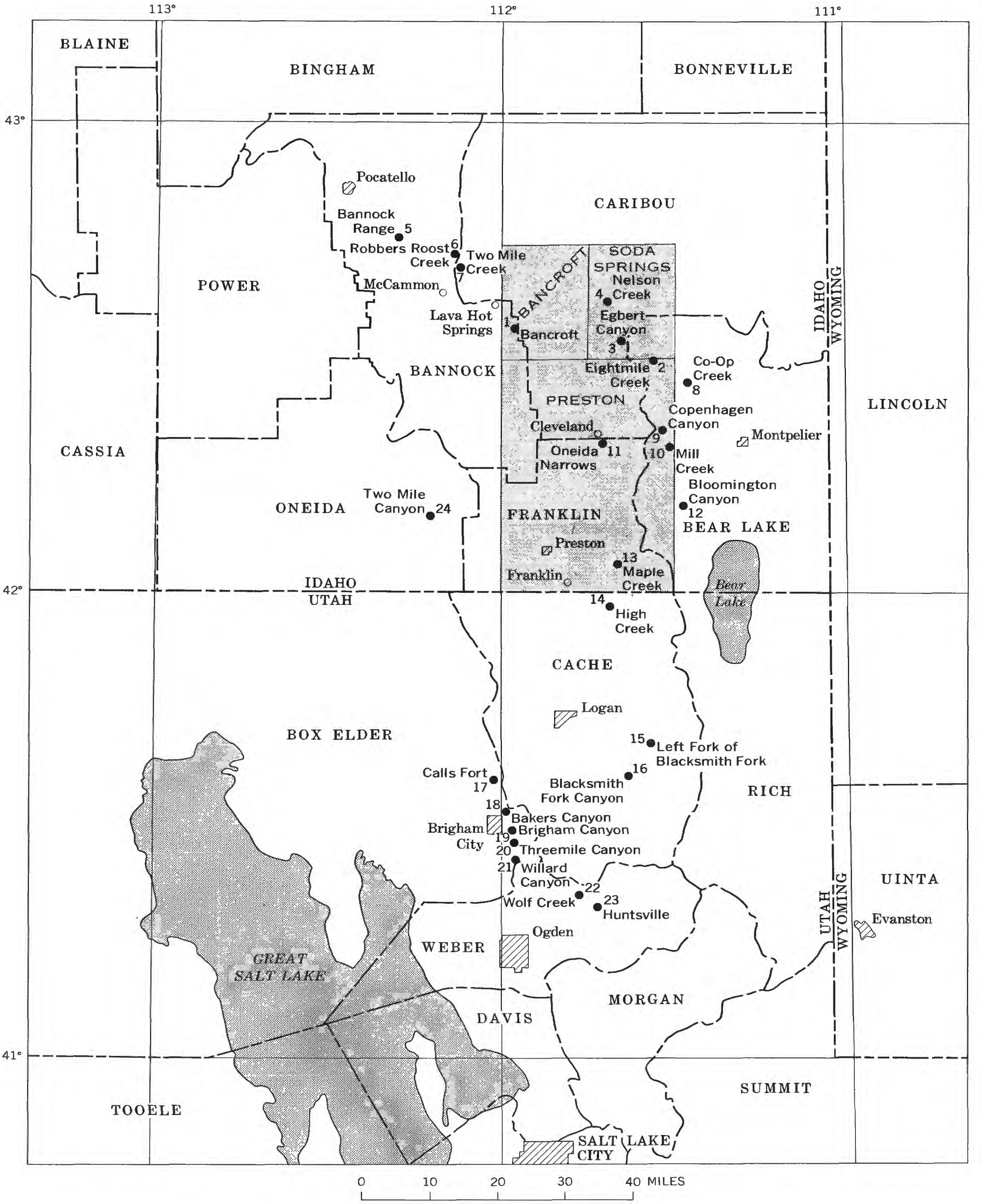


FIGURE 1.—Southeastern Idaho and northern Utah showing the locations of the Bancroft, Soda Springs, and Preston quadrangles (shaded) and of the stratigraphic sections discussed (numbered dots).

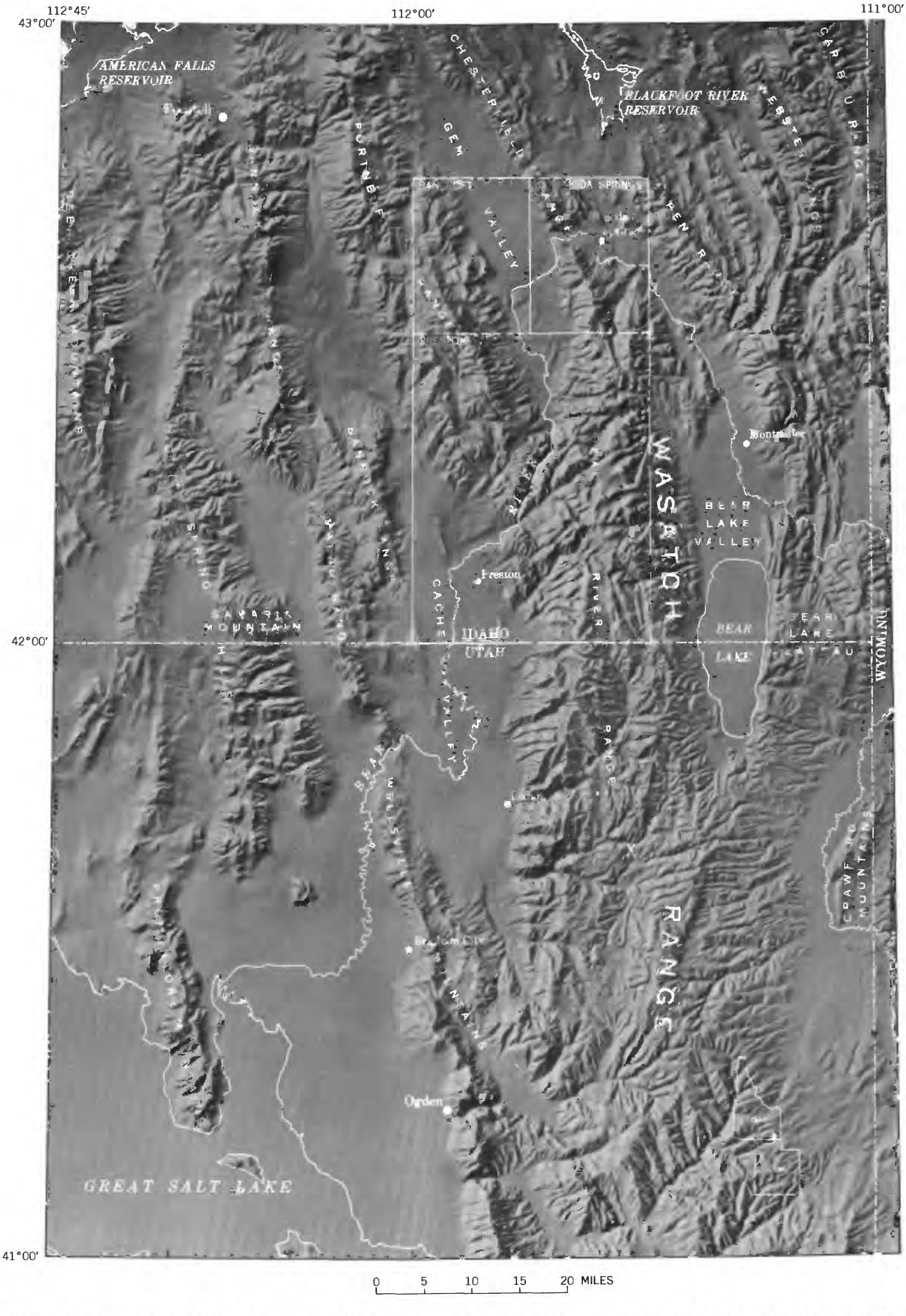


FIGURE 2.—Southeastern Idaho and northern Utah showing the major physiographic features mentioned and their relations to the Bancroft, Soda Springs, and Preston quadrangles. The type area for several of the formations discussed is shown by an × along Blacksmith Fork Canyon.

Quartzite, the base of which is not exposed in this part of southeastern Idaho.

Oriel mapped the Bancroft quadrangle, and Armstrong the Soda Springs. In measuring stratigraphic sections, Armstrong used Brunton compass and tape and reduced the measurements to true stratigraphic thickness by use of Mertie's (Mertie, 1922, pl. VI) nomogram. Oriel and his associates measured stratigraphic sections with a 5-foot Jacob staff equipped with an Abney level for direct measurement of true stratigraphic thicknesses.

ACKNOWLEDGMENTS

Problems described here came into sharper focus as a result of discussions in the field with Allison R. Palmer, William H. Fritz, Max D. Crittenden, Jr., Lucian B. Platt, Wilfred J. Carr, Donald E. Trimble, Robert C. Bright, William H. Hays, and Kenneth L. Shropshire, to whom we are grateful. We are especially indebted to Mr. Crittenden and Mr. Palmer for discovering the most important new fossil locality described here while they accompanied us in the field and to Mr. Fritz for making identifications of his collections available to us.

Gratitude is expressed to Mr. Palmer, Mr. Platt, and Mr. Crittenden for their numerous constructive criticisms of early drafts of this manuscript; we are also indebted to William J. Mapel and Keith B. Ketner for the same assistance. The debt owed previous students of southeastern Idaho and of the Cambrian for the foundations they erected should be apparent to all readers. The noteworthy contribution by George B. Maxey (1958) has been especially helpful.

Our greatest debt, though, is to Mr. Palmer. His enthusiastic support and stimulating ideas have had a major impact on the development of our thinking. Indeed, if this report has any merit, it is largely attributable to him.

FACIES

The northern part of the Bear River Range in the Soda Springs quadrangle contains dissimilar sequences of Middle Cambrian strata. Three sequences have been recognized (Armstrong, 1969): one in Nelson Creek [1] on the west side of the Bear River Range about 3½ miles northeast of Grace, Idaho; another, in Egbert Canyon on the west side of the Bear River Range about 4½ miles southeast of Grace; a third in the area southeast of Eightmile Creek. The facies in the Nelson Creek area is confined principally to the northern 4 miles of the Bear River Range; the facies in the Egbert Canyon area occurs farther south along the west flank of the range. Near the facies change are postdepositional faults that trend eastward across the range. The Nelson Creek strata resemble strata in Blacksmith Fork Canyon, Utah; the Egbert Creek strata, although somewhat akin to the sequence in the Portneuf Range to the west, differ from it and are even more different from the strata in Blacksmith Fork Canyon, Utah; the strata southeast of Eightmile Creek may more closely resemble units in the Portneuf Range than any of the others.

[1] Most localities cited in this report are shown on the Bancroft, Soda Springs, Preston, and Montpelier quadrangle topographic sheets of the U.S. Geological Survey.

BRIGHAM QUARTZITE

A thick sequence of detrital rocks, mainly quartzite, directly beneath fossiliferous limestones and mudstones of Middle Cambrian age in southeasternmost Idaho and adjacent northernmost Utah, has commonly been assigned to the Brigham Quartzite. This detrital sequence forms the base of the exposed sedimentary column in most parts of southeastern Idaho. Only the upper part of the Brigham sequence is exposed in the Bancroft and Soda Springs quadrangles; the middle and lower parts are exposed in the Preston quadrangle and in the Pocatello area.

Most, but not all, quartzite strata in the Brigham are characterized by poor to very poor size sorting. Grain sizes range from very fine to very coarse; both pebble conglomerates and scattered pebbles are not uncommon, but granule conglomerates are the most abundant. Grains and pebbles consist overwhelmingly of quartz and quartzite; a minor constituent is chert. Despite the presence of weathered detrital cleavage fragments of feldspar in some parts of the section, most of the rocks are chemically mature. Dominant colors are shades of light tan, light gray, and pink; purple and purplish red to brown are common low in the sequence and green to olive brown, near the top. Weathered surfaces are dominantly reddish brown, red, brown, and pink; locally, some beds are shades of gray and others are almost white.

Argillites and phyllites in the Brigham differ from claystones in overlying units both in compositional sorting and in degree of metamorphism. Most are "dirty," having formed as very silty to partly sandy mudstones; quartz is almost as abundant as clayey minerals. Laminae of quartzitic siltsone and very fine grained, quartzite are abundant throughout the argillite units. Argillaceous laminae and beds now consist of quartz, sericite, and muscovite and some chlorite. Colors are dominantly shades of gray, tan, and green; but the greens are grayish green or greenish gray, in contrast to the brighter green of the claystone in higher stratigraphic units.

BANCROFT QUADRANGLE

Three distinct, conformable lithologic units were recognized and mapped among the 2,500 feet of Brigham strata exposed in the part of the Portneuf Range that lies in the Bancroft quadrangle (pl. 1). These are designated, in ascending order, the Kasiska Quartzite Member, the Windy Pass Argillite Member, and the Sedgwick Peak Quartzite Member of the Brigham Quartzite and are defined and described below. They are assigned a member rank because they seem to have only a very limited areal extent. Comparable lithologic subdivisions were sought but not found in exposures of the upper part of the Brigham Quartzite in nearby ranges.

KASISKA QUARTZITE MEMBER

NAME

The lowest unit of the Brigham Quartzite recognized is here named for the Kasiska Ranch, along Dempsey Creek in the NW¼ sec. 34, T. 10 S., R. 38 E. The unit is well exposed in cliffs along the west flank of the Portneuf Range several miles east of the ranch.

TYPE

The type area is the belt of steep slopes and cliffs on the west side of the crest of the Portneuf Range, from the NW¼NW¼ sec. 12, T. 10 S., R. 38 E., to the mountain peak (8,728 ft) in the NE¼NW¼ sec. 4, T. 11 S., R. 39 E., 1¼ miles southeast of Sedgwick Peak (Oriel, 1965a). The incompletely exposed sequence in the western part of sec. 12, T. 10 S., R. 38 E., west of Twin Knobs, is designated the type section (fig. 3).

COMPOSITION

The Kasiska Quartzite Member consists almost entirely of quartzite (pl. 1), with a few thin units of phyllitic argillite, argillite, and quartzitic siltstone.

The quartzite is light gray, light tan, purple, and dark purplish red in the lowest exposures seen; white, pale to medium pink, buff, and very light gray near the middle; and very light gray, tan, and almost white in the upper part of the unit. Colors on weathered surfaces are mainly various shades of yellow brown, brown, and red, but they include almost black to purplish black where manganiferous coatings are abundant. Grain sizes range mostly from very fine to granule, and most beds are poorly sorted, coarse grains to granules are abundantly distributed in finer grained matrices. A few thin beds of conglomeratic quartzite contain well-rounded white, pink, and red quartzite and vein quartz pebbles as much as 2 inches across; smaller pebbles and granules range from angular to very well rounded. Beds are very thin to massive, with beds 1 to several feet thick most abundant; the steepest cliffs contain no sign of bedding in units up to 12 feet thick. A few beds are crossbedded; although not seen in three dimensions, cross-strata seem to dip gently and mainly northward, although more extensive regional measurements of crossbedding suggest a westward direction of transport in Idaho (Seeland, 1969) and to the south (Stewart, 1970, p. 64, 70). Some beds, especially those that are purplish red, exhibit liesegang bands, at least some of which resemble crossbedding.

Thin argillaceous layers within the Kasiska Member make up 5–10 percent of the unit. They consist of tan, brown, and green argillite and phyllitic argillite interbedded and interlaminated with quartzitic siltstone, very fine grained quartzite, and green to brown muddy sandstone.

CONTACTS

The base of the Kasiska Quartzite Member is not exposed in the Bancroft quadrangle. The lowest exposed beds are in fault contact with younger formations.

The top of the member is placed at the top of the uppermost thick quartzite beds and at the base of a dominantly argillaceous sequence that contains quartzite units only a few feet thick. The contact, which is conformable, is gradational at some places. The contact coincides with an abrupt break in topography; the slopes below are steep and include cliffs and ledges; those above are gentle, locally almost flat, with only a few small ledges.

DISTRIBUTION AND THICKNESS

The Kasiska Quartzite Member is exposed in a moderately continuous southeasterly trending belt from a point 3 miles southeast of Lava Hot Springs (fig. 1) to some hills southeast of Bear River, south of Cleveland. The belt lies west of the crest of the Portneuf Range on the north, but forms the crest southward from a point about three-fourths of a mile south of Sedgwick Peak.

The thickness of the member is not known; 1,280 feet was measured in the incomplete type section west of Twin Knobs. Computations from mapped broader exposures indicate that the unit is at least 1,600 feet thick farther south in the Bancroft quadrangle, but this section also is incomplete.

AGE

No traces of organic remains have been recognized in the Kasiska Quartzite Member. The member lies several hundred feet stratigraphically below the lowest bed that contains Cambrian fossils, and it is therefore assigned a Precambrian age.

The general problem of defining the base of the Cambrian System (for example, Neuman and Palmer, 1956; Rodgers, 1956b, p. 408–410) bears on the ages assigned to members of the Brigham Quartzite in the Portneuf Range. The definition used here is consistent with the proposal of Wheeler (1947) and the present practice of the U.S. Geological Survey (for example, Barnes and Christiansen, 1967, p. G4) in placing the base of the Cambrian at the base of strata that contain the oldest preserved Early Cambrian fossils and at the base of equivalent unfossiliferous strata.

GENERAL REMARKS

Because the base of the section is cut by a fault in the type area of the Kasiska Member, the question arises as to how the term should be applied to more complete sections. For example, the upper three gross units measured by Bright (1960, p. 28–39) near the Oneida Narrows of the Bear River (near Cleveland) seem to coincide in compositions with the three members of the Brigham Quartzite described here, and thicknesses of the upper two members are similar (pl. 2). The lowest of Bright's three units is quartzite 6,582 feet thick, which is underlain by a unit of purple, maroon, and green argillite. The upper strata of his quartzite unit are probably the same as those assigned here to the Kasiska Quartzite Member. The name Kasiska may be applied to all 6,582 feet or to only an upper part, *if* the unit proves to be divisible in subsequent mapping. One basis for possibly subdividing Bright's 6,582-foot quartzite unit that has been used in mapping nearby areas (Crittenden, 1968; Trimble and Schaeffer, 1965) is color. The upper part is dominantly light-gray quartzite whereas the lower part is dominantly purple quartzite. Thus the name Kasiska could be restricted to the upper light-gray part, if such a unit were mappable in nearby areas. Attempts to map such a boundary proved impractical in the Preston quadrangle (Oriel and Platt, 1968), because no sharp color boundary exists and because at least part of the color is secondary. The middle part of Bright's thick quartzite unit consists of interbedded light-gray, tan, and purple quartzite, with first one color dominant, and then another. Moreover, in at least some places within the Preston and Bancroft quadrangles, streaks of purple can be seen to cut across bedding, which is defined by layers composed of different grain sizes. Therefore, our inclination to assign only the upper part of Bright's 6,600 feet of quartzite to the Kasiska Member proved impractical here.

WINDY PASS ARGILLITE MEMBER

NAME

The second of the Brigham Quartzite units described here, the Windy Pass Argillite Member, is here named for the exposures at and near Windy Pass in the southwestern part of sec. 12, T. 10 S., R. 38 E.

TYPE

The type area is the belt of gentle slopes slightly west of the crest of the Portneuf Range, from a point west of Twin Knobs, in the central part of sec. 12, T. 10 S., R. 38 E., south-southeastward to a point south of Sedgwick Peak, near the middle of sec. 32, T. 10 S., R. 39 E. (Oriel, 1965a). The sequence exposed near the middle of sec. 12, T. 10 S., R. 38 E., on the spur extending southwestwardly from the northern of the Twin Knobs (fig. 3), is designated the type section.

COMPOSITION

Despite its lithologic designation, which contrasts the unit with adjacent members, 30–50 percent of the Windy Pass Argillite Member consists of detrital quartz. The member consists dominantly of somewhat metamorphosed thinly bedded to thinly laminated mudstone, claystone, and siltstone interbedded with quartzite in lenses and beds as much as 30 feet thick. Quartzitic siltstone is abundant throughout the unit, and small angular grains of quartz are scattered abundantly throughout most of the more argillaceous layers. Colors of the argillaceous rocks are dominantly green, tan, light to very dark gray, and brown. Quartzite beds are flesh colored to pink and partly light tan; their grain size is generally medium or smaller with scattered coarser grains. Some thinly laminated beds grade upward from fine-grained quartzite through siltstone to very dark gray or green phyllite. Also found are both simple and interference ripple marks.

All beds are somewhat metamorphosed. The quartzose beds are now quartzite. Argillaceous beds range from argillite to phyllite, and both sericite and muscovite in flakes as much as 1 mm in diameter are abundant. However, no schistosity is present and slaty cleavage across bedding is evident in only a few layers. A few argillaceous units exhibit pale-gray and tan to light-pinkish-tan liesegang bands, which are especially conspicuous on cleavage surfaces.

UPPER CONTACT

Quartzite is moderately abundant near the top of the Windy Pass Argillite Member; the member grades into the overlying Sedgwick Peak Quartzite Member. The top of the Windy Pass Member is placed at the base of a prominent quartzite ledge above which quartzite is overwhelmingly dominant.

DISTRIBUTION AND THICKNESS

The Windy Pass Argillite Member is exposed in the Bancroft quadrangle in a south-southeasterly trending belt that is directly east of the belt underlain by the Kasiska Quartzite Member. The similarity of Windy

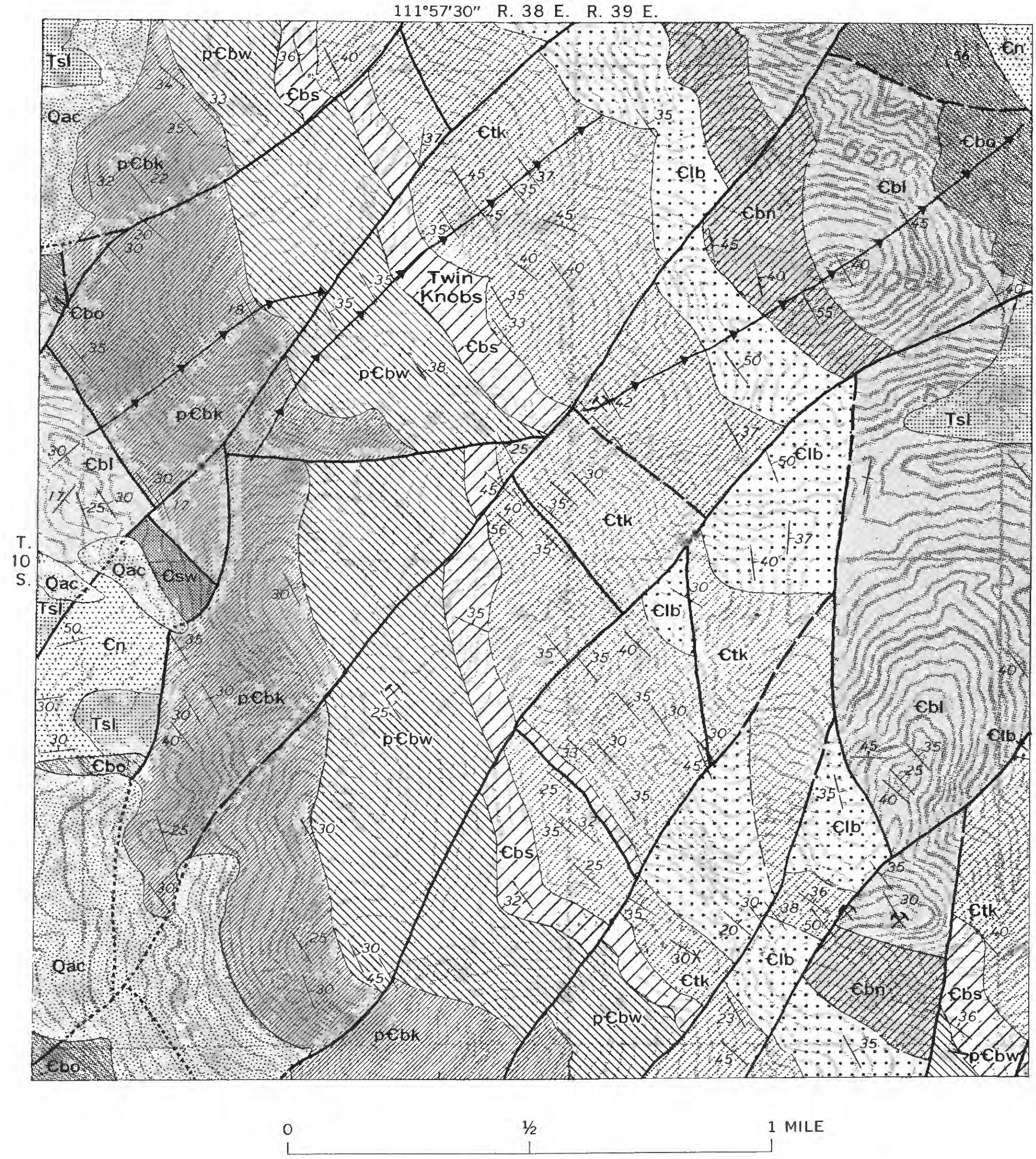


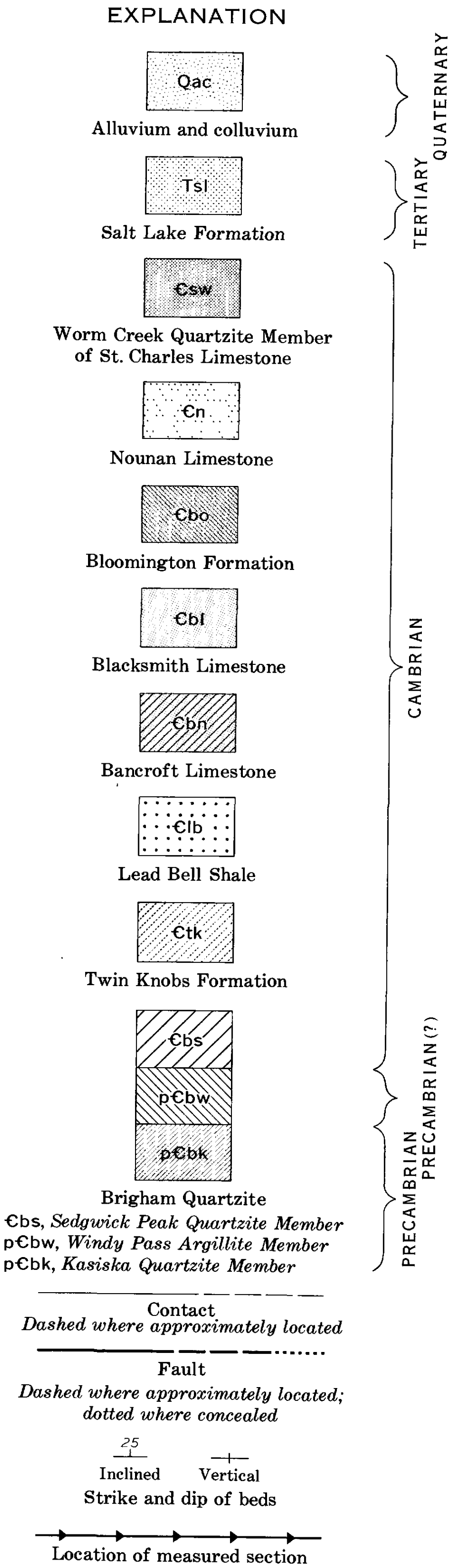
FIGURE 3.—Geologic map of secs. 12 and 13, T. 10 S., R. 38 E., and secs. 7 and 18, T. 10 S., R. 39 E., in the Bancroft quadrangle (Oriel, 1965a), showing the locations of measured and type sections of new rock-stratigraphic units.

Pass Argillite Member to the upper unit of micaceous argillite and shale in the Brigham Quartzite described by Bright (1960, p. 29–30) suggests that the belt extends southeastward to the Cleveland area (pl. 2).

The member is 762 feet thick where measured west of Twin Knobs. The thickness of the uppermost argillite unit in the Cleveland area is 575 feet (Bright, 1960), p. 29–30).

AGE

The Windy Pass Argillite Member is not known to contain diagnostic fossils. Some bedding surfaces in the Bancroft quadrangle contain equivocal features that may be sole markings or poorly preserved worm trails. Worm trails and tubes were observed in argillite exposed in the Oneida Narrows of the Bear River near Cleveland, but the stratigraphic level of these was not



determined. Although some or all of the strata may have been deposited during Cambrian time, the unit underlies the lowest rocks in which unequivocal Cambrian fossils have been found. It is here, therefore, assigned a Precambrian(?) age.

SEDGWICK PEAK QUARTZITE MEMBER

NAME

The uppermost quartzite unit of the Brigham Quartzite in the Bancroft quadrangle is here named for Sedgwick Peak, the highest point in the Portneuf Range within the quadrangle where the unit is exposed.

TYPE

The type area of the Sedgwick Peak Quartzite Member lies along the crest of the Portneuf Range from Sedgwick Peak north-northwestward for about 5 miles (Oriel, 1965a). Exposures on the southwest side of the northern of the Twin Knobs, in the SW¼NE¼ sec. 12, T. 10 S., R. 38 E. (fig. 3), are designated the type section.

COMPOSITION

The member consists of thin- to medium-bedded quartzite (pl. 1) interbedded with a few thin units of argillite and siltstone.

Almost all the quartzites, in contrast to those in the Kasiska Quartzite Member, are fine to very fine grained and have shades of tan or green on fresh surfaces and dark brown and dark green to black on weathered surfaces. A few beds contain some scattered coarser grains; and some pink, reddish-tan, brown, and pale-gray quartzite beds are present. Unlike sandstones in the overlying Twin Knobs Formation, the strata are all dominantly quartzitic, very well indurated, and subvitreous.

The thin, finer grained units consist of thinly laminated green, tan, and brown argillite and tan quartzitic siltstone.

UPPER CONTACT

The top of the Sedgwick Peak Quartzite Member, which is the top of the Brigham Quartzite in the Bancroft quadrangle, is placed at the base of the lowest limestone in the overlying Twin Knobs Formation, despite the presence of some quartzite and sandstone above this stratigraphic horizon. This agrees with Walcott's practice (1908b, p. 199) of including some sandstone in the lower part of the Langston Formation.

DISTRIBUTION AND THICKNESS

The Sedgwick Peak Quartzite Member forms a moderately continuous belt along and near the crest of the

Portneuf Range in the southwestern quarter of the Bancroft quadrangle (Oriel, 1965a). It also forms extensive dip slopes on the east side of the range near Sedgwick Peak.

The member is 300 feet thick at its type section. In the Cleveland area, an uppermost quartzite in the Brigham Quartzite, which may be the same unit, is 345 feet thick (Bright, 1960, p. 28–29).

AGE

The Sedgwick Peak Quartzite Member contains numerous "*Scolithus* tubes," whose presence has long been known, and markings on bedding surfaces which are regarded as worm trails. Far more significant, however, is the presence in the unit of trilobites first discovered by Max D. Crittenden, Jr., and Allison R. Palmer on July 24, 1963. The find is especially significant because it is the first indisputable record of Early Cambrian deposition in southeastern Idaho.

The trilobites found about 130 feet above the base of the unit were identified by Allison R. Palmer as "*Olenellus* sp." "The aspect of these specimens," according to Palmer (written commun., Dec. 4, 1963),

> although scrappy, is of forms from the younger parts of the Early Cambrian. Therefore, the Sedgwick Peak Quartzite Member may possibly be correlative with the Busby Quartzite in the Deep Creek Range of western Utah. The Busby is separated by the Cabin Shale from the "Prospect Mountain" Quartzite in much the same manner as the Sedgwick Peak is separated by Windy Pass from the Kasiska.

Additional olenellid fragments were subsequently found in a brown-weathering green quartzite bed 15–20 feet stratigraphically below the bed from which the first collection was made.

The middle of the Sedgwick Peak Quartzite Member is therefore late Early Cambrian in age. The age of the upper part of the unit is probably also Early Cambrian. We regard it as probable that the lowest part of the unit also was deposited in Early Cambrian time. The Sedgwick Peak Quartzite Member is therefore designated as Early Cambrian.

SODA SPRINGS QUADRANGLE

Although the subdivisions of the Brigham Quartzite defined above have been useful in mapping parts of the Portneuf Range in the Bancroft area, they are not applicable everywhere. Counterparts of these subdivisions, for example, have not been identified in the northern part of the Bear River Range, only 12 miles east-northeast of Brigham exposures in the Portneuf Range.

In mapping the northern end of the Bear River Range in the Soda Springs quadrangle, the Brigham was not subdivided. In the forested southeast corner of the quadrangle, southeast of Eightmile Creek, Brigham exposures are poor, and no basis for subdivision was evident when the area was mapped in 1950. In the Nelson Creek area, at the northern tip of the Bear River Range, and in the Egbert Canyon area, to the south along the west flank of the range, the Brigham was not subdivided because the stratigraphic interval present is too thin and exposed in too small an area. Lithologic contrasts among the Nelson Creek and Egbert Canyon rocks and the rocks southeast of Eightmile Creek are shown best in the units that overlie the Brigham—the Langston Formation and the conformably overlying Ute Limestone.

NELSON CREEK AREA

About 440 feet of the upper part of the Brigham is exposed in the Nelson Creek area at the north end of the Bear River Range. This stratigraphic interval is divisible along a gradational contact into two units (pl. 1).

The exposed part of the lower unit, 210 feet thick, is composed of quartzite and sandy quartzite. It is dominantly tan in its upper half and dominantly reddish brown and greenish brown in its lower. Three thin layers of tan-weathering arenaceous dolomite are interbedded with the quartzite; dolomite was not recognized in this stratigraphic interval other than along the illustrated measured section.

The upper unit, 230 feet thick, is composed of interbedded tan to olive-drab tan micaceous thin-bedded sandstone and sandy quartzite. About 150 feet below the top of the upper unit three small, closely spaced medium-gray-weathering black limestone lenses were found at the same stratigraphic position along the line of one of the measured sections. The outcrop of the northern lens measures approximately 12 inches thick by 18 inches long; the center lens, about the same size, has been mostly removed in fossil collections; the outcrop of the southern lens is about 12 inches thick by about 40 feet long. Fossils were found in only the center lens, and the lenses were the only limestone found in this stratigraphic interval. These limestone lenses may represent the extreme north end of the Naomi Peak Limestone Member of the Langston described by Maxey (1958, p. 669). This suggested northwestward change in lithology is supported by Bright's observation (1960, p. 41) that in the Cleveland area the Naomi Peak Member contains sand.

In a poorly exposed partial section measured about 6,000 feet to the northwest, neither limestone nor dolomite was found in the upper 350 feet of the exposed Brigham; however, the gradational break between sandstone and sandy quartzite above and quartzite below was recognized, but it seems to be about 60 feet stratigraphically higher than in the better exposed section to the southwest.

EGBERT CANYON AREA

The Brigham is discontinuously exposed in the Egbert Canyon area of the Soda Springs quadrangle in a narrow strip along the west flank of the Bear River Range. In a section 6½ miles south of the northern facies section, 155 feet of the upper part of the Brigham was measured (pl. 1). Below this point the rocks are poorly exposed, and about 100 feet stratigraphically below the measured interval the Brigham is cut by a fault. The top 50 feet of the measured Brigham is tan micaceous quartzitic sandstone. The remaining exposed 105 feet consists in its upper part of tan and green quartzite interbedded with micaceous quartzitic sandstone; the amount of quartzite progressively increases downward, and red and brown quartzites are dominant in the lower part.

Thus, only the upper 150–250 feet of the Brigham in the Egbert Canyon area is exposed, whereas the Sedgwick Peak Quartzite Member of the Brigham in the Portneuf Range, and its probable correlative at Cleveland, are 300 and 345 feet thick, respectively. If argillaceous rocks comparable to the Windy Pass Member are present below the observed arenaceous sequence, they are not exposed.

AREA SOUTHEAST OF EIGHTMILE CREEK

In the southeastern part of the Soda Springs quadrangle a stratigraphic interval of about 4,000 feet of Brigham, as estimated from map outcrop pattern, was mapped without subdivisions. Correlation of the Middle Cambrian formations in this area with Middle Cambrian formations in other parts of the quadrangle is not well established. The formations above the Brigham are only partly similar to those of the Egbert Canyon area on the west flank of the range, and the upper part of the Brigham as mapped is not comparable to the thin quartzite unit exposed in the Egbert Canyon area.

A partial stratigraphic section measured in 1964 a short distance south of the quadrangle boundary, near the north base of Sherman Peak in the Preston 30-minute quadrangle, showed the following units in the Brigham, in ascending order (pl. 1). About 150 feet of purplish-brown, brown, and pink pebble-and-grit conglomeratic quartzite in beds 2–4 feet thick and locally containing white quartzite pebbles 1½ inches in diameter is overlain conformably by 90 feet of arkosic quartzite that grades from tan at the base to purplish-brown at the top. Above this is 80 feet of purplish-brown gritty quartzite and sandy quartzite, whose upper limit is a fault at the measured section. Above the fault is 90 feet of poorly exposed olive-tan, micaceous sandy argillite. The top of the units here assigned to the Brigham consists of 250 feet of dominantly white thick-bedded quartzite that contains layers of quartzite-pebble conglomeratic quartzite. Some tan, brown, and red colors occur in the lower part of this unit.

Although this measured section demonstrates that there are distinctive lithologic units within the Brigham in this area, how they coorelate with the units in the Portneuf Range is not known. Certainly the top white quartzite is not similar in grain size, color, or thickness to the Sedgwick Peak Quartzite Member.

CONTACTS

The base of the Brigham Quartzite is not exposed within the Soda Springs quadrangle.

The top of the formation is recognizable on the basis of lithologic differences, although the rock types differ from one part of the quadrangle to another.

In the Egbert Canyon area, the top of the Brigham is placed at the contact between partly quartzitic tan and yellow-brown sandstone and conformably overlying black and olive-green fossiliferous shale. The shale unit differs markedly in appearance and composition from argillite layers within the Brigham and much more closely resembles shale units that have been assigned to the Langston and Ute Limestones in other parts of the region.

In the Nelson Creek area, reddish-brown and greenish-brown vitreous quartzite grades upward by interbedding into tan subvitreous quartzite and sandy quartzite, which in turn grades upward into tan and olive-drab micaceous thin-bedded sandy quartzite and sandstone. Within this overwhelmingly quartzose detrital unit, three small lenses of limestone were found 150 feet below its top, and three thin sandy dolomite beds were found 250–400 feet below its top. These carbonate rocks were found on only one spur ridge, the one on which the stratigraphic section (pl. 1) was measured; they were looked for but not found elsewhere. Overlying this detrital unit is a thick carbonate unit. The top of the Brigham was placed at the top of the detrital unit.

The upper detrital units of the Brigham in the Nelson Creek and Egbert Canyon areas in the Bear River Range resemble some of the detrital units assigned to the Twin Knobs Formation, above the Brigham in the Portneuf Range (p. 20). In the Portneuf Range the detrital units are interbedded with thick carbonate units that apparently pinch out eastward toward the Bear River Range. One result of these possible relations is that the top of the Brigham as mapped in the Bear River Range lies at a higher stratigraphic level (pl. 7) than in the Portneuf Range. Faunal data presented (p. 10) support this interpretation.

In the area southeast of Eightmile Creek the top of the Brigham is placed at the top of the white quartzite unit. Conformably overlying the white quartzite is thin-bedded brown, reddish-gray, and green quartzite and sandy quartzite that grades upward into green and greenish-tan micaceous sandstone and phyllitic siltstone. The contact is placed between the quartzite below and the dominantly argillaceous sandstone above.

AGE

Middle Cambrian fossils have been found 150 feet below the top of the Brigham in the Nelson Creek area in the north end of the Bear River Range. The fossils, found in the middle limestone lens, include the following trilobites identified by A. R. Palmer (written commun., Nov. 23, 1955);

Athabaskia sp.
Chancia sp.
Dolichometopsis? sp.
Pagetia cf. P. *clytia*.

The assemblage is probably equivalent to that composing the *Ptarmigania* fauna and belongs in the *Albertella* zone of early Middle Cambrian age. The upper 150 feet of the Brigham in the Nelson Creek area is thus of early Middle Cambrian age or younger. This is younger than the late Early Cambrian age assigned to the middle part of the Sedgwick Peak Quartzite Member.

No fossils have been found in the Brigham of the Egbert Canyon area. *Glossopleura* zone fossils have been found, however, at several places in the shale unit directly above the Brigham. Because the *Glossopleura* zone overlies the *Albertella* zone, the Egbert Canyon detrital unit that underlies the shale can be of *Albertella* age, as is the upper part of the Nelson Creek detrital unit.

Fossils have not been found in the Brigham southeast of Eightmile Creek. Correlation and age are based solely on lithologic similarities and sequences, particularly the basal part of the Ute Limestone described below.

SOME NEARBY SECTIONS

The rocks assigned to the Brigham Quartzite in the Bancroft and Soda Springs quadrangles are more meaningful when considered in regional context. Descriptions of Brigham sections from nearby areas in southeastern Idaho (pl. 2) suggest the following conclusions:

1. Subdivisions of the Brigham recognized in the Bancroft area are probably present in nearby parts of the Portneuf Range.
2. Marked contrasts in the sequence of detrital units in other nearby areas support the inference of rapid local facies changes suggested by the Soda Springs sections.
3. The contacts used by geologists for the Brigham and the ages cited for the formation have not been consistent.

These considerations lead, in turn, to some general problems of the Brigham and, indeed, to the more fundamental question of what is meant by use of the term. This is discussed in a section that follows.

PORTNEUF RANGE

The most complete section of the Brigham Quartzite exposed in a nearby part of southeastern Idaho is that in the Portneuf Range along the Oneida Narrows of the Bear River near Cleveland. More than 10,800 feet of beds was measured and described by Bright (1960, p. 28–39), who cautioned readers about a probable fault about 5,000 feet above the base of the section (1960, p. 17). Subsequent mapping (Oriel and Platt, 1968) confirmed the probable presence of a steep fault along which a part of the Brigham is probably omitted. No basis is evident for computing the amount of stratigraphic throw.

The Oneida Narrows section (No. 11, pl. 3), measured by Bright, may be summarized as follows (top to base):

Feet	
345	Quartzite, tan, gray, and green.
575	Micaceous argillite, and tan shale.
4,727	Quartzite, mainly tan, pink, and white in upper part, and reddish purple and reddish brown in middle and lower parts.
Fault (?)	
1,855	Quartzite, white, tan, brick-red, and purple.
346	Argillite, reddish-purple and reddish-maroon.
[2] 1,467	Quartzite, tan, purple, reddish-purple, and pink.
37	Quartzite, tan, and tan to gray argillite.
358	Quartzite, white to light-gray.
905	Argillite, tan to green and gray, interbedded with tan to light-gray quartzite.
200+	Argillite, laminated, black to gray.
Base concealed.	
10,815+	Total measured.

Both the lithologies and the thicknesses reported for the upper two (345- and 575-ft-thick) units suggest that they are counterparts of the Sedgwick Peak Quartzite and the Windy Pass Argillite Members of the Brigham Quartzite in the Bancroft quadrangle. At least the upper part of the third unit is comparable to strata assigned to the Kasiska Quartzite Member in the Bancroft quad-

[2] A discrepancy of 56 ft is evident in Bright's (1960, p. 36–37) section between the thicknesses shown for each of his units and his cumulative thicknesses. The discrepancy is at his entry shown for cumulative thickness 1,501.0 ft (from base). The smaller thickness has been used here.

rangle. Argillite units lower in the sequence resemble, in both composition and approximate stratigraphic positions, those recognized in the Pocatello and Huntsville areas (pl. 3).

Farther north in the Portneuf Range, two partial sections of the Brigham Quartzite have been measured in two University of Idaho Master's thesis studies of adjoining areas a few miles north-northeast of McCammon, Idaho. The first section, probably measured near Robbers Roost Creek in secs. 16 and 17, T. 8 S., R. 37 E., was regarded by Holmes (1958, p. 21–23) as complete, for he assigned adjoining carbonate beds erroneously to the Precambrian Blackrock Limestone of Ludlum (1942). The Robbers Roost section may be summarized as follows:

Feet	
346	Sandstone, light-gray and yellowish-gray, thin-bedded and argillaceous.
433	"Shale" [argillite], mainly greenish gray, and thin interbeds of standstone.
2, 500	Quartzite and quartzitic conglomerate, white, red, green, and brown.
3, 279	Total measured.

The units are clearly comparable to the three members recognized in the Bancroft area.

About 2 miles south of the Robbers Roost Creek, the other partial section was measured and described along Two Mile Creek, in the southern part of sec. 28, T. 8 S., R. 37 E., by Storey (1959, fig. 2), who correctly interpreted the base of the exposed Brigham as a fault, against which the Cambrian Nounan Limestone has been dropped. The Two Mile Creek section (pl. 2) may be summarized as follows:

Feet	
121	Sandstone, olive-gray, thin-bedded.
193	Claystone, yellowish-brown and greenish-gray, and spare thin-bedded grayish-red sandstone.
466	"Claysone" [argillite], mainly olive-gray to dark-gray and brown.
1, 198	Quartzite and conglomeratic quartzite, light- to medium-gray and partly red.
1, 978	Total measured.

Fault at base of section.

We have not examined the second (193-ft-thick) unit to determine whether it reflects a change in grain size from rocks at about the same stratigraphic level in the Robbers Roost Creek section or a difference in parameters used by the observers. Whatever the explanation, the Two Mile Creek section is also somewhat comparable to the units recognized in the Bancroft area.

Thus, the members recognized in the upper part of the Brigham Quartzite are likely to be useful in detailed studies within the Portneuf Range.

BANNOCK RANGE

The Bannock Range is probably the least geologically understood range in the region, although it is important because it exposes the oldest known rocks. Studies have been confined to the northern part of it, in the Pocatello area, where the only complete section of rocks assigned to the Brigham Quartzite in southeastern Idaho is known.

Estimates of the thickness of Brigham strata south of Pocatello have been disputed. Although more than 10,000 feet was assigned to the Brigham by Anderson (1928, p. 5), the unit was regarded by Ludlum (1943, p. 979) as only 3,200 feet thick, with an apparent thickness of 8,000 feet due to isoclinal folding. Recent mapping of the Pocatello quadrangle by D. E. Trimble indicates no isoclinal folds are present.

A generalized summary of the detrital rocks beneath the lowest Cambrian limestones in the Pocatello area (Trimble and Schaeffer, 1965; D. E. Trimble, written commun., Jan. 24, 1967) is as follows (pl. 3):

Feet	
1, 500	Argillite, olive, tan, and gray-green; minor number of siltstone and thin sandstone layers and 115 ft of tan, gray, and brown quartzite about 350 ft above the base of unit.
3, 600	Quartzite, tan to white, vitreous.
3, 600	Quartzite, purple to white, coarse-grained, crossbedded, partly conglomeratic, and thin units of maroon argillite.
900	Siltite, argillite, and very fine grained quartzite, green to green-gray.
1, 300	Quartzite, pink to purple.
50	Dolomite.
1, 650	Quartzite, white to tan and pink.
1, 800	Siltite and argillite, greenish- to dark-gray, thin and wavy-bedded, and thin-bedded brown quartzite.
14, 400	Total measured between the Blackrock Limestone and overlying Middle Cambrian limestone.

Top of underlying Blackrock Limestone of Ludlum (1942), which overlies his Pocatello Formation.

The units recognized in the Portneuf Range are not evident in this section, just as they are not evident in sequences examined in the Bear River Range. However, the Pocatello sequence does suggest close analogies with units recognized by Crittenden (1968) near Huntsville, Utah (Crittenden and others, 1971).

BEAR RIVER RANGE

Few sections of the Brigham Quartzite have been measured in the Bear River Range. South of the Soda Springs quadrangle, the range consists of a broad, gentle, and broken syncline (Oriel and Platt, 1968). Brigham Quartzite is exposed on both the east and the west flanks of the range, but range-front faults make unbroken sections difficult to find.

Almost 3,000 feet of strata was measured by Coulter (1956, p. 7) on the west side of the range along the north side of Maple Creek, largely in the southern part of sec. 32, T. 15 S., R. 41 E. A summary of the section is as follows (pls. 2, 3):

Feet	
70	Shale, dusky-yellow-green [which we would exclude from the Brigham and assign to an overlying unit].
326	Quartzite, thick-bedded, pale-yellowish-orange to pale-yellowish-brown.
92	Thinly interbedded grayish-orange sandstone and yellow-green "shale" [argillite].
2,434	Quartzite, mainly pale-orange but also light-gray, olive, and red, partly conglomeratic.
2,922	Total measured.

Although the upper 326 feet of quartzite may be comparable to the Sedgwick Peak Member in the Portneuf Range, a counterpart for the Windy Pass Argillite Member is incompletely represented.

A few miles south, however, along Flat Creek in the southern part of sec. 19, T. 16 S., R. 41 E., about 4,800 feet of quartzite is present (Williams, 1948, p. 1132). The quartzite is mainly gray and light brown, but also pink and grayish brown. "In the upper few hundred feet *Scolithus* is common in greenish-brown beds. At the top of the formation, at all exposures, buffy-brown micaceous shale partings separate thin beds of quartzite" (Williams, 1948, p. 1132). Thus, the upper resistant quartzite at Maple Creek becomes increasingly argillaceous southward.

The upper 1,000–1,600 feet of the Brigham exposed on the east side of the range has been described by Mansfield (1927, p. 52) as vitreous quartzite or quartzitic sandstone, generally purplish or pinkish, but also white, gray, deep red, or nearly black, and partly conglomeratic; near the top, locally, lie beds of micaceous shale. Our observations confirm Mansfield's description. At some localities, interbedded argillite and quartzite directly underlie Middle Cambrian carbonate units; at others they underlie thick units of resistant vitreous pink quartzite. Although some units of thick-bedded to massive vitreous white and light-gray quartzite form continuous, traceable ledges locally, our attempts to distinguish mappable stratigraphic units on the basis of color have not been successful. Moreover, purple quartzite, which occurs in distinctive units well below the top of the Brigham in some areas, is found close to the top in parts of the Bear River Range.

From the foregoing information and from data in the Soda Springs quadrangle, we conclude that differences in local sequences of detrital units indicate rapid local facies changes in the upper part of the Brigham Quartzite in this area. Rock-stratigraphic subdivision of the basal quartzite sequence is likely to prove very difficult in the northern Bear River Range.

CONTACTS

The base of the Brigham, exposed in very few places in southeastern Idaho, has been placed (Anderson, 1928, p. 5; Ludlum, 1943, p. 978; M. D. Crittenden, Jr., written commun., 1969) at the top of the uppermost limestone in the underlying Precambrian Blackrock Limestone. More recently, argillites believed to overlie the Blackrock Limestone have been excluded from the Brigham (Crittenden and others, 1971, fig. 7, p. 591).

The top of the formation, observable at many more localities, has not been recognized consistently because of heterogeneity of overlying strata. These strata, which have commonly been assigned to the Langston Formation, as described below, consist of sandstone, claystone, quartzite, dolomite, and several kinds of limestone. Where indisputable Brigham Quartzite is directly overlain by a thick carbonate sequence, the contact between them is easily recognized and universally agreed upon. Where a different type of detrital unit lies between typical Brigham Quartzite and the lowest overlying carbonate bed, there is disagreement.

Dark-bluish-black and green claystone that rests directly on quartzite, for example, has been assigned to a unit above the Brigham by Walcott (in Resser, 1939b, p. 14), and to the Brigham by Coulter (1956, p. 7). Other authors have simply not accepted these relations and have inferred a concealed limestone between the claystone and the quartzite (Maxey, 1958, p. 655).

The presence of argillaceous strata between thick quartzites below and Middle Cambrian limestone or dolomite above makes placement of the top of the Brigham somewhat equivocal locally. Nevertheless, agreement is possible on the basis of the composition of the argillaceous strata. If the strata resemble argillites within the quartzite sequence, we assign them to the Brigham; if they resemble the claystones interbedded with carbonate rocks of the Langston and Ute Limestones, we assign them to an overlying unit.

Claystone above the Brigham does not resemble argillite within the Brigham; it differs in composition, color, degree of metamorphism, and, therefore, in general appearance. The claystone is far better sorted than the sandy, muddy argillite below, which contains both scattered sand grains and abundant laminae and thin beds of quartzitic sandstone. Claystones above also display cleaner colors; they are very dark to light gray and moderately bright green whereas the argillites below are somewhat rusty gray and dark greenish gray to olive gray with moderately abundant limonitic and manganiferous stains. The claystone above is fissile or shaly and contains muscovite flakes as much as 1 mm across on some fracture surfaces; the argillite below displays a more pervasive schistosity, generally parallel to bedding, and contains chlorite and locally biotite flakes as well as larger muscovite flakes. Moreover, trilobite fragments are moderately abundant in the claystone whereas they have not been found in the argillite.

Thus, on the basis of lithology, we exclude from the Brigham the topmost trilobite-bearing shale that Coulter (1956, p. 7) assigned to it, whereas we accept Williams' (1948, p. 1132) assignment of micaceous shale and thinly interbedded quartzite to the Brigham. Lithologic considerations also lead to one minor disagreement between the authors of this paper; Oriel would prefer to place the top of the Brigham above the mainly quartzitic sandstones assigned to the lower part of the Langston (pl. 1) in the area southeast of Eightmile Creek in the Soda Springs quadrangle (Armstrong, 1969).

The top contact of the Brigham has been discussed at some length not because it may shift boundaries on geologic maps a fraction of a millimeter, but because it bears on considerations of age.

AGE

Arguments regarding the age of the Brigham Quartzite have long been notably tortuous, due to paucity of fossils. The early assertion that the unit contains Middle Cambrian fossils (Walcott, 1908a, p. 9) was subsequently supplanted by inferences that the Brigham can be no older than Middle Cambrian (Resser, 1939b, p. 6; Deiss, 1940, p. 782–785; Lochman-Balk, 1955, p. 33). The great thickness of the formation and an assumed Middle Cambrian age for the uppermost part have led some (Walcott, 1912, p. 153, footnote a; Wheeler, 1943, p. 1810) to assign the lower part to the Early Cambrian; others (Williams, 1948, p. 1131; Maxey, 1958, p. 668; Coulter, 1956, fig. 2) have assigned all the formation to the Early Cambrian, without disregarding the possibility that Precambrian rocks may also be present (Maxey, 1958, p. 667; Bright, 1960, pls. 3, 7). And it has been mentioned (Lochman-Balk, 1956, p. 588) that an unrecognized regional angular unconformity may be present between Middle Cambrian rocks and Precambrian rocks within the Brigham. More recently, the basal detrital sequence has been assigned a Cambrian and Precambrian age (Trimble and Schaeffer, 1965; Oriel, 1965b; Crittenden, 1968).

Previous reports of diagnostic fossils in the quartzites of the Brigham are equivocal. The fossils collected by C. D. Walcott and listed by Resser (1939b, p. 15, colln. 59c) are virtually useless, for they are not precisely located either areally or stratigraphically; from the lithologies mentioned, we doubt that they came from the Brigham. The trilobite reported by Coulter (1956, p. 7) came from claystone that would be better referred to a higher rock-stratigraphic unit.

Except for the collections from the Bancroft and Soda Springs quadrangles, described earlier in this report, no distinctive fossils are known in southeastern Idaho. Indeterminate trilobite fragments have been found in the upper few feet of the Brigham by W. H. Fritz at Pole Canyon in the Bear River Range (SW¼ sec. 23, T. 12 S., R. 42 E.), and these "suggest a Middle Cambrian age" (W. H. Fritz, written commun., Apr. 17, 1969). Worm trails, trilobite tracks, and *Scolithus* tubes have been noted at many localities (Walcott, 1908a, p. 9; Mansfield, 1927, p. 53; Williams, 1948, p. 1132), but these fossils are less than compelling evidence for age assignments (Rodgers, 1956a, p. 355).

The sum of the evidence available for southeastern Idaho, therefore, supports the long-held concept that the top of the basal detrital sequence in the Cordilleran region transgresses time and becomes younger eastward (McKee, 1945, p. 135, fig. 1; Thomas, 1949, p. 13, fig. 5; Keefer and Van Lieu, 1966, p. B11). The presence of *Olenellus* in the topmost member of the Brigham Quartzite in the Bancroft area supports an age assignment of late Early Cambrian and Precambrian for the formation in the Portneuf Range and westward. The presence of *Albertella*-zone fossils in a limestone lens near the top of the Brigham in the Soda Springs area and the probable Middle Cambrian trilobite fragments found at Pole Canyon by Dr. Fritz support an age assignment of early Middle Cambrian and older for the formation in the Bear River Range. Farther east, the basal transgressive sandstone, the Flathead Sandstone, becomes progressively younger eastward (Lochman-Balk, 1956, p. 610, 616). Moreover, both the physical stratigraphy and the faunal content of strata above the Brigham Quartzite, as shown on plate 7 and discussed later, support the concept of eastward transgression.

MEANING AND PROBLEMS OF THE BRIGHAM

The term "Brigham" has been used in an inclusive sense, in the foregoing paragraphs, for the complete sequence of quartzites and interbedded argillites at the base of the Paleozoic section in southeastern Idaho, despite suggestions that the term be abandoned or used in a restricted sense. Some of our colleagues working in nearby areas have disagreed with our usage, thereby reflecting the continuing pertinence of questions raised in previous work. The meaning of the term "Brigham," therefore, merits discussion because not only nomenclature is involved but also the state of our knowledge of regional relations. Pertinent data and questions can, perhaps, best be considered by first reviewing the definition and previous usages of the term.

PREVIOUS USAGE

DEFINITION

The Brigham Quartzite was proposed as a formation by Walcott (1908a, p. 8–9) for the "massive quartzite sandstone" exposed along the west front of the Wasatch Range northeast of Brigham City, Utah (figs. 1, 2). Its upper contact apparently was placed at the base of the lowest limestone of the overlying Langston Formation; its lower contact was not described or discussed by Walcott.

An apparent motive for defining the unit was to distinguish it temporally from the earlier described (Hague, 1883, p. 253–254) Prospect Mountain Quartzite. "The Brigham formation," according to Walcott (1908, p. 9), "should not be confused with the much older Prospect Mountain 'quartzite' formation of central Nevada, which is of Lower Cambrian age. . . . Characteristic Middle Cambrian fossils were found in the upper portion of . . . [the Brigham] . . . west of Liberty, Bear Lake County, Idaho." The latter statement was never supported with data by Walcott; indeed, subsequent papers by him (1908b, p. 199; 1912, p. 153) mention only annelid trails and trilobite traces as the preserved organic remains. The dubious value of a later description (Resser, 1939b, p. 15) of the Walcott collection of "Brigham" fossils has been mentioned in a previous paragraph. Walcott (1912, p. 153, footnote a) apparently changed his mind about the age of the Brigham after the initial description and said, "The line of separation between the Middle and Lower Cambrian occurs somewhere in the Brigham quartzite, and this thickness (5,420 ft) probably includes several hundred feet of Lower Cambrian beds." On the basis of these assertions, the age accepted for many years by the U.S. Geological Survey for the Brigham was Middle and Early(?) Cambrian.

Although the strata in the type area have previously been described (Eardley and Hatch, 1940) and mapped (Williams, 1948, pl. 1), a modern detailed analysis of the rocks in terms of units being recognized elsewhere probably would be helpful. The section along Bakers Canyon, regarded as Walcott's probable type locality northeast of Brigham City, seems to be unfaulted but is incomplete. Our examination of the section described by Eardley and Hatch (1940, p. 809–810) and shown on plate 3 of this report supports their description and suggests that if units recognized in the Bancroft quadrangle are present in this section, they are far less distinct. The unit (46) of Eardley and Hatch that may be a counterpart of the Windy Pass Argillite Member at Bakers Canyon contains far more quartzite than in the Portneuf Range.

Exposures in Brigham Canyon along Box Elder Creek, directly east of Brigham City, are faulted (Eardley and Hatch, 1940, p. 812; Williams, 1948, p. 1132). However, Crittenden believes (written commun., Jan. 25, 1967) that rocks assigned to the Brigham in that area (Eardley and Hatch, 1940, fig. 3; Williams, 1948, pl. 1) include strata that belong both to topmost units and to units very low in the quartzite sequence at Huntsville (Crittenden, 1968); the various parts of the quartzite sequence are in fault contact with one another, with significant omission of beds (Crittenden and others, 1971, p. 591).

IDAHO USAGE

Since definition of the formation, the term Brigham has been used in a more inclusive sense in Idaho and northernmost Utah than in other parts of Utah. The term has been applied to virtually all the quartzites and interbedded argillites, no matter what their stratigraphic position, in the Bear River Range (Mansfield, 1927; Williams, 1948; Coulter, 1956), in the Portneuf Range (Bright, 1960), and in the Bannock Range (Anderson, 1928; Ludlum, 1943). The various rock units assigned to the Brigham, as mentioned in foregoing paragraphs that discuss sections described in southeastern Idaho, aggregate more than 10,000 feet in thickness at some places.

UTAH USAGE

The term Brigham has commonly been used in a restricted sense in north-central Utah, although the bases for restriction have differed from one place to another and have not been mutually consistent.

The earliest restriction of the term Brigham known to us was based on both an inferred age and a local unconformity. The unconformity was observed in Big Cottonwood Canyon (south of Salt Lake City) by Blackwelder (1910, p. 522–523), who concluded, "It seems clear, therefore, that there is an unconformity not far below the top of the great quartzite-slate series, and it will probably be found to have a much wider distribution than now known." The reported occurrence of Early Cambrian fossils in shales above the quartzite near Salt Lake City led Blackwelder (1910, p. 523) to add, "The Brigham quartzite may therefore be assigned also to the early Cambrian and the quartzites and slates beneath the unconformity to the Algonkian." Blackwelder later acknowledged (1935, p. 154) that the unconformity was not evident everywhere in the northern Wasatch, for ". . . no line of demarcation [of the Precambrian quartzites and slates] from the overlying fossiliferous Cambrian strata has yet been detected, although more careful work may be expected to reveal it."

The absence of a recognizable unconformity in the northern Wasatch Range led Eardley and Hatch (1940, p. 808, fig. 3) to adopt a lithologic basis for distinguishing quartzite assigned to the Brigham Quartzite and to the Cambrian System from that assigned to the Proterozoic(?). The top of the highest thick argillite unit was used as the contact. A thick argillite unit is not exposed at Bakers Canyon, and therefore all the quartzite there was assigned to the Brigham. Tracing of beds southward from Bakers Canyon to Brigham and Threemile Canyons, where thick argillite is present, led Eardley and Hatch (1940, p. 810–813) to conclude that the uppermost quartzite assigned to the Brigham is about 2,000 feet thick and rests on about 600 feet of argillite assigned to the Precambrian. However, even this relation is now in doubt because of the fault recognized by Eardley and Hatch at Brigham Canyon. The argillite present at Brigham Canyon may represent a unit far lower in the sequence at unfaulted localities (Crittenden and others, 1971, p. 591) than previously thought.

Still another basis for restricting use of the term Brigham has been color. Where uppermost quartzites are dominantly light gray and tan and overlie quartzites that are dominantly purple, the name Brigham is applied to the gray unit, and Mutual, to the purple (Trimble and Schaeffer, 1965; Stokes, 1963). This practice is based on relations observed to the south, near Salt Lake City.

In the mountains east and northeast of Salt Lake City, strata with Cambrian fossils are underlain by some 800 feet of light-colored quartzite to which the name Tintic Quartzite (Tower and others, 1900), has been applied (Crittenden and others, 1952, p. 7; Granger and Sharp, 1952). In Big Cottonwood Canyon this quartzite is underlain with slight angular unconformity by other quartzites that are predominantly red-purple and are designated the Mutual Formation (Crittenden and others, 1952). Designation of these strata as Mutual, which is regarded as Precambrian, is based on recognition of the unconformity and the distinctive red-purple quartzite. The Tintic, which is assigned to the Cambrian, at some places rests directly on the Mineral Fork Tillite,[3] which underlies the Mutual (Crittenden and others, 1952). However, no unconformity was detected in the East Tintic Mountains, Utah, within the 3,000 feet of strata assigned to the Tintic Quartzite (Morris and Lovering, 1961, p. 14–17). These strata are dominantly light-colored quartzite, although the lower 500 feet includes light-red to dark-red-purple quartzite. Strata exposed beneath a disconformity in the area of the type Tintic are assigned to the Big Cottonwood Formation (Morris and Lovering, 1961, p. 13), which underlies the Mineral Fork Tillite in the Salt Lake City area (Crittenden and others, 1952, p. 3–4). A question raised by these relations is whether the basal part of the type Tintic is not only similar to, but also correlative with, rocks assigned to the Mutual in the Salt Lake City area.

Structure has been another basis for restricting use of the name Brigham. The Willard thrust fault (Blackwelder, 1910, p. 534–537) separates areas to the north, where the name Brigham has been used, from those to the south, where Tintic is used (Stokes, 1963). Thicker quartzites assigned to the Brigham are believed (Eardley and Hatch, 1940, p. 809; Crittenden, 1961, p. D129) to be allochthonous—that is, to have been deposited in a deeper part of a geosyncline and to have been later moved some 40 miles or more eastward (Crittenden, 1961) onto a thinner platform facies, which is assigned to the Tintic. Both are assigned to the Cambrian System to distinguish them from underlying units assigned to the Precambrian (Stokes, 1963).

Still another lithologic basis has been suggested recently for distinguishing the uppermost quartzite unit from underlying Precambrian units in the Huntsville area, Utah. The presence of basalt layers, interpreted as flows, in a thin unit of basalt and argillite (pl. 3) was used by Crittenden (1968) to distinguish a higher unit of light-colored quartzite, 3,300–4,000 feet thick, which he noted is commonly assigned to the Brigham Quartzite even though the unit may include some rocks of Precambrian as well as those of Cambrian age. Below the basalt and argillite unit is a thick sequence of purple quartzite and argillite correlated with the Mutual Formation, and other, underlying distinctive rock-stratigraphic units, which closely resemble those recognized in the Pocatello area (Crittenden, 1968).

Thus, although the name Brigham has been used in a restricted sense in Utah, the criteria used as bases for restriction have been varied.

MODIFICATIONS PROPOSED FOR THE BRIGHAM

Contrasts in previous usages of the term Brigham and in the various rocks that have been assigned to the unit have led to some past suggestions that the name be

[3] The glacial origin of the Mineral Fork Tillite has recently been questioned again by Condie (1967). Whatever its origin, it is unfortunate that a genetic term is included in the designation for an otherwise acceptable rock-stratigraphic unit.

modified, redefined, or, more drastically, abandoned. The suggestions merit some attention here.

FORMATION VERSUS QUARTZITE

The diversity in composition of rocks assigned to the Brigham has led to some suggestions (Coulter, 1956, p. 6; Bright, 1960, p. 5; Holmes, 1958, p. 21) that the second part of the binomial designation be changed from "Quartzite," now in common use, to "Formation," as suggested originally by Walcott (1908a, p. 8). We are unsympathetic, for hardly any formation designated by a descriptive lithologic term is composed entirely of that lithology. Yet lithologic terms are useful for contrasting a unit with others above and below. Despite the presence of argillite, sequences of rock normally assigned to the Brigham consist dominantly of quartzite which is more extensively and prominently exposed than the less resistant, thinner units of argillite. "Quartzite," therefore, seems not only appropriate but preferable to us.

ABANDONMENT VERSUS RETENTION

A more drastic proposal is that the name Brigham be abandoned. The almost ubiquitous occurrence of thick quartzite units beneath Middle (and locally Lower) Cambrian fossil-bearing limestones and claystones in the Cordilleran region has led to observations that the Prospect Mountain, Tintic, and Brigham Quartzites are at least partially equivalent and largely lithogenetically equal (Eardley and Hatch, 1940, p. 828, fig. 5; Wheeler, 1943, p. 1810). This has led to the conclusion that the names are synonymous, and to the suggestion that two of the names be abandoned in favor of Prospect Mountain (Wheeler, 1943, p. 1810–1811; Maxey, 1958, p. 667), which has priority.

Abandonment of Brigham in favor of Prospect Mountain seems to us to be unwarranted because: (a) The precise relation of the Brigham in southeastern Idaho to the quartzite sequence in north-central Utah is not known, and the relation of these sequences to still another sequence a great distance away in central Nevada is a major problem yet to be solved; (b) the Prospect Mountain Quartzite is poorly exposed in its type area (Nolan and others, 1956, p. 6) and offers no advantages over the type Brigham; (c) descriptions of the Prospect Mountain Quartzite (Nolan and others, 1956, p. 6–7) are not identical with those of the Brigham; and (d) the term Prospect Mountain, like Brigham, has been used in divergent ways, both in an inclusive sense (Nolan and others, 1956; Drewes, 1958) and in a restricted sense based to some extent on inferred age (Misch and Hazzard, 1962, p. 303; Woodward, 1967, p. 235), and its use requires constant qualification. Extending the use of the name Prospect Mountain into southeastern Idaho and northern Utah, therefore, is undesirable and is not recommended for the reasons cited.

Divergent usages of the term Brigham may still make abandonment attractive to some, even if use of Prospect Mountain is undesirable in southeastern Idaho. We disagree. Retention of old names when possible seems far preferable to us than the proliferation of new ones; problems presented by the old ones can be resolved by clarifications and redefinitions. The name Brigham is deeply entrenched in the geologic literature and is meaningful to geologists working in the west: it denotes not only a dominant rock type, but also a particular part of the stratigraphic sequence and a particular part of the Cordilleran region.

RESTRICTED VERSUS INCLUSIVE

Continuing differences of opinion as to the precise meaning of the term Brigham reflect divergent past usage. The term has been used, as discussed in this report, in an inclusive sense in Idaho and in a restricted sense in Utah. These differences require resolution.

Former attempts to use the name Brigham in a restricted sense have not been entirely successful, for the very good reason that objective lithologic criteria are not evident to define the base of such a restricted unit regionally. Criteria that have been suggested for definition of the base have included the following:

1. *Base of the Middle Cambrian*, as suggested by the original definition, or whatever else was Walcott's (1908a, p. 8) intent. Attempts to decipher Walcott's intent from his brief and less than specific descriptions are likely to be futile exercises in the psychology of geologists, for his intent may be irrelevant in terms of a modern stratigraphic code.
2. *Base of the Cambrian System*, as suggested by Blackwelder (1910, p. 523). The use of age for defining the base of a rock-stratigraphic unit violates the Stratigraphic Code (Am. Comm. Strat. Nomenclature, 1961, art. 4d), of course, even if one could recognize the boundary between unfossiliferous Cambrian and uppermost Precambrian strata.
3. *An unconformity*, as suggested by Blackwelder (1910, p. 522). An unconformity may be used where it is present to define a rock-stratigraphic unit, but it cannot be used where none is evident. Attempts to project the horizon of an unconformity at one locality into a seemingly continuous section at another involve correlation in unfossiliferous strata and clearly have age connotations. Moreover, the early search for unconformities was based on the dogma that geologic systemic boundaries are marked by world-

wide contemporaneous disastrophic episodes recorded in correlative unconformities.

4. *Top of the first thick argillite*, as suggested by Eardley and Hatch (1940, p. 808). Argillaceous units are present at different stratigraphic levels at different localities, reflecting moderately rapid facies changes within the dominantly quartzite sequence. Indeed, in some localities argillite is present at the very top of the sequence, whereas none is present in the upper part of the Huntsville sequence (Crittenden, 1968), and an argillite is described as lying 2,000 feet below the top of the Brigham at nearby Brigham Canyon (Eardley and Hatch, 1940, fig. 3). Although the presence of argillites may prove invaluable in defining local units, it likely is not useful regionally.
5. *Top of purple quartzite unit*, as suggested by Trimble[4] and Schaeffer (1965). Although distinct, mappable units of purple quartzite are present at some localities, at many other localities purple beds are interbedded with light-gray beds almost throughout the sequence. In some places the purples distinctly cut across bedding, suggesting that the color is secondary. Moreover, the top of the purples apparently climbs section, for it is present almost at the top of the sequence in the Montpelier area (Mansfield, 1927, p. 53).
6. *Top of basalt layers*, as suggested by Crittenden (1968). Basalt has not been recognized in the sequence except very locally.
7. *Structure*, as suggested by Eardley and Hatch (1940, p. 809), Crittenden (1961, p. D129), and Stokes (1963). Restricting the name Brigham to the allochthonous equivalent of the Tintic Quartzite, although attractive in some ways, has many pitfalls. Although the name Tintic is applied commonly to thin autochthonous Cambrian quartzite, the type locality of the Tintic is admittedly allochthonous. No practical means is evident for recognizing the horizon that is equivalent to the base of the Tintic in the thicker, more continuous sections farther north; furthermore, an "equivalent" horizon has age connotations. Moreover, the "autochthonous" versus "allochthonous" criterion requires a complete knowledge of structural relations—an ultimate objective of many studies—before rock-stratigraphic names can be applied in preliminary stages of a study. Finally, the criterion violates the Stratigraphic Code (Am. Comm. Strat. Nomenclature, 1961, art. 4c) in making inferred geologic history a part of the definition of the unit.

[4] Also stressed by D. E. Trimble (written commun., 1969) is the association with the purple color of coarse grain size (and abundant conglomerate) and abundant crossbedding.

Despite the inapplicability of many of these criteria to definition of a restricted unit on a regional basis, two distinct categories of rock-stratigraphic units, local units and broad units, are clearly needed for the quartzite sequence beneath the Cambrian limestones in southeastern Idaho and northern Utah. Sufficiently detailed studies have been in progress during the past few years to delimit distinctive local rock-stratigraphic units (Trimble and Schaeffer, 1965; Crittenden, 1968). These relatively thin (some are several thousand feet thick) units deserve nomenclatural emphasis, for they are potentially significant regionally. On the other hand, stratigraphic details in parts of the region and the relations of relatively small units in one place to those in another remain to be established. We have been unable to subdivide the quartzite sequence, except locally in the Portneuf Range; our inability may reflect absence of distinctive rock-stratigraphic units, poor exposures, complex structure, scale of mapping, or various combinations of these. Therefore, a broad term is needed (a) to stress the essential vertical and horizontal unity of sequences of smaller local units and (b) for use in areas where precise units have not been distinguished and where the relation of the rocks to units in other areas remains unknown.

The term Brigham is admirably suited for use of the broad unit, although it has also been used in a restricted sense. The Stratigraphic Code (Am. Comm. Strat. Nomenclature, 1961, art. 14b) supports this view, for it states, "When a unit is divided into two or more of the same rank as the original, the original name should not be employed for any of the divisions." Moreover, a request that the U.S. Geological Survey determine the more preferable of the various definitions of the term Brigham for use in Geological Survey reports resulted in these recommendations: (a) That the Brigham Quartzite be used in the broad sense; (b) that the Brigham be raised to group status where divisible (in other regions) and remain of formation rank where not divisible (as in the Soda Springs region); and (c) that the age of the Brigham be designated as Precambrian and Cambrian. These recommendations have been followed in this report.

REGIONAL RELATIONS

The presence of the distinctive and somewhat comparable rock-stratigraphic units that have been recognized in both the Brigham and the underlying sequence in the Bannock Range near Pocatello, Idaho, and near Huntsville, Utah (Crittenden and others, 1971, p. 581, 597), and their apparent absence from the Soda Springs and Bancroft quadrangles is puzzling. The quadrangles we have studied lie close to, but not directly between, the Bannock Range and Huntsville sections (fig. 1).

Subdivisions of the Brigham recognized at Pocatello and Huntsville are so distinctive and so traceable (mappable) that they are defined as new formations of the Brigham Group (Crittenden and others, 1971, p. 590). Moreover, both the similarities in composition of individual units and the similarity of the sequence of units in the Bannock Range and Huntsville sections, as well as in ranges farther southwest, may indicate that the units are of regional extent. Indeed, some of these units are inferred to be not only identical in composition at distant localities, but also correlative (Crittenden and others, 1971, figs. 7, 8, p. 597).

Yet the distinctive subdivisions of the Brigham recognized by our colleagues in nearby areas are not equally apparent or mappable in exposures we have examined in the Portneuf and Bear River Ranges. Individual rock types and features described by our colleagues can be recognized in our areas, but they are distributed throughout the section and are not confined to distinctive subdivisions. Indeed, we have been more impressed by abrupt facies changes within the Brigham than by lateral continuity of individual units.

An explanation is needed for our diverse views of the Brigham. We conclude that the differences are not between the geologists involved and their approaches, but rather between the rocks that have been observed in the different areas.

A possible geologic explanation is that the units described by our colleagues accumulated well within a deeply subsiding and extensive depositional basin whereas the rocks we have seen formed along the eastern margin of the basin. Several observations support this inference. First, the rocks are different. Next, the Bancroft and Soda Springs quadrangles do lie east of a line connecting Pocatello and Huntsville. Moreover, the Soda Springs quadrangle contains the easternmost known exposures of the Brigham Quartzite; whether the Brigham extends much farther eastward in subsurface is not established. Finally, both the changes in facies observed in the area and the change in age of the uppermost part of the Brigham from the Bancroft to the Soda Springs quadrangle are consistent with the inference of accumulation at the edge of a depositional basin. The apparent differences in rock sequence, therefore, can be explained by the conclusion that the rocks in our area were not deposited along the sedimentary strike of the rock sequences deposited in the Pocatello and Huntsville areas.

LANGSTON AND UTE LIMESTONES AND ASSOCIATED ROCKS

Despite heterogeneities in composition and in sequence, rocks above the Brigham Quartzite in southeastern Idaho and northern Utah have commonly been assigned to the Langston Limestone and to the overlying Ute and Blacksmith Limestones. The heterogeneities are so marked between the Bancroft and the Soda Springs quadrangles that the rock sequences are described separately below.

BANCROFT QUADRANGLE

Rocks in the Bancroft quadrangle contrast so greatly with those exposed in the Blacksmith Fork area in Utah that the names Langston and Ute are inapplicable despite a previous attempt to use them (Oriel, 1965b). For this reason they are here assigned to new formations (pl. 1) defined in the paragraphs that follow.

TWIN KNOBS FORMATION

NAME

The rock unit directly above the Brigham Quartzite in the Bancroft quadrangle is named in this report for the two mountain peaks here designated Twin Knobs, directly north of Windy Pass (fig. 3) in the northeastern part of sec. 12, T. 10 S., R. 38 E.

TYPE

The type area is the belt of faulted exposures from the crest of the Portneuf Range in sec. 1, T. 10 S., R. 38 E., to the east slope of the range in sec. 29, T. 10 S., R. 39 E. (Oriel, 1965a). The section measured near the southern of the Twin Knobs (fig. 3), in the SW¼ sec. 7, T. 10 S., R. 39 E., is designated the type section.

COMPOSITION

The Twin Knobs Formation can be divided, in its type area, into three informal members, the middle of which is not present everywhere. They are, in ascending order, a brown sandstone and limestone member, a green claystone member, and a gray *Girvanella*-bearing limestone member (pl. 1).

The lowest, or brown sandstone and limestone member, is 300–400 feet thick and consists of interbedded sandstone, limestone, and quartzite; the limestone is about as abundant as the sandstone and quartzite combined.

The sandstone occurs in layers several feet thick to thin laminae in limestone. It is mainly fine grained, though it ranges in grain size from very fine to medium;

it is calcitic, moderately well sorted though locally muddy, and tan to buff; and it consists dominantly of quartz. Weathered surfaces are rusty yellow brown, earthy, porous, and moderately limonitic. Gently inclined crossbedding and ripple marks are evident in some outcrops; a few bedding surfaces are moderately argillaceous or micaceous.

At least five types of limestone are present in the lowest member. Brown-weathering sandy limestone is the most abundant and consists of fine to very fine grains of quartz in medium- to dark-gray calcilutite and calcarenite; most layers are crossbedded; the proportion of quartz grains varies so that the rock grades into calcareous sandstone. Oolitic limestone is also very abundant and consists of dark-gray to black small to medium oolites in a light-gray to white matrix; some beds are crossbedded; most are interlayered with sandy limestone. Also present is thin-bedded dark-gray finely to very finely crystalline limestone. A few beds of *Girvanella*-bearing limestone are present, particularly in the upper part of the member; the limestone is medium gray to brownish gray weathering and fine grained and contains numerous spheroidal and ovoidal concentrically banded nodules of algal origin; the nodules are as large as 1 inch in diameter. Least abundant is medium to coarsely bioclastic light- to medium-gray limestone; only a few thin beds were seen near the base of the member, and they did not yield well-preserved fossils.

Quartzite composes less than 10 percent of the lowest unit; it is present throughout the member, however, and is most abundant in its lower part. Many quartzite beds are green, fine to very fine grained, and indistinguishable from beds in the underlying Sedgwick Peak Quartzite Member of the Brigham. Other fine to very fine grained beds are tan, flesh colored, brownish green, olive drab, and brown. Most beds, which are as much as 1 foot thick and locally crossbedded, weather medium to dark brown. Units of quartzite as much as 10 feet thick were observed to pinch out between limestone beds within a distance of 30 feet along strike.

A 20-foot-thick green claystone is presented above the brown sandstone and limestone member in one of three sections measured; it may be present in the other two, for exposures of nonresistant beds along those sections are very poor. This member consists of finely interlaminated to thinly interbedded claystone, sandstone, and limestone in about equal proportions. The claystone is green and finely micaceous in part, and it weathers to mottled brown and brownish green. The sandstone is green, fine to very fine grained, and very argillaceous, and it weathers to mottled reddish green and brown. The limestone is medium to light gray and medium to coarsely bioclastic.

The upper member of the Twin Knobs Formation is characterized by prominent resistant ledges of *Girvanella*-bearing limestone, which form extensive dip slopes on the east side of the Portneuf Range in the Bancroft quadrange. The gray *Girvanella*-bearing limestone member, which also includes siltstone, sandstone, and other kinds of limestone, is 200–300 feet thick.

Limestone is the most abundant rock and is light to medium gray and mainly subaphanitic; some layers contain *Girvanella*, and other layers contain oolites. Both the *Girvanella* and the oolites are principally dark gray to black; in a few places they seem both silty and iron rich, weathering rusty reddish brown and imparting a very spotted appearance to the rock. *Girvanella* are as much as 1½ inches in diameter; the largest oolites are coarse-sand size.

Siltstone and sandstone beds are pink, red, and tan. In poor exposures on slopes they form bright-red, reddish-brown, and bright-brown soils that contain numerous chips of red and yellow-brown fine-grained sandstone and siltstone. Siltstone and sandstone strata are thin bedded and are composed of quartz grains that are as large as fine-sand size; locally the beds are calcitic or quartzitic. Sandstone and siltstone are present throughout the member and appear to be most abundant in its upper part.

UPPER CONTACT

The top of the Twin Knobs Formation is placed between the uppermost prominent ledge of *Girvanella*-bearing limestone member below and a thick sequence of claystone above. Although easily distinguished and most serviceable for mapping, this contact may not be at the same time-stratigraphic position throughout the quadrangle.

DISTRIBUTION AND THICKNESS

The Twin Knobs Formation is exposed in a moderately continuous, though faulted, southeasterly trending belt from a point 3 miles southeast of Lava Hot Springs (Oriel, 1965a) to the north side of Smith Creek, about 4 miles west of Thatcher Meetinghouse (Oriel and Platt, 1968). Some exposures are also present at the north end of the Oneida Narrows.

The formation is about 590 feet thick where measured at the type section and thins southeastward. It is about 40 feet thick in the Cleveland area.

AGE

Only unidentifiable fragments of fossils were seen in limestone beds of the Twin Knobs Formation in sections measured at Twin Knobs. Moderately well preserved trilobites were collected from limestone in small prospect pits in the SE¼NE¼NW¼ sec. 1, T. 10 S., R. 38 E., but the collection was later lost; the trilobites were believed by the senior author (hardly a competent Cambrian paleontologist) to resemble those assigned at other places to the *Ptarmigania* fauna. Well-preserved forms of the *Ptarmigania* fauna are present in the Cleveland area (Bright, 1960, p. 42–44), but the strata there have not been connected by continuous detailed mapping with those in the Bancroft area.

The stratigraphic position of the formation indicates that it is younger than the underlying olenellid-bearing Sedgwick Peak Quartzite Member of the Brigham and older than the overlying trilobite-bearing rock unit, which contains elements of the *Glossopleura* fauna. Although the Twin Knobs Formation may contain beds of latest Early Cambrian age, we believe it to be entirely of earliest Middle Cambrian age. Although the evidence is clearly equivocal, we believe it probable, on the basis of the *Ptarmigania* forms seen, that the unit is of late *Albertella*-zone age.

LEAD BELL SHALE

NAME

The formation above the Twin Knobs Formation is here named the Lead Bell Shale for extensive exposures northeast of the abandoned Lead Bell mine. The mine is in the NW¼SE¼SW¼ sec. 18, T. 10 S., R. 39 E., and the exposures are in the NE¼SW¼ of the section. The mine, an abandoned adit reported to have been driven 630 feet by the Lead Bell Mining Co. (Campbell, 1927, p. 60), is erroneously shown as the Leadville mine on the 1949 edition of the U.S. Geological Survey Bancroft quadrangle topographic sheet and as the Lead Belle mine on the 1958 edition of the U.S. Geological Survey Preston 2° topographic sheet.

TYPE

The type area of the Lead Bell Shale is the belt exposed in the slopes northeast of the crest of the Portneuf Range, from the north side of Baldy Mountain along the west edge of T. 10 S., R. 39 E., northward toward the northwest corner of the township in the Bancroft quadrangle (Oriel, 1965a). The incompletely exposed section measured in the NE¼SW¼ sec. 7, T. 10 S., R. 39 E., about half a mile east of the southern of the Twin Knobs (fig. 3), is here designated the type section.

COMPOSITION

The Lead Bell Shale consists of claystone, siltstone, sandstone, and limestone (pl. 1). The claystone, which is most abundant, is fissile, dark gray to black near the bottom but mainly green and tan, thinly laminated, and moderately fossiliferous; slopes formed on it are tan and the soil contains olive, tan, and light-gray chips of shale. Tan and pink, on both fresh and weathered surfaces, partly argillaceous siltstone and fine-grained sandstone form thin layers interlaminated with the claystone, especially in the lower part of the member; locally the siltstone and sandstone are quartzitic and calcareous. Light- to medium-gray and some dark-gray limestone, not very abundant and present only in the upper part of the member, includes *Girvanella*-bearing, oolitic, and subaphanitic layers.

UPPER CONTACT

The Lead Bell Shale grades upward into the overlying limestone formation; any contact selected must be arbitrary. The contact used here is the base of the lowest thick ledge-forming limestone unit which is both prominent and continuous enough to be useful in mapping and which is overlain dominantly by limestone. The contact selected is overlain by interbedded thin green claystone and limestone units several feet thick.

DISTRIBUTION AND THICKNESS

The Lead Bell Shale forms strike valleys on the east flank of the Portneuf Range in the southwestern part of the Bancroft quadrangle. The belt of strike valleys is bounded on the west by the crest of the range, underlain by the Brigham and the Twin Knobs Formations, and bounded on the east by a belt of prominent knobs and ridges that is underlain by the Bancroft and Blacksmith Limestones. The formation is 475–500 feet thick in this area.

The Lead Bell apparently is present farther north in the Portneuf Range in the section along Two Mile Creek (pl. 4), where it is 460 feet thick (Storey, 1959, p. 19), and farther south in the Portneuf Range near Cleveland, where it is about 400 feet thick (Bright, 1960, p. 50, 64, 65). The formation is also likely present at other nearby localities, as discussed on page 35.

AGE

Trilobites were collected from several horizons within the Lead Bell Shale in the Bancroft quadrangle. The lowest collections (USGS collns. 4268–CO and 4270–CO), taken 20 feet above the base of the formation at the type section (pl. 1), include the following, according to A. R. Palmer (written commun., Dec. 4, 1963):

Oryctocephalus walcotti Resser
Peronopsis brighamensis (Resser)
Ogygopsis klotzi (Rominger)
Elrathina? sp.

Fossils collected from unmeasured strata in the lower and middle parts of the Lead Bell at other localities, in the SW¼SW¼NE¼ sec. 1, T. 10 S., R. 38 E. (USGS colln. 3839–CO), and in the NW¼ sec. 20, T. 10 S., R. 39 E. (USGS colln. 4273–CO), include, in addition to the foregoing, the following trilobites (A. R. Palmer, written commun., Jan. 31, 1963, and Dec. 4, 1963):

Oryctocara geikei? Walcott
cf. *Clappaspis spencei* Resser
Clavaspidella? sp.
Kootenia? sp.
Bathyuriscus atossa Walcott.

These collections from the Lead Bell contain elements of the *Glossopleura* zone of middle Middle Cambrian age. The forms are characteristic of typical Spence Shale Member fauna of Resser (1939a) and of the *Glossopleura* zone (Resser, 1939a).

Trilobites were also collected (USGS colln. 4269–CO) at the type section of the Lead Bell Shale about 25 feet below the top (pl. 1) and identified by A. R. Palmer (written commun., Dec. 4, 1963) as follows:

Elrathina? sp.
Peronopsis cf. *P. montis* (Matthew).

"The *Peronopsis* lacks any transverse axial furrows on the pygidium and also lacks pygidial spines. [The specimens resemble] forms in the *Bathyuriscus-Elrathina* zone. The *Elrathina*? in the sample is inconclusive. However, the agnostid evidence suggests the possibility that the top of the Lead Bell Shale could be a correlative of the basal shale of the true Ute" [at Blacksmith Fork Canyon].

The age of the Lead Bell Shale, therefore, is undoubtedly middle Middle Cambrian. Although the *Glossopleura* zone is represented by collections at the base and in the middle of the formation, and the *Bathyuriscus-Elrathina* zone by collections near the top, the boundary between the two has not been determined.

BANCROFT LIMESTONE

NAME

The thin- to medium-bedded limestone unit directly above the Lead Bell Shale is here named the Bancroft Limestone for exposures near the town of Bancroft in the Bancroft quadrangle.

TYPE

The faulted belt of exposure along the east side of the Portneuf Range, in the southwest quarter of the Bancroft quadrangle (Oriel, 1965a), is the type area. The section measured in the center of sec. 7, T. 10 S., R. 39 E. (fig. 3) is designated the type section.

COMPOSITION

The Bancroft Limestone consists of thin- to medium-bedded limestone and a few thin interbedded units of green claystone, especially near the base. It is only moderately resistant, in contrast to the far more resistant overlying rock unit, the Blacksmith Limestone, which consists of thick to massive beds of ledge- and cliff-forming limestone. Mottled and banded thin-bedded silty aphanitic limestone is dominant in the Bancroft; yellow-brown-and red-to reddish-brown-weathering silt mottles and bands give the rock a striking appearance characteristic of many Middle Cambrian strata in Western North America. The mottled beds are especially abundant in the upper part of the formation. Abundant in the lower part and present throughout the formation is light- to medium-gray subaphanitic limestone with some beds abundantly oolitic and other beds with numerous *Girvanella* spheroids and ovoids.

UPPER CONTACT

The top of the Bancroft Limestone is the boundary between thin to medium beds below and massive layers of carbonate rock assigned to the Blacksmith Limestone above. Where well exposed, the contact is placed beneath thick to massive ledges that are thinly to medium banded and consist of layers of oolitic limestone and subaphanitic limestone and in places brightly mottled tan- and red-weathering silty limestone. In areas of poor exposures, however, the base of a somewhat higher bed of tan- to rusty-reddish-brown-weathering dolomitic limestone was used in mapping because the bed is so distinct from overlying and underlying medium- to dark-gray limestone.

DISTRIBUTION AND THICKNESS

The Bancroft Limestone is exposed on the east side of the Portneuf Range in the Bancroft quadrangle, where it is 300–500 feet thick. The formation is about 520 feet thick at its type section and thins southeastward.

AGE

Trilobites collected from near the top of the formation in the SW¼SW¼NE¼ sec. 7, T. 10 S., R. 39 E. (USGS colln. 4272–CO) were identified by A. R. Palmer (written commun., Dec. 4, 1963) as follows: "*Alokistocarella* sp., which has been found elsewhere between the base of the Ute Limestone and the base of the Bloomington Formation." On the basis of stratigraphic position the formation is assigned to the *Bathyuriscus-Elrathina* zone of Middle Cambrian age.

SODA SPRINGS QUADRANGLE

Rocks assigned to the Langston Formation and Ute Limestone in the Soda Spring quadrangle differ so markedly in composition from one part of the area to another that they are described below as separate facies.

The facies in the Nelson Creek area more nearly resemble the rocks at Blacksmith Fork Canyon in Utah than do the others. The facies in the Egbert Canyon area may be transitional between the rocks in Nelson Creek area and the rocks of the Portneuf Range. The sequence southeast of Eightmile Creek differs from the others and may be more nearly like that in the Bancroft area.

NELSON CREEK AREA

The Brigham Quartzite is overlain in the Nelson Creek area by carbonate rocks that form two distinct, easily mapped rock-stratigraphic units (pl. 1). The lower unit, 425–460 feet thick, is resistant, composed dominantly of thick-bedded dolomite, and assigned to the Langston Formation. The upper unit, above 250 feet thick, is weak relative to the resistant bounding Langston below and the thick-bedded Blacksmith above, composed dominantly of thin- to medium-bedded limestone, and assigned to the Ute Limestone. Both formations can be subdivided into informal members, as described below, although the subdivisions have not been mapped.

LANGSTON FORMATION

The Langston Formation in the northernmost part of the Bear River Range may be subdivided into two members: a thin limestone member below and a thick dolomite member above. The lower member (pl. 1) is about 50 feet thick and consists of medium- to dark-gray finely crystalline limestone in beds 1–4 inches thick. About 30 feet above the base is a discontinuous zone of pelletal, oolitic limestone.

The gray limestone member is not present everywhere. In a partial section measured about 6,000 feet north-northwest of the section illustrated on plate 1, the limestone is absent and dolomite of the upper member rests on sandstone and sandy quartzite of the Brigham. In another partial section measured 1,000 feet farther north-northwest, the lower member of the Langston is 18 feet thick and consists of two units. The lower unit, 8 feet thick, is medium-blue-gray limestone in beds 1–3 inches thick with tan silty partings along the bedding; this unit lies on tan dolomitic sandstone in the top of the Brigham. The upper unit is a 10-foot interval of tan arenaceous dolomite that contains irregular discontinuous beds of medium-gray limestone ½–3 inches thick. Overlying this unit is dolomite characteristic of the upper member of the Langston.

In one exposure, limestone beds of the lower member pass gradationally along strike into dolomite of the upper member. The transition takes place along a jagged, irregular zone that clearly does not follow bedding.

The most characteristic and abundant rock type of the upper member, which is about 400 feet thick, is tan-weathering coarsely crystalline white dolomite. The dolomite is in beds 2–6 feet thick and forms bold outcrops and cliffs. At the base and near the middle of the illustrated section (pl. 1) are thin units of medium-purplish-brownish-gray and medium-gray finely to medium crystalline dolomite in beds about 2 feet thick; near the top, 2- to 18-inch-thick beds of pink- and tan-weathering dolomite are interbedded with pink and reddish-brown micaceous sandy shale. About 7,000 feet to the northwest the thin-bedded shale at the top is not present, and medium-gray medium-crystalline dolomite occurs only near the middle member.

UTE LIMESTONE

The Ute Limestone can be divided into three units (pl. 1). The basal unit, about 100 feet thick, is characterized by red and pink colors. Near its base is a distinctive coarsely oolitic bright-red limestone in which the oolites and matrix are the same color. Also present are thin beds of gray dense limestone, tan silty limestone, red shale, and red micaceous slightly calcareous fine-grained sandstone. Oolitic limestone is abundant and occurs in shades of red, pink, tan, and gray. The reds at the base of this unit give way upward to shades of pink and tan.

The middle unit, which is not present in the measured section shown (pl. 1), forms a prominent white ledge that is present throughout almost the entire extent of the facies of Nelson Creek area. The ledge (Armstrong, 1969) is about 25 feet thick and consists of white-weathering light- to medium-gray finely crystalline to dense limestone in beds 2–36 inches thick. Locally a few beds contain *Girvanella* as large as a fourth of an inch in diameter.

The top unit, about 120 feet thick, is thin bedded and is characterized by tan-, tannish-gray-, and sparse pinkish-tan-weathering limestone float. Medium- to dark-gray finely crystalline limestone is interbedded with pinkish-tan sandy limestone and shale, a little tan shale and siltstone, and with tannish-gray limestone, some of which is locally oolitic and crossbedded and elsewhere is finely micaceous on its parting planes.

EGBERT CANYON AREA

The rocks between the Brigham Quartzite and the Blacksmith Limestone in the Egbert Canyon area are somewhat thicker and far more difficult to subdivide than those in the Nelson Creek area. Dolomite is absent, and the entire sequence consists of thin- to medium-bedded limestone and thin units of claystone and siltstone. Despite the difficulties, this sequence was subdivided into two units during mapping of the Soda Springs quadrangle (Armstrong, 1969). The lower unit, about 450 feet thick, is comparable in thickness and stratigraphic position, but not in composition, to the unit assigned to the Langston Formation in the Nelson Creek area; it was assigned to the Langston also, although the marked difference in composition makes use of a query advisable as shown below. The upper unit, about 480 feet thick, though thicker than the Ute Limestone in the Nelson Creek area, has a comparable stratigraphic position and a not greatly different composition; it therefore is assigned to the Ute with moderate assurance. The contact between the two formations in the Egbert Canyon area, though subtle, was mapped on the basis of minor differences in both composition and color, as discussed below.

LANGSTON(?) FORMATION

Strata assigned to the Langston(?) Formation in the Egbert Canyon area can be divided into two informal members: a shale below and a limestone above (pl. 1).

The shale member of the Langston(?) is about 150 feet thick. Well-preserved trilobites have been collected from it at several places. The basal 30 feet is black fissile shale that contains a few 6-inch beds of black finely crystalline limestone. The upper 120 feet is olive-green to tan micaceous shale, whose fissility decreases upward. In the lower part of this interval are several 1-foot-thick beds of dark-gray-weathering black finely crystalline limestone. In its upper part are found abundant small pieces of float of tan, gray, and pink limestone, some of which are oolitic, that probably are derived from thin beds and lenses of limestone in the shale.

The limestone member of the Langston(?) in the Egbert Canyon area is about 300 feet thick; it has not yielded fossil collections. The lower 90 feet is dominantly dark-gray finely crystalline limestone. Sparsely scattered through this are thin beds of tan, pink and medium-pinkish-gray finely crystalline limestone, some of which are oolitic.

The overlying 210 feet is poorly exposed, and knowledge of it is gained principally from small, equidimensional pieces of float that occur in a tan soil. The interval consists of interbedded limestone, shale, and siltstone, in approximately that order of abundance. Dominantly tan and red oolitic limestone in the lower part gives way to tan oolitic, some coarsely oolitic, limestone in the upper part. Interbedded with the oolitic limestone are thin beds of dark-gray finely crystalline limestone. Near the middle of the unit are beds of dark-gray finely crystalline *Girvanella*-bearing limestone, in which the *Girvanella* attain a maximum diameter of about a quarter of an inch.

In this 210-foot interval, interbeds of shale are most abundant in the lower part, and the proportion of siltstone to shale increases stratigraphically upward. Olive-drab micaceous shale near the base gives way to tan micaceous siltstone and tan micaceous shale near the top.

UTE LIMESTONE

The distinctive basal red unit and the middle white cliff unit of the Nelson Creek area are not present in the Ute Limestone of the Egbert Canyon area. However, the characteristic pink and tan, and locally even red, colors are present.

In the only complete section measured (pl. 1), a 90-foot-thick discontinuous unit of medium-gray finely crystalline limestone, which occurs in beds 1–2 feet thick and contains a few interbeds of oolitic limestone, was assigned to the base of the Ute. This stratigraphic interval is occupied in nearby sections by thin-bedded tan, pink, and red limestone, on whose bedding planes are tan, pink, and red sandy and silty partings; much of the limestone is oolitic and interbedded with sandy limestone, olive-drab and tan micaceous calcareous siltstone, and sparse red micaceous shale.

Above this lies about 390 feet of dominantly thin bedded (1–6 in.) limestones on which a tan to reddish-tan soil is developed. These limestones are tan, pink, and locally red; many beds are oolitic, some coarsely oolitic; and between beds are tan, pink, and red silty and shaly partings. The partings are more abundant in, and sparse tan micaceous thin shale layers are restricted to, the lower half of the unit. Interbedded with these limestones is dark-gray finely crystalline limestone in beds 1–2 feet thick that commonly contain *Girvanella* $\frac{1}{4}$–$\frac{1}{2}$ inch in diameter. Moderately thick units of *Girvanella*-bearing limestone occur about 110 feet above the base and also near the top of this unit.

The Ute Limestone of the Egbert Canyon area thus displays a twofold division somewhat similar to that recognized in other parts of the region. Shaly layers are restricted to, and silty and shaly partings are much more abundant in, the lower part of the Ute than in the upper.

AREA SOUTHEAST OF EIGHTMILE CREEK

LANGSTON(?) FORMATION

In the area southeast of Eightmile Creek a sequence of rocks, known mostly from float, about 330 feet thick has been assigned to the Langston Formation (Armstrong, 1969) on the basis of stratigraphic position and thickness. This interval can be roughly divided along a gradational contact into a lower unit about 110 feet thick and an upper unit about 220 feet thick. Fossils have not been found in these rocks.

The lower unit consists dominantly of brown, reddish-brown, and green quartzite and sandy quartzite. Sandy quartzite becomes more abundant stratigraphically upward, and some micaceous sandy layers are present near the top.

The upper unit consists dominantly of thin-bedded, micaceous sandstone and phyllitic siltstone, with the phyllitic siltstone becoming more abundant upward. Green in the lower part yields to greenish tan in the upper. Near the base are a few 1-inch-thick quartzitic sandstone beds; near the top are a few thin fine-grained calcareous sandstone beds.

The rocks differ so markedly in composition from those at Blacksmith Fork Canyon that their previous assignment to the Langston must be regarded as tentative.

UTE LIMESTONE

Only the lower 242 feet of rocks assigned to the Ute Limestone was measured southeast of Eightmile Creek (pl. 1). At the base is a poorly exposed unit about 150 feet thick composed of thin-bedded medium-gray finely crystalline limestone, some beds of which are oolitic. Pink, tan, and red silty partings are common on bedding planes in the lower part. In the upper part are a few thin red and green quartzitic sandstone beds.

Overlying the limestone is a unit about 50 feet thick that, as judged from its float, is thin-bedded micaceous argillite that contains sparse limestone concretions.

Above this is about 35 feet of poorly exposed thin-bedded medium-gray limestone, with tan silty partings. Some beds are oolitic and others contain *Girvanella.*

CONTACTS

TOP OF LANGSTON

The top of the Langston Formation in the Nelson Creek area of the Soda Springs quadrangle is easy to identify and has been placed at the top of the uppermost tan-weathering coarsely crystalline white dolomite. Placement of the contact is greatly aided by the presence in the basal part of the overlying Ute Limestone of pink, red, and light-gray dense limestone outcrops and float in a red soil. Much of this limestone is oolitic. A very coarsely oolitic brilliant red limestone just above the basal beds of the Ute is highly distinctive, and in its best development is restricted to the Nelson Creek area.

The upper contact of the Langston(?) in the Egbert Canyon area of the Soda Springs quadrangle is very difficult to identify, partly because of poor exposures and partly because of very little lithologic difference between the Langston(?) and the Ute. At some places the contact has been mapped at the boundary between a poorly exposed limestone-shale-siltstone interval below and a less poorly exposed dark- to medium-gray finely crystalline limestone interval above. Some geologists might have included this latter interval in the Langston, but interbedded claystone and limestone have not been observed above this limestone. Moreover, the limestone is not recognizable throughout the Egbert Canyon area. In a large part of the area, a much less satisfactory criterion, color, has been used for distinguishing the Langston from the Ute. This color difference is best displayed by thin interbeds of shale and siltstone and shaly and silty partings on the bedding planes in limestone. In the Langston, green and olive-drab colors in the lower part pass upward into olive-tan and tan colors in the upper part. In turn, the olive tans and tans pass gradationally upward across the Langston-Ute contact to tans, pinkish tans, reddish tans, and locally even reds in the lower part of the Ute. Although use of this color criterion makes it evident that the upper contact of the Langston probably has not been mapped at the same stratigraphic position everywhere in the Egbert Canyon area, it does have the merit of grouping pink and red rocks, which occupy about the same stratigraphic position, in the Egbert Canyon area with similarly colored rocks in the Nelson Creek area and in the area southeast of Eightmile Creek, all of which have been assigned to the lower part of the Ute Limestone.

In the area southeast of Eightmile Creek the upper contact of the Langston has been mapped as the boundary between a greenish-tan micaceous sandstone–phyllitic siltstone unit below and a medium-gray finely crystalline limestone unit above. The limestone has pink. red, and tan silty partings on its bedding planes.

TOP OF UTE

Placement of the Ute-Blacksmith contact in the Soda Springs quadrangle follows in large part Mansfield's criterion of placing it below low cliffs that are formed by thick-bedded limestone beds in the base of the Blacksmith. Additional criteria used were: (a) The Blacksmith commonly weathers to a bluish gray, whereas the Ute commonly weathers to a tannish gray; (b) silty partings usually are more abundant in the Ute; (c) at most places bedding is thicker in the Blacksmith; (d) *Girvanella* ordinarily are more abundant and larger in the Blacksmith; and (e) perhaps the most useful, the Blacksmith usually has an irregular blotchy appearance on weathered surface that results from random distribution of areas colored slightly different shades of gray.

Although the list may appear impressive and although it applies to the Nelson Creek and Egbert Canyon areas and to the area southeast of Eightmile Creek, the criteria are elusive, inconclusive, and at many places unreliable. In areas of good exposure the contact can be placed with moderate accuracy and certainty, but in areas of poor exposure placement of the contact is difficult and approximate only.

AGE

LANGSTON(?) FORMATION

No diagnostic fossils were found in the Soda Springs quadrangle in the Nelson Creek area of the Langston or in the rocks assigned to the Langston(?) southeast of Eightmile Creek.

The Langston(?) Formation of the Egbert Canyon area, however, has yielded about a dozen collections of well-preserved fossils from its basal shale member. Typical examples from among these are the following fossils identified by A. R. Palmer (written communs., Nov. 28, 1956, and Oct. 18, 1957):

25 ft above base of formation (USGS colln. 2401–CO), from measured section (pl. 1)
- *Ehmaniella?* sp.
- *Peronopsis* sp.

50–75 ft above base of formation (USGS colln. 2150–CO), not from measured section
- *Alokistocare* sp.
- *Pagetia clytia* Walcott
- *Peronopsis brighamensis* (Resser)
- *Spencia typicalis* Resser
- *Zacanthoides* sp.
- "*Dictyonina*"
- "*Homotreta*"
- "*Pegmatreta*"

75–100 ft above base of formation (USGS colln. 2151–CO), not from measured section
- *Alokistocare* sp.
- *Bathyuriscus atossa* Walcott
- *Elrathia idahoensis* Resser
- *Hyolithes* sp.
- *Helcionella* sp.
- *Oryctocare geikei* Walcott
- *Peronopsis* sp.
- *Zacanthoides* sp.
- "*Dictyonina*"
- "*Pegmatreta*"
- "*Homotreta*".

The forms in these and other collections from this member are assigned to the *Glossopleura* zone of the middle Middle Cambrian and are characteristic of the Spence Shale Member fauna of Resser (1939a) found at Spence Gulch.

UTE LIMESTONE

No fossils were collected from the Ute Limestone of the Egbert Canyon area or from the Ute southeast of Eightmile Creek.

Fossils were collected, however, from several places in the Nelson Creek area of the Ute, but only one form is distinctive and well-enough preserved to be useful. The trilobite found about 110 feet above the base of the measured section (pl. 1) (USGS colln. 2146–CO) was identified by A. R. Palmer (written commun., Nov. 28, 1956) as *Ehmaniella* cf. *E. burgessensis* Rasetti. The fossil, according to Palmer, is ". . . very similar to one described by Rasetti from the Stephen formation of British Columbia and . . . is probably the age equivalent in part at least of the *Bathyuriscus-Elrathina* zone of medial Middle Cambrian age."

SOME NEARBY SECTIONS

Rocks between the Brigham Quartzite and the Blacksmith Limestone in nearby parts of southeastern Idaho have been assigned to the Langston Formation and Ute Limestone in different ways at different places. A review of previously described sections not only illustrates conflicting usages (pls. 4–6) but also helps to delineate the areal distribution of principal facies types. These considerations emphasize the inadequacies of previous rock-stratigraphic nomenclature.

PORTNEUF RANGE

Sections described in nearby parts of the Portneuf Range resemble the section described for the Bancroft quadrangle (p. 20–23). The rocks measured along the Oneida Reservoir, in the southern part of sec. 6, T. 13 S., R. 41 E., about 1 mile south of Cleveland, were described and assigned by Bright (1960, p. 40–65) to the following units (pl. 5):

Feet	
	Ute Limestone, upper part:
414	Limestone, thin- to medium-bedded, medium-gray, and thin units of green to tan shale and green to maroon and red fine-grained sandstone.
	Ute Limestone, lower part:
202	Shale, tan to gray-tan, and siltstone, sandstone, and sandy limestone in very thin layers.
	Langston Formation:
	Spence Shale Member:
205	Shale, black to medium-gray, and thin units of medium- to light-gray siltstone.
	Naomi Peak Limestone Member:
5	Limestone, thin- to medium-bedded, medium-gray, medium- to coarse-grained.
	Brigham Quartzite [uppermost part]:
3	Sandstone, thin-bedded, tan, slightly calcareous.
½	Limestone, medium-gray, coarse-grained, underlain by quartzites thousands of feet thick.

The upper unit of the Ute is clearly comparable to rocks assigned in the Bancroft quadrangle to the Bancroft Limestone; the underlying two units, to rocks assigned to the Lead Bell Shale; and the basal part of the Langston and topmost part of the Brigham, to rocks assigned to the Twin Knobs Formation.

Comparable units are also evident farther north in the Portneuf Range. A section measured by Holmes (1958, p. 24–28), probably along Two Mile Creek in the NW¼ sec. 28, T. 8 S., R. 37 E., may be summarized as follows, with his stratigraphic assignments (pl. 4):

Feet

Ute Formation:

533 Limestone, thin- to medium-bedded and medium-gray, with silty partings and thin units of greenish-gray micaceous shale.

380 Shale, greenish-gray.

Langston Formation:

358 Limestone, thick-bedded near top to thin-bedded below, mainly medium gray, with units of dark- and medium-gray shale and yellow-brown sandstone in lower part.

The upper unit is similar to the Bancroft Limestone in the Bancroft quadrangle; the middle, to the Lead Bell Shale; the lower, to the Twin Knobs Formation.

Another section measured along Two Mile Creek by Storey (1959, p. 18–20) is described as somewhat thicker (pl. 4):

Feet

Ute Formation:

631 Upper limestone part.

430 Lower shale part.

Langston Formation:

442 Limestone, medium-light-gray, with units of gray shale in lower part.

We have no basis for deciding which are the more accurate thicknesses.

BANNOCK RANGE

West of the Portneuf Range, the rocks above the Brigham are not well known. The sequence in the Bannock Range near Pocatello consists dominantly of poorly exposed limestone, which was tentatively assigned to the Langston (?), Ute (?), and Blacksmith (?) Limestones by Anderson (1928, p. 6–7).

Recent work (W. J. Carr and D. E. Trimble, written commun., 1969) indicates that the sequence between argillites we assign to the upper part of the Brigham and claystones assigned to the Bloomington Formation is about 2,100 feet thick in the Bannock Range and is dominantly limestone. This limestone unit may include strata correlative with the Langston, Ute, and Blacksmith Limestones. Poor exposures have inhibited mapping of units recognized within the thick limestone sequence. These units include (pl. 4):

Limestone, thick-bedded to massive, mainly gray, largely oolitic, with intraformational conglomerate; probably more than 1,000 ft thick.

Limestone, thin- to medium-bedded, dark-gray; several hundred feet thick.

Shale, about 100 ft thick, with trilobites of the ***Bathyuriscus-Elrathina*** zone.

Limestone, thin-bedded, light- to medium-gray; several hundred feet thick.

Although another area within the Bannock Range has been studied farther south, exposures there were too poor to permit a detailed description of the sequence above the Brigham (Murdock, 1961).

MALAD RANGE

The Two Mile Canyon section in the Malad Range, 2 miles southeast of the town of Malad, has long been an important locality because of the fossils found there by Walcott (Resser, 1939b, p. 11), but the rocks are not well known. A section measured by Walcott is described (Resser, 1939b, p. 9–10) as follows:

Blacksmith Dolomite, 585 feet thick, light-gray to drab dolomite.

Ute Formation, 797 feet thick, thin- to thick-bedded bluish-gray limestone, and layers of green shale and dolomite.

Spence Shale Member of Ute, 155 feet thick, blue-black, and thin-bedded dark-gray limestone.

Langston Limestone, 6 feet thick, dark-gray.

Somewhat different thicknesses were measured (pl. 5) in the same area by C. F. Deiss. He reported (in Resser, 1939b, p. 9, footnote 1):

205 feet of Spence Shale Member, and

60 feet of impure limestone, interbedded with pure limestone which contains the *Ptarmigania* fauna.

The Two Mile Canyon area, visited several times by Oriel, is complexly faulted and will require detailed mapping[5] before its stratigraphy is understood. However, our observations support those of Deiss. The Brigham Quartzite is overlain by a moderately thick unit of interbedded limestone, sandstone, and quartzite, which resembles the Twin Knobs Formation in the Bancroft quadrangle. Fossils collected by Walcott probably came from more than one limestone horizon. The shale above the limestone-bearing unit resembles the Lead Bell Shale.

BEAR RIVER RANGE

Recent mapping in the Bear River Range south of the Soda Springs quadrangle demonstrates clearly the moderately abrupt facies changes in the rocks directly above the Brigham Quartzite (Oriel and Platt, 1968), although very few sections have been described in detail. The facies contrast as markedly as in the Soda Springs quadrangle. In general, shale and limestone are domi-

[5] After completing this report, we learned that the area was mapped by D. C. Axtell in a 1967 M.S. thesis study for Utah State University, entitled "Geology of the Northern Part of the Malad Range, Idaho." Axtell's map, plate 1, confirms that faults are present at Two Mile Canyon.

nant in the western part of the range, whereas dolomite is abundant in the eastern part, and boundaries between different facies apparently cross the range northeastward.

Facies changes are particularly well exposed near Mill Creek, close to the type locality of the Spence Shale Member. A section exposed along the divide between Mill Creek and the North Fork of Mill Creek, in sec. 2, T. 13 S., R. 42 E., was measured and described by Maxey (1958, p. 655–656) as follows (pl. 5):

Feet	
	Ute Formation:
	Not measured, thin- to medium-bedded dark-gray limestone interbedded with light-green to greenish-tan shale.
	Langston Formation:
155	Dolomite, light- to dark-gray, finely to coarsely crystalline, medium-bedded to massive.
170	Limestone, dark-gray, finely crystalline, thin- to medium-bedded.
80	Limestone and shale, interbedded.
	Spence Shale Member:
65	Shale, light green in upper part and dark gray to to black in lower.
20	Covered.
	Brigham Quartzite.

The section along the North Fork of Mill Creek can be traced south-southeastward to Spence Gulch, a small tributary to Mill Creek in the SE¼ sec. 11, T. 13 S., R. 42 E. At Spence Gulch, the basal shale unit is more than 40 feet thick and rests directly on quartzite; no limestone is present between the two, as previously inferred by Maxey (1958, p. 655). Above the shale at Spence Gulch, the carbonate rocks are overwhelmingly coarsely crystalline dolomite, whereas they are only partly dolomite 1 mile to the north.

When traced northward from the section along the North Fork of Mill Creek, the carbonate rocks give way rather abruptly to a sequence of shale and limestone with no vestige of dolomite. This argillaceous facies is particularly well exposed in the divide between Pole and Copenhagen Canyons in the NW¼ sec. 26, T. 12 S., R. 42 E. The sequence here, measured by W. H. Fritz (written commun., Apr. 17, 1969) consists of 380 feet of very dark gray and olive-green claystone with thin but persistent units of thin-bedded partly oolitic dark-gray limestone (pl. 4; fig. 7). These rocks, assigned to the Lead Bell Shale, are overlain by a unit several hundred feet thick of dominantly thin bedded limestone with laminae and thin layers of green shale; this unit has been assigned to the Ute Limestone (Oriel and Platt, 1968), but assignment to the Bancroft Limestone is more appropriate.

The claystone facies of the Langston has been traced northward from about a fourth of a mile north of the North Fork of Mill Creek to the north edge of the Preston quadrangle. This facies overlies the Brigham along this part of the Paris thrust plate. The base of the exposed Brigham along the east flank of the Bear River Range is the Paris thrust fault, along which Cambrian and Precambrian quartzites have overridden Triassic and Permian rocks. In a few places small slices and blocks of other rocks have been dragged up along the Paris fault. One such locality is along Co-op and Stauffer Creeks, in the southwestern part of T. 11 S., R. 43 E., where Cambrian carbonate rocks, mismapped as the Ordovician Garden City Limestone (Mansfield, 1927, pl. 9), lie between the Brigham Quartzite (partly mismapped by Mansfield as Swan Peak Quartzite) and the Triassic Thaynes Limestone. The carbonate rocks are particularly well exposed along the north side of Co-op Creek, in the northern part of sec. 20, T. 11 S., R. 43 E., where the sequence, though not measured, consists approximately (pl. 4) of:

Feet	
	Ute Limestone (incomplete)
~100	Limestone, thin-bedded, dark-gray, with thin laminae of green shale.
~40	Claystone, green, shaly.
~40	Limestone, thin-bedded, dark gray.
	Langston Formation:
~250	Dolomite, light- to medium-gray, coarsely crystalline and thick-bedded; weathers to shades of orange and brown.
~40	Claystone, green shaly.
~80	Limestone and dolomite, interbedded.

Thus, in the Bear River Range west of Georgetown, a western claystone facies has overridden and rests on an eastern dolomite facies of the Langston along the Paris thrust fault.

Another locality where a slice of Langston dolomite lies between Brigham Quartzite and Permian and Triassic rocks is in the north-central part of sec. 32, T. 13 S., R. 43 E., about 2 miles southwest of Lanark. This exposure was recognized by Mansfield (1927, pl. 9) but was assigned by him to the Ute Limestone.

Several other sections of the dolomite facies have been measured and described in the Bear River Range. One such section is that measured by Keller (1963, app. 2) along the south side of Bloomington Canyon in the SE¼ sec. 19, T. 14 S., R. 43 E. This section can be summarized as follows (pl. 5):

Feet	
	"Ute Formation" [blacksmith(?) Limestone]:
	Not measured; interbedded olive shale and thin-bedded light-gray oolitic limestone.
	Langston Formation:
44	Dolomite, finely crystalline; weathers light brown.
39	Limestone, light-blue to gray oolitic and pisolitic.
122	Dolomite, light- to medium-gray; weathers to brown and red.

Feet

Langston Formation—Continued:

25 Olive shale and light-gray oolitic and pisolitic limestone, with thin layer of medium-gray quartzite at base.

105 Dolomite, light-gray; weathers light brown.

This section, therefore, is comparable to that observed along Co-op Creek.

A more complete section has been measured along Maple Creek, in sec. 4, T. 16 S., R. 41 E., on the west side of the Bear River Range. The section described by Coulter (1956, p. 9–11) may be summarized as follows (pl. 5):

Feet

Ute Formation:

490 Thin-bedded bluish-gray commonly oolitic limestone and green shale which weathers to yellowish orange; shale is more abundant in the lower half, decreasing in abundance upward; limestone is dominant in the upper half.

Langston Formation:

191 Dolomite, thick-bedded to massive, coarsely crystalline, gray to white; weathers to pale red and yellowish brown.

183 Limestone, thin- and thick-bedded, very finely crystalline, dark-gray to black.

"Brigham Quartzite" [Spence Shale Member of Langston]:

70 Shale, yellow-green.

Another section with somewhat less dolomite was measured a short distance south, along High Creek in Utah, in sec. 11, T. 14 N., R. 2 E. The section, described by Maxey (1958, p. 653–655), may be summarized as follows (pl. 5):

Feet

"Ute Formation" [Blacksmith(?) Limestone]:

225 Limestone, thick-bedded, light-gray.

Ute Formation:

235 Limestone, thin-bedded, dark-blue-gray.

30 Shale, green.

75 Limestone, thin-bedded, dark-blue-gray.

35 Shale, green.

85 Limestone, thin-bedded, dark-blue-gray.

60 Green shale and dark-blue-gray thin-bedded partly silty limestone.

Langston Formation:

35 Limestone, thick-bedded, bluish-gray, finely crystalline.

35 Dolomite, thick-bedded, gray, finely crystalline; weathers to reddish buff.

175 Limestone, thick-bedded, dark-gray, finely crystalline.

Spence Shale Member:

207 Shale, dark-olive to olivaceaus-black, with lenses of dark-gray limestone in lower 7 ft.

Naomi Peak Limestone Member:

32 Limestone, thick- to thin-bedded, dark-bluish-gray, finely to medium-crystalline, and thin interbeds of tan shale and dark-gray medium-grained sandstone at base.

The argillaceous facies on the west side of the Bear River Range is illustrated by a section along Birch Creek, in the SW¼ sec. 8, T. 14 S., R. 41 E., measured and described by Keller (1952, p. 6). The sequence consists of:

Feet

Ute Limestone:

490 Limestone, thin-bedded, blue-gray; silty with oolitic and pisolitic layers; interbedded olive and brown shale.

Langston Formation:

133 Shale, dark-olive-green.

CONTACTS

TOP OF LANGSTON

The foregoing stratigraphic sections from many sources have been included in this paper, at the risk of wearying the reader, to demonstrate the diverse ways in which the terms Langston and Ute have been used and to illustrate the diversity of criteria used to select the boundary between the two.

The top of the Langston Formation near its type section, along the Left Fork of Blacksmith Fork Canyon, as discussed below, is the boundary between rusty-brown-weathering dolomite below and interbedded green claystone and thin-bedded limestone of the Ute Formation above (Maxey, 1958, p. 657). Where the rocks above the Brigham Quartzite lie in the dolomite facies, therefore, there is moderate agreement on the top of the Langston. The top is placed at the top of the highest dolomite, as on the North Fork of Mill Creek (Maxey, 1958, p. 655), on Co-Op Creek (this report), on Bloomington Creek (Keller, 1963, app. 2), and on Maple Creek (Coulter, 1956, p. 9).

Where thick-bedded limestone lies between the highest dolomite assigned to the Langston and the higher interbedded green shale and thin-bedded limestone assigned to the Ute, the top of the dolomite has not been used. Instead, the top of the thick-bedded limestone or the base of the lowest overlying green shale has been used, as at Blacksmith Fork (Deiss, 1938, p. 1112), on High Creek (Maxey, 1958, p. 654), and at localities along the east side of the Bear River Range (Mansfield, 1927, p. 53).

Where the rocks above the Brigham Quartzite are not in the dolomite facies, chaos reigns in the selection of a top for the commonly mapped Langston Formation. Where thick shale is dominant in the rocks directly above the Brigham, the contact has been variously placed, in part reflecting confusion about the stratigraphic position of the Spence Shale Member, as discussed below. The top of the thick shale unit is used as the top of the Langston at some places, as at Birch

Creek (Keller, 1952, p. 6) and in the northeastern part of the Preston quadrangle (Oriel and Platt, 1968). The base of the shale unit is used as the top of the Langston at other places, as at Two Mile Canyon in the Malad Range (Resser, 1939b, p. 10) and at Two Mile Creek in the Portneuf Range (Holmes, 1958, p. 28; Storey, 1959, p. 19). A color change within the shale has also been used as the top of the Langston along the Oneida Reservoir near Cleveland, where black to dark-gray shale below is assigned to the Langston and green shale above, to the Ute.

Color has also been used as a basis for selection of the contact in sections dominated by thin-bedded limestone, as in the Egbert Canyon area of the Soda Springs quadrangle (Armstrong, 1969), as discussed on page 26.

TOP OF UTE

The top of the Ute Limestone in Blacksmith Fork Canyon and in nearby sections in Utah coincides with the base of the overlying Blacksmith Dolomite and is easy to recognize. A similar basis for selecting the top of the Ute is possible at only a few places in southeastern Idaho, for few of the rocks assigned to the Blacksmith consist of dolomite. The change from thin-bedded limestone below to thick-bedded dolomite above is used as the contact, for example, at Two Mile Creek in the Portneuf Range (Holmes, 1958, p. 30; Storey, 1959, p. 18) and at Two Mile Canyon in the Malad Range (Resser, 1939b, p. 10).

The contrast between massive layers of the Blacksmith carbonate beds and the thin bedding in the Ute was stressed by Walcott (1908a, p. 7–8), and this criterion has been used even where the Blacksmith is dominantly or entirely limestone rather than dolomite. The similarity in composition between the Ute and the Blacksmith was noted by Mansfield (1927, p. 55), who placed the contact between them at the base of massive thick-bedded carbonate units that form low cliffs on the east side of the Bear River Range. The change from thin-bedded nonresistant limestone below to thick-bedded resistant limestone above has been used as the top of the Ute at many other localities (for example, Coulter, 1956, p. 12; Armstrong, 1969). The change from thin to thick bedding does not coincide at some places with the change from limestone below to dolomite, where dolomite is present, as at High Creek (Maxey, 1958, p. 653); at such places there is lack of agreement on the top of the Ute.

Color has also been used to place the top of the Ute, as in the Cleveland area. The contact was placed by Bright (1960, p. 54) at the top of the uppermost tan- to brown-weathering silty limestone, above which limestones assigned to the Blacksmith are distinctly gray.

AGE

Numerous fossils have been collected from sections assigned to the Langston and Ute Formations in southeastern Idaho, and a few fossil zones are shown on plates 5 and 6. All are of Middle Cambrian age, and a few collections permit even more precise age assignments. Discrepancies in the rock-stratigraphic units to which various fossiliferous strata have been assigned, however, make it difficult to discuss the fossil collections without resorting to circumlocutions. The discussion, therefore, is deferred to a later part of this report.

MEANING OF THE TERMS LANGSTON, UTE, AND SPENCE

The foregoing discussions of the rocks assigned to the Langston and Ute Formations and to the Spence Shale Member of the Ute of Walcott (1908a) and of the Langston of Williams and Maxey (1941) clearly demonstrate conflicts in usage and discrepancies in the assignment of strata to the various units. These difficulties reflect both deficiencies in definition and subsequent usage and inadequacies of the available rock-stratigraphic nomenclature. Before nomenclatural changes are proposed, a review of previous usage is desirable to improve our understanding of these Cambrian rocks.

PREVIOUS USAGE

DEFINITIONS

The Langston Formation was named (Walcott, 1908a, p. 8) for strata exposed in Blacksmith Fork Canyon, Utah, that strike into Langston Creek. Although first described as 107 feet of "massive bedded, bluish gray limestone with many round concretions" (Walcott, 1908a, p. 8), it was later said to consist of 498 feet of "massive bedded, bluish gray limestone" and "massive bedded, dark, arenaceous limestone, passing . . . down into a calcareous sandstone, and then a gray sandstone" (Walcott, 1908b, p. 198–199).

The Langston was described as being directly overlain by the Spence Shale Member, a unit defined by Walcott (1908a, p. 8) as the basal member of the overlying Ute Formation. The Spence, named for Spence Gulch, 5 miles west-southwest of Liberty, Idaho, and about 40 miles northeast of Blacksmith Fork Canyon, consists of abundantly fossiliferous green "argillaceous shales."

The name Ute Limestone was first used by King (1876, p. 477; 1878, p. 232–233) for a 2,000-foot sequence of carbonate rocks beneath the unit now known as the Swan Peak Quartzite of Middle Ordovician age. The formation was not defined in its modern sense until Walcott (1908a, p. 7–8) restricted the name to 750 feet in the lower part of King's sequence and described it as "blue to bluish gray, thin-bedded, fine-grained limestones and shales, with some oolitic, concretionary, and intraformational conglomerate layers."

Although Ute Peak, east of Paradise, Cache County, Utah, was designated the type locality by King, no section at this area has ever been described; Walcott's descriptions (1908a, p. 8; 1908b, p. 195–198) were based on exposures in Blacksmith Fork Canyon. These exposures were redescribed and designated the type locality by Deiss (1938, p. 1120–1121).

EMENDED DEFINITIONS

The type Langston in Blacksmith Fork Canyon (pl. 6) has a heterogeneity in composition not evident in Walcott's first descriptions. This heterogeneity led Deiss (1938, p. 1119) to emend the definition of the formation. Stressed in the emendation were the presence at the base of 78 feet of thin-bedded calcitic sandstone, overlain by abundant pale-gray red-brown-weathering dolomite; abundant smalloval concretions (*Girvanella?*) in widely separated beds; oolitic and medium to coarsely crystalline textures in many beds; and a paucity of fossils in the type locality. Most of the fossils attributed to the Langston by Walcott (1908b, p. 198–199) had come from a section at Two Mile Canyon near Malad City, Idaho, about 50 miles northwest of the type locality at Blacksmith Fork Canyon. Comparison of fossils found at the two type localities led Deiss (1938, p. 1165) to conclude erroneously that the Spence fauna, though found in strata directly above Brigham Quartzite at Spence Gulch, is much younger than the fauna at the base of the Ute Limestone in Blacksmith Fork Canyon, and that therefore the two should not be correlated.

The emended Ute Limestone (Deiss, 1938, p. 1120–1121) was described as 685 feet thick and divisible into two parts (pl. 6). The lower 175 feet is composed of alternating drab-green to buff shale in zones from less than 1 to more than 8 feet thick, interbedded with dark- or black-gray and gray-green thin-bedded limestone. The upper 510 feet consists of thin- and some thick-bedded dark-blue-gray fine- to medium-grained limestone with stringers of tan- and red-weathering siliceous clay [silt]. The upper beds contain *Girvanella* concretions.

REDEFINITIONS

Study of numerous sections in the region led Williams and Maxey (1941, p. 281) to conclude that " . . . the Langston formation, a sequence of shales, limestones, and dolomites . . . though changing laterally to some extent, constitutes a satisfactory mappable unit." It was they who first recognized that the shales at Spence Gulch underlie dolomite beds of the Langston Formation; the Spence, therefore, was redesignated as a member of the Langston Formation (Williams and Maxey, 1941, p. 280–281).

Although no limestone is exposed beneath the claystone at Spence Gulch, the basal limestone is present a few miles northward along strike (Williams and Maxey, 1941, p. 280). The sequence along Mill Creek near Spence Gulch was therefore regarded as similar to that in localities to the south and southwest in Utah in consisting (pl. 5) of an upper dolomite unit; a middle limestone unit; an argillaceous shale unit, locally richly fossiliferous; and a basal limestone unit, locally richly fossiliferous. This sequence has been described (Maxey, 1958, p. 669) as "typical" and "characteristic" of the Langston. As the shale unit in northern Utah was believed to be the same as that at Spence Gulch, it was designated the Spence Shale Member of the Langston Formation (Williams and Maxey, 1941, p. 281). The underlying limestone, which includes the *Ptarmigania* fauna at many localities, was subsequently named the Naomi Peak Limestone Member (Maxey, 1958, p. 671). The Langston at its type locality consists essentially of two tan to light-pink tan-weathering dolomite units separated by a limestone unit (pl. 6); the basal dolomite is believed to thin northward and westward (Maxey, 1958, fig. 2), were the Spence Shale and Naomi Peak Limestone Members occupy its place (Williams and Maxey, 1941, p. 281). Where argillaceous sediments directly underlie the Naomi Peak Limestone Member, they were assigned to the Pioche(?) Formation (Maxey, 1958, p. 662, 668).

Redefinition of the Spence Member has left the basal shales of the Ute Limestone in southeastern Idaho and northern Utah (Maxey, 1958, p. 672) with no formal designation. The confusion possible in distinguishing between the unit at Spence Gulch and the basal shale unit of the Ute Limestone led Coulter (1956, p. 12) to suggest that the name Spence be abandoned.

The Ute Formation was redefined by Williams and Maxey (1941, p. 281) as a nonresistant unit composed of "thin-bedded silty limestone and green shales," conformably overlying the Langston Formation and underlying the Blacksmith Dolomite, both of which are resistant, persistent, and readily recognized units.

MODIFICATIONS PROPOSED HERE

The name Langston Formation, as now used, is not a rock-stratigraphic term, for it fails to convey composition. It has been used, instead, to indicate stratigraphic position; it is applied to strata that lie directly above the Brigham and below the Ute. The name has been applied in some places to strata consisting dominantly of dolomite; in other places to different kinds of limestone; in still other places, to claystone (pls. 4–6).

The distribution of the main rock types, as shown in figure 4, suggests patterns that have been recognized in other parts of the Cordilleran region. The easternmost sections are composed dominantly of dolomite that grades westward into limestone, as in the Middle Cambrian of the Grand Canyon (McKee, 1945, p. 59, fig. 1). The limestone grades westward into claystone, as in the Upper Cambrian (Palmer, 1960) and in the Middle and Upper Cambrian (Robison, 1964) of the eastern Great Basin. In some places the dolomite grades directly into claystone. The similarity of Cambrian facies relations in southeastern Idaho and northern Utah to those of the Grand Canyon and of the Great Basin has been recognized previously by others (for example, Maxey, 1958, p. 680; Rigo, 1968, p. 58). Yet an outmoded rock-stratigraphic nomenclature continues to mask available knowledge.

The principal names in use in the Grand Canyon—the Muav Limestone, the Bright Angel Shale, and the Tapeats Sandstone—unerringly indicate composition and serve further to connote genesis. The names are readily applicable despite lateral and vertical facies variations. The use of tongues of the principal end members is a guide not only to geometry, but also to local geologic events. A comparable nomenclature clearly would be desirable in the northern Cordillera, for it not only would provide a framework for summarizing available data but would likely stimulate further, meaningful research.

The principal end members recognized in the eastern Great Basin, thus far, are evident in the stratigraphic sections summarized in this paper. They have been related to broad depositional provinces designated (Palmer, 1960; Robison, 1960, 1964) the inner detrital belt, the middle carbonate belt, and the outer detrital belt. The principal rock types are thus a guide to genesis (Robison, 1964, p. 997).

Redesignation of Middle Cambrian units in southeastern Idaho and northern Utah would serve a dual purpose. First, it would make rock-stratigraphic terms more meaningful, in terms of composition, to geologists working in the region. It would further serve to link observations in the region to genetic concepts evolving throughout the Western United States.

Four principal end members seem to us to be required in our region of study, and where possible, available names should be retained for them. The first, for basal and eastern sequences composed dominantly of sandstone, can be referred to the inner detrital belt. The names Brigham Quartzite in Idaho and Flathead Sandstone in Wyoming are available for this end member. An outer subfacies of the inner detrital belt, to which the Pioche and Ophir Shales have been assigned (Robison, 1964, p. 99), is not volumetrically important in our area.

The second end member is dolomite. Although the "rusty-brown dolomite" facies is assigned to the Muav Limestone in the Grand Canyon, this type of rock is so distinctive, prominent, and extensive in our area that we believe it merits emphasis by a separate name. The dominance of dolomite in the type section of the Langston suggests that perhaps the Langston should be redefined to denote this end member. (See p. 37.) The dolomite facies of the Langston marks the inner part of the middle carbonate belt.

The third end member is mainly medium- to dark-gray limestone and marks the outer part of the middle carbonate belt. No name is now available for this end member; a new one is needed. The limestone is so well displayed at High Creek (Maxey, 1958, p. 654) that High Creek Limestone is a suitable name. (See p. 37.)

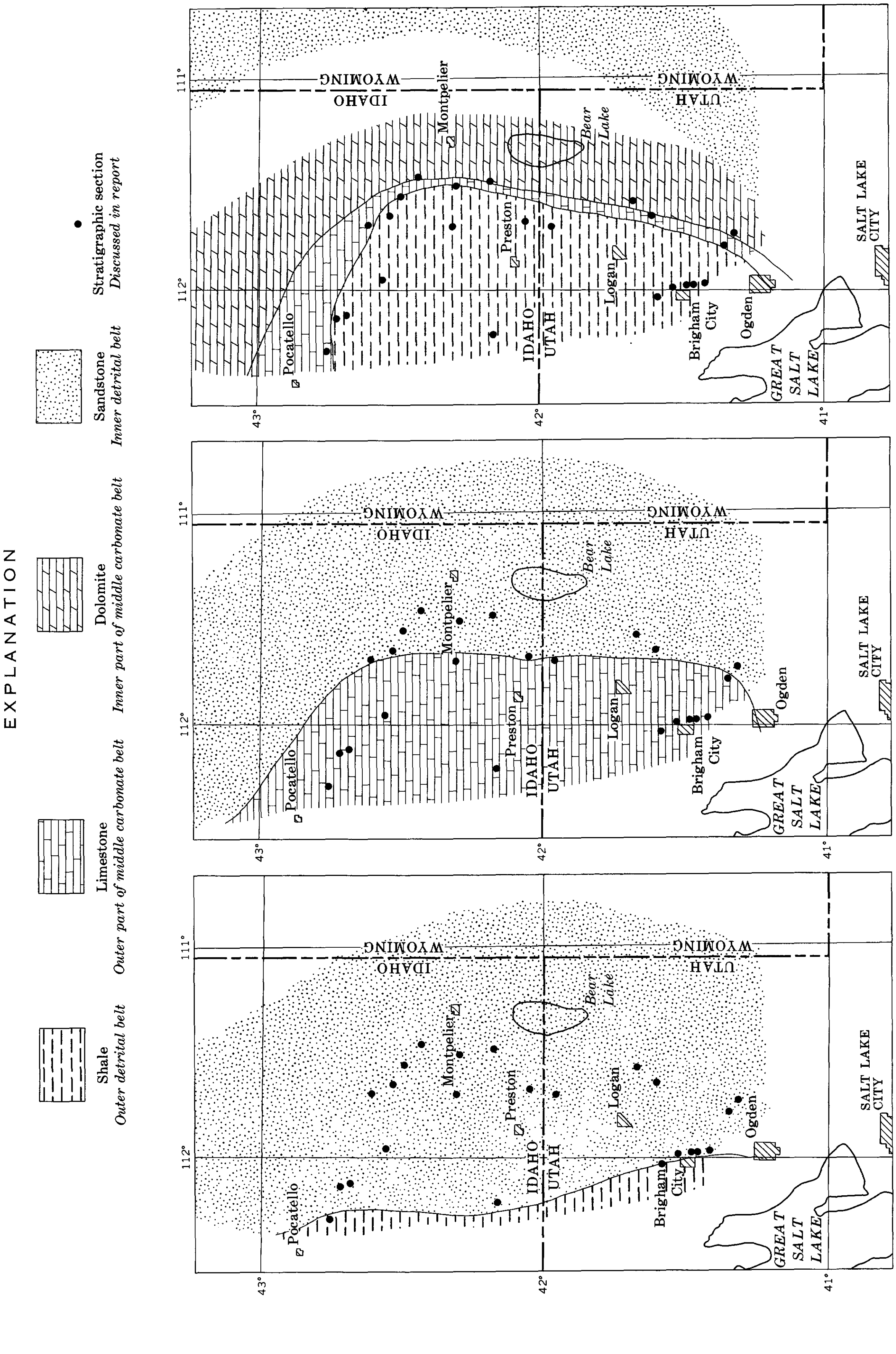
The fourth end member is shale, ranging from very dark gray and almost black to olive-green claystone; it represents the outer detrital belt. Although the name Spence has been used for this lithology, the name has been applied in conflicting ways and has some connotations of stratigraphic position. We prefer the name Lead Bell Shale, defined in this report, for inclusive use.

Designation of the principal end members (fig. 5) does not solve all problems, for there are sequences of rocks of mixed compositions, thin units of one facies which extend into thick units of another, and questions that remain on the boundaries of such units as the Ute Limestone. These are some of the matters discussed in the sections that follow.

LEAD BELL SHALE, SPENCE AND CUB TONGUES

The relation of the Lead Bell Shale in the Portneuf Range to the various "Spence shales" in northern Utah and southeastern Idaho (Coulter, 1956, p. 12) has been the clue to unraveling Middle Cambrian stratigraphic relations and to explaining the various mixed "Spence" faunas that have troubled paleontologists in the past (Deiss, 1938, p. 1165). The Lead Bell Shale, therefore, merits discussion first.

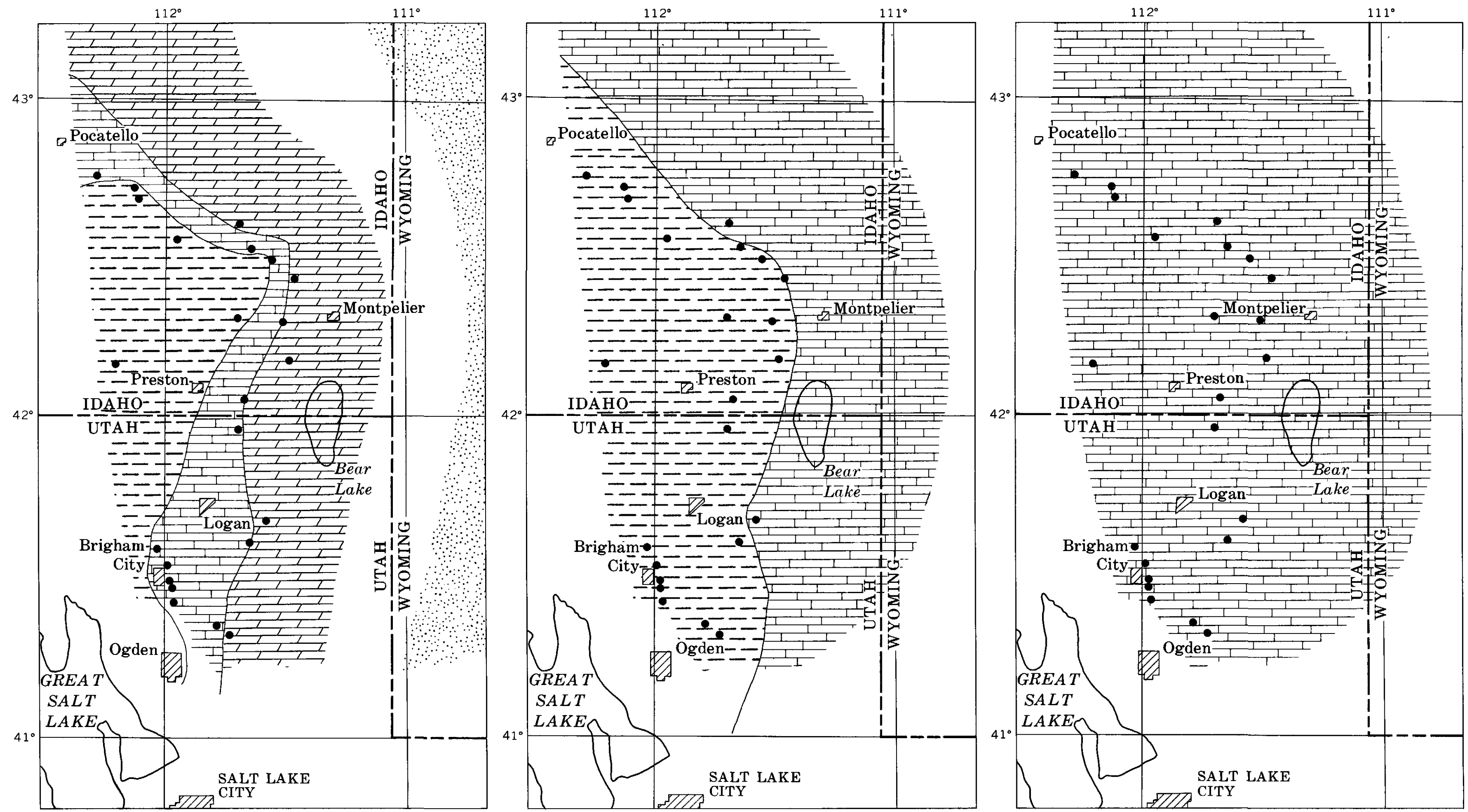
The Lead Bell Shale, named and defined in this paper, is about 400–500 feet thick where fully developed (pl. 4) in the Portneuf and Malad Ranges, in the Cleveland area, in the northeastern part of the Preston quadrangle, and in the area southeast of Eightmile Creek in the Soda Springs quadrangle at the section measured in sec. 27, T. 10 S., R. 41 E. (Armstrong, 1969). The relation of the Lead Bell Shale to the Langston Dolomite (p. 37), suggested by regional data (Maxey, 1958, fig. 2) and by



A. DURING DEPOSITION OF SEDWICK PEAK QUARTZITE MEMBER OF BRIGHAM QUARTZITE (UPPER PART OF *OLENELLUS* ASSEMBLAGE ZONE)

B. DURING DEPOSITION OF UPPER PART OF THE TWIN KNOBS FORMATION (UPPER PART OF THE *ALBERTELLA* ASSEMBLAGE ZONE)

C. DURING DEPOSITION OF THE LOWER PART OF THE LEAD BELL SHALE (*GLOSSOPLEURA* ASSEMBLAGE ZONE)



D. DURING DEPOSITION OF MIDDLE PART OF LEAD BELL SHALE (NEAR BOUNDARY BETWEEN THE *GLOSSOPLEURA* AND *BATHYURISCUS-ELRATHINA* ASSEMBLAGE ZONES)

E. DURING DEPOSITION OF THE UPPER PART OF THE LEAD BELL SHALE (LOWER PART OF *BATHYURISCUS-ELRATHINA* ASSEMBLAGE ZONE)

F. DURING DEPOSITION OF THE MIDDLE PARTS OF THE BANCROFT AND UTE LIMESTONES (LOWER MIDDLE PART OF *BATHYURISCUS-ELRATHINA* ASSEMBLAGE ZONE)

0 10 20 30 40 MILES

FIGURE 4.—Areal distribution of dominant rock types deposited in southeastern Idaho and northern Utah during Middle Cambrian times and in late Early Cambrian time.

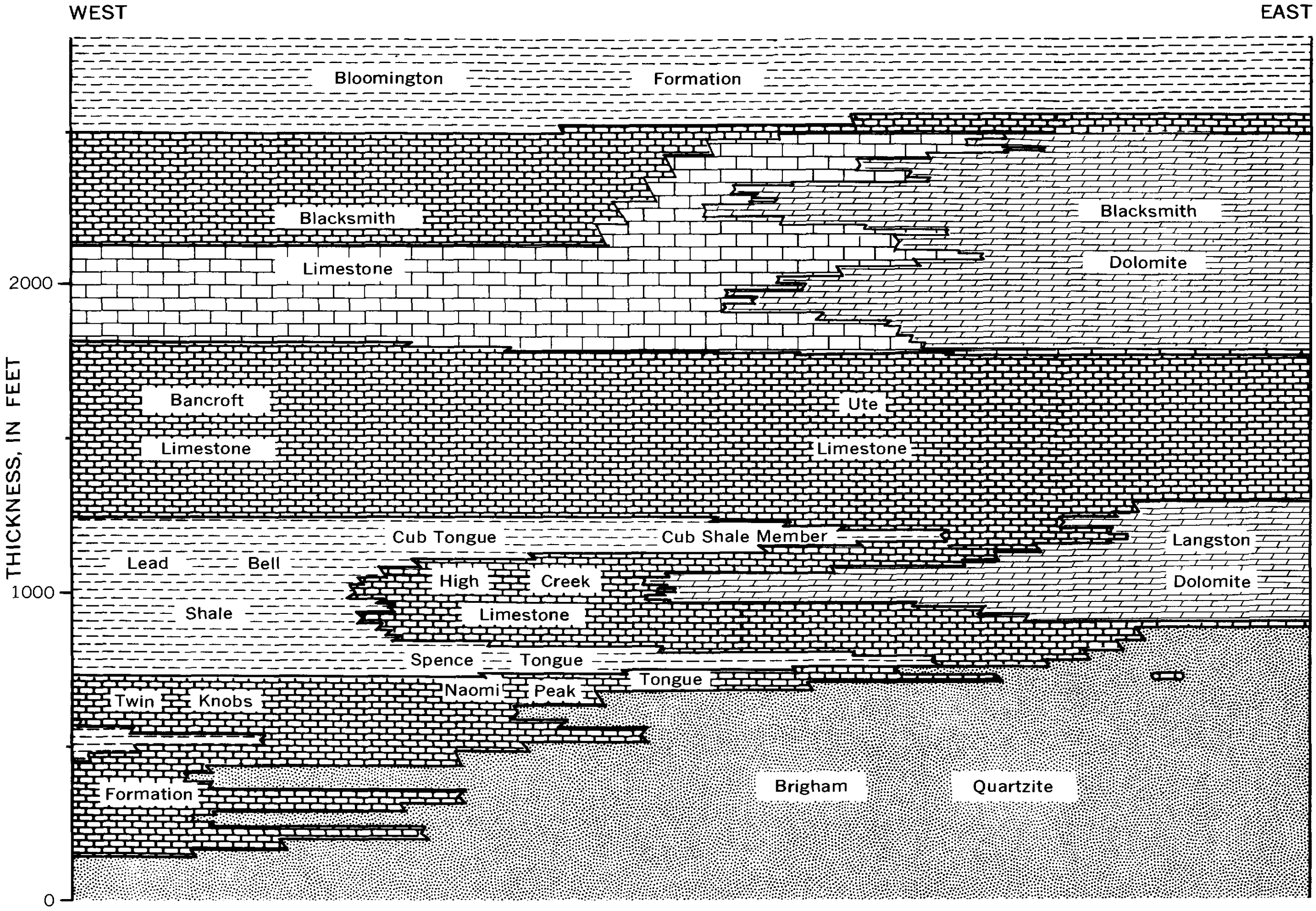


FIGURE 5.—Diagrammatic west-to-east section of the rocks between the Bloomington Formation and the Brigham Quartzite, showing the distribution of facies and the stratigraphic relations of rocks named or redefined in this report.

regional genetic considerations (Palmer, 1960), is evident in the rapid facies change north of Mill Creek in the SW¼ sec. 25, T. 12 S., R. 42 E., where Lead Bell Shale grades abruptly southward into limestone and then dolomite. Tongues of the shale, however, persist southward both above and below the dolomite.

The lower shale tongue can be traced, through very poor exposures, southward to Spence Gulch, where it clearly underlies dolomite and rests directly on Brigham Quartzite. Inasmuch as this is the type locality of the Spence, the lower shale is here designated the Spence Tongue of the Lead Bell Shale.

Although the upper tongue cannot be traced physically very far southward, it is presumed to be the same shale unit as that present above the Langston Dolomite and in the lower part of the Ute Limestone at Maple Creek (Coulter, 1956, p. 10–11) and at Blacksmith Fork Canyon (Deiss, 1938, p. 1112–1115). This shale, which is better developed along Maple Creek 2½ miles west of Cub Basin than elsewhere, is here named the Cub Tongue of the Lead Bell Shale. The type locality is the section measured by Coulter (1956, p. 10–11) in sec. 4, T. 16 S., R. 41 E. This shale tongue is thick enough to map in the southern part of the Preston quadrangle (Oriel and Platt, 1968).

With the formal designation of the Lead Bell, Spence, and Cub shale units, perhaps some of the mysteries of the various "Spence faunas" will begin to be dispelled.

More thin shale units are present in some parts of the middle carbonate belt than those here named and described. These units, however, are far too thin and their relations from one section to another are now too poorly known for them to receive additional attention here. Some may merit formal designation when far greater detail requires it.

HIGH CREEK LIMESTONE

The Lead Bell Shale intertongues with and grades into limestone eastward and southeastward. In general, the limestone ranges from thin bedded and very dark gray with numerous shale partings in the outer part of the middle carbonate belt to thick bedded and medium to light gray with abundant intraformational conglomerate, oolites, and *Girvanella* near the middle of the middle carbonate belt. Despite moderate contrasts in the compositions of the limestone beds, all are assigned to the unit here named the High Creek Limestone. The type section is that measured by Maxey (1958, p. 651) at High Creek in sec. 11, T. 14 N., R. 2 E., about 7 miles northeast of Richmond, Utah.

In places, tongues of the High Creek Limestone are traceable for many miles in sections dominated by Lead Bell Shale. Such tongues are laterally persistent, for example, both north and south of the well-exposed section at the divide between Pole and Copenhagen Canyons in the NW¼ sec. 26, T. 12 S., R. 42 E., in Idaho. No doubt some of these tongues will be named, eventually, as more detailed studies are made of these richly fossiliferous sections.

LANGSTON DOLOMITE

Easternmost sections of the strata directly above the Brigham Quartzite are dominated by dolomite. The dolomite is thick bedded, very light gray to blue gray and tan, and coarsely to medium crystalline on fresh fractures. Weathered exposures are rounded and rusty brown to orange, with a somewhat granular appearance which led Walcott (1908b, p. 198) to describe the rock as "arenaceous limestone." The dolomite facies is particularly well displayed and dominant in Blacksmith Fork Canyon at the type section of the Langston (Walcott, 1908b, p. 198; Deiss, 1938, p 1114–1115; Maxey, 1958, p. 657–658). Rather than abandon the name Langston because it has been used in a time-rock sense, we prefer to redefine it to apply to the dominantly dolomitic section exposed at the type locality.

The Langston Dolomite intertongues westward with the High Creek Limestone, as recognized by Maxey (1958, fig. 2). A tongue of the Langston Dolomite, for example, is present at High Creek, whereas a tongue of High Creek Limestone is present at Blacksmith Fork Canyon and at Maple Creek. Our belief is that the choice of names for any locality where more than one rock type is present ought to be based on the dominant lithology.

The Langston Dolomite, as here redefined, is especially well represented on the east side of the Bear River Range to as far north as Mill Creek and in the facies of the Nelson Creek area of the Soda Springs quadrangle. It is not present in the Portneuf and Malad Ranges nor in the Egbert Canyon or Eightmile Creek areas of the Soda Springs quadrangle.

TWIN KNOBS FORMATION AND NAOMI PEAK TONGUE

The Lead Bell Shale, High Creek Limestone, and Langston Dolomite rest, in many places, directly on Brigham Quartzite. In some places, however, a thin unit of limestone or a mixed unit of limestone and detrital rocks rests on the Brigham. The names Naomi Peak Limestone Member of the Langston and Twin Knobs Formation have been applied to these.

The name Naomi Peak Limestone Member was proposed by Maxey (1958, p. 671) for 30–40 feet of strata that earlier were informally designated the "*Ptarmigania* strata" (Resser, 1939b). Because the unit is thin and seems to grade eastward into the dominantly dolomitic rocks at Blacksmith Fork Canyon, it was assigned a member status in Maxey's Langston Formation. Although the unit includes some detrital rock at its type locality along High Creek, the concept of the member has been that it is the first relatively pure limestone key bed above the Brigham and that it contains the *Ptarmigania* fauna (Maxey, 1958, p. 669–671). The limestone is recognizable at many localities because even where it is not directly overlain by Lead Bell Shale, the Spence Tongue of the Lead Bell Shale separates it from overlying High Creek Limestone or Langston Dolomite.

The presence of a 600- to 700-foot-thick unit of mixed composition, unlike any unit previously described, beneath the Lead Bell Shale in the Bancroft quadrangle has led us to define the Twin Knobs Formation in this report. This formation, composed of interbedded quartzite, sandstone, shale, and limestone, represents deposition under alternating conditions near the boundary between the inner detrital and middle carbonate belts. The formation differs from the Naomi Peak by definition and by concept in being considerably thicker, in including a significant proportion of detrital rocks, and in including many limestone beds only one or several of which may contain the *Ptarmigania* fauna. Thus, we regard limestone of the Naomi Peak as an eastern tongue of the Twin Knobs Formation.

The name Twin Knobs Formation is here applied to the limestone-bearing unit beneath the Lead Bell Shale in the Portneuf Range, at Two Mile Creek, as well as in the Bancroft quadrangle and in the Malad Range at Two Mile Canyon.

BANCROFT AND UTE LIMESTONES

The laterally related group of rocks assigned to the Lead Bell Shale, High Creek Limestone, and Langston Dolomite is overlain by thin-bedded limestone that is assigned to the Bancroft at some places and to the Ute at others. These two limestones, though closely related, are not quite synonymous.

The Bancroft Limestone, as defined in this paper, overlies the Lead Bell Shale; its top is placed at the change from thin-bedded limestone below to thick-bedded limestone above that is tentatively assigned to the Blacksmith Limestone (described below). The Ute Limestone, in contrast, overlies the Langston Dolomite or High Creek Limestone and includes the Cub Shale Member, which is a tongue of the Lead Bell Shale at some localities; the top of the Ute is placed at the base of overlying Blacksmith Dolomite at the Ute's type locality in Blacksmith Fork Canyon. Thus, the Ute is more inclusive than the Bancroft, because it includes a basal tongue or member of shale. Where a twofold subdivision of the Ute Limestone is possible, the basal unit is designated the Cub Shale Member; the upper unit, the limestone member. Whether the tops of the Bancroft and Ute Limestones coincide, in the change from limestone to dolomite on the east and from thin to thick bedding on the west, has not been determined.

The Bancroft and Ute Limestones, though somewhat comparable in composition, also differ in topographic expression. The Bancroft Limestone forms small foothills and ledges between the strike valleys formed by the Lead Bell Shale below and the cliffs and peaks formed by thick-bedded Blacksmith Limestone above. The Ute Limestone forms valleys between spurs underlain by resistant Langston Dolomite and cliff and steep slopes underlain by Blacksmith Dolomite.

The choice of units to which rocks may be assigned may be difficult to make at some places where the rocks are of mixed composition. For example, in a section composed dominantly of High Creek Limestone but which contains some thin units of shale, a distinctive Cub Tongue of the Lead Bell Shale may not be present or mappable to separate the High Creek from overlying limestone. This apparently is true in the Bannock Range near Pocatello, where only a limestone unit, from the Brigham to the base of the Bloomington Formation, has been mapped, although in some places a shale sequence is exposed that may represent the Cub Tongue; the shale may be more extensive, but it is too poorly exposed to be mapped.

AGES

Despite the moderate abundance of diagnostic trilobites in the rocks described in this paper (pls. 4–6), a discussion of ages has been deferred for two reasons. First, a discussion of the faunal zones would have been difficult earlier before a consistent nomenclatural framework was developed; circumlocutions like "Spence Shale Member of Langston Formation of Storey (1959)" would have been necessary. The second, more important, reason has been our desire to develop a rock-stratigraphic classification completely independent of possible inferences regarding age; although our classification is consistent with faunal data, as we shall see below, it does not depend on them.

Trilobites have long been known to be abundantly preserved in the rocks under discussion (Walcott, 1908a, p. 5; 1908b, p. 198–199); they have been assigned to the *Ptarmigania* fauna (Resser, 1939b) and to the Spence fauna (Resser, 1939a). The precise relation of these faunas to the proposed standard Cordilleran Middle Cambrian biostratigraphic units suggested by Lochman-Balk and Wilson (1958) is not entirely clear. Problems arise partly because collections from different localities and different parts of the section have been lumped together and partly because of apparent overlap of genera assigned to distinctive zones. Discrepancies are apparent in zones proposed by different geologists (compare Lochman-Balk and Wilson, 1958; Maxey, 1958, p. 677–680).

Middle Cambrian trilobite faunas of the Cordilleran region have been subdivided into the following faunizones (Lochman-Balk and Wilson, 1958), in descending order:

An unnamed faunizone, with a *Bolaspidella* subzone at the top
Bathyuriscus-Elrathina faunizone
Glossopleura faunizone
Albertella faunizone
Plagiura-Poliella faunizone

The term "faunizone," used before publication of the current Stratigraphic Code in 1960, was defined (Lochman-Balk and Wilson, 1958, p. 317) in the sense of an assemblage zone.

Subsequent biostratigraphic work in Utah has led to the assignment of uppermost Middle Cambrian trilobites to the *Bolaspidella* Assemblage Zone, equal in rank to the *Bathyuriscus-Elrathina* Assemblage Zone (Robison, 1964).

Informal use of the word "zone" in the discussion that follows is in the sense of the more formal "Assemblage Zone" recommended in the Stratigraphic Code.

The discussion of ages below may be undermined by three possible weaknesses that we are unqualified to assess. First, not all the published faunal lists permit one to ascertain which specimens came from which precise horizons; fossil localities are lumped together. Second, not all the collections to be cited have been examined by any one paleontologist to assure consistent generic and specific assignments. Finally, problems remain on the assemblage zone assignment of some faunas. The *Ptarmigania* fauna in the Naomi Peak Tongue, for example, is assigned by Lochman (1952, p. 74–75) and by Maxey (1958, p. 669–670), on the basis of most included genera, to the *Albertella* zone. The absence of genera of the *Plagiura-Poliella* zone led Lochman-Balk (1955, p. 33; 1956, p. 586) to regard the *Ptarmigania* fauna as perhaps younger than earliest Middle Cambrian. But the *Ptarmigania* fauna is reported to include *Kochaspis* (Williams and Maxey, 1941, p. 282, fig. 2), which is believed by Lochman-Balk and Wilson (1958, p. 321, fig. 2) to be earliest Middle Cambrian in age.[6] The *Ptarmigania* fauna, despite its assignment to the *Albertella* zone, has been regarded as earliest Middle Cambrian in age by Maxey (1958, p. 677).

For convenience, the *Plagiura-Poliella* and *Albertella* Assemblage Zones are here considered, informally, to be of early Middle Cambrian age; the *Glossopleura* Assemblage Zone, middle Middle Cambrian; and the *Bathyuriscus-Elrathina* and *Bolaspidella* Assemblage Zones, late Middle Cambrian.

EARLY MIDDLE CAMBRIAN

All collections of the "*Ptarmigania* fauna" previously reported are from rocks beneath the Lead Bell Shale and the Spence Tongue of the Lead Bell. All collections came from rocks here assigned to the Twin Knobs Formation and to the Naomi Peak Tongue of the Twin Knobs.

Genera reported by Maxey (1958, p. 655) in the moderately thin limestone at the type locality of the Naomi Peak Tongue at High Creek include the following, listed by assemblage zones[7] to which they were assigned by Lochman-Balk and Wilson (1958, figs. 2, 3):

Albertella zone:
- *Albertella*
- *Kochina*
- *Ptarmigania*
- *Oryctocephalus*

Plagiura-Poliella zone:
- *Kochaspis*
- *Kochiella*
- *Oryctocephalus*

Upper *Olenellus* (uppermost Lower Cambrian) zone:
- *Prozacanthoides*
- *Poulsenia*

and *Clavaspidella* and *Dolichometopsis*. Most of these genera are present in collections from other localities assigned to the *Ptarmigania* fauna. An exception is *Albertella*, which has been found at very few places; whether this genus is restricted to a part of the type Naomi Peak is not made clear by Maxey (1958, p. 655).

Another *Ptarmigania* fauna collection from a Naomi Peak exposure at Calls Fort includes *Albertella*, many of the other genera, and *Ogygopsis* (*Taxioura* of Resser, 1939b, p. 62) as well.

All the aforementioned genera, with the exception of *Albertella*, *Kochiella*, and *Clavaspidella*, are present in strata at Two Mile Canyon in the Malad Range (Resser, 1939b, p. 11) assigned here to the Twin Knobs Formation. The lumping together of specimens from numerous limestone beds makes it impossible to determine if possible subzones may be present. *Albertella* has been said to be present at Two Mile Canyon (Bright, 1960, p. 43), but Rasetti (1951, p. 94), who is cited as the source, does not give a precise locality. A noteworthy point made by Rasetti (1951, p. 95) is that *Ogygopsis* does not occur with *Albertella* in Idaho, but above it.

The Two Mile Canyon locality was visited in 1966 with W. H. Fritz, of the Geological Survey of Canada, and several collections were made in an attempt to duplicate the collections by Walcott cited by Resser. The canyon is apparently controlled by a northeasterly trending, steeply dipping fault with moderate stratigraphic throw (southeast side down). The rocks on the north side of the canyon are also cut by smaller, northward-trending faults. Exposures on both sides of one such fault, along a small gully, are summarized in figure 6 by W. H. Fritz. The fossils identified from the Geological Survey of Canada collections shown in figure 6 are as follows (W. H. Fritz, written commun., Apr. 17, 1969):

Collection loc. No.	
83453	*Albertella* cf. *A. proveedora* Lochman
	Kootenia sp.
	Onchocephalus sp.
	Poliella? sp.
83452	*Albertelloides* sp.
	Alokistocare? sp.
	Caborcella granosa (Resser)
	Chancia venusta (Resser)
	Helcionella sp.
	Kootenia brevispina Resser
	Kootenia convoluta Resser
	Oryctocephalus maladensis Resser
	Pagetia resseri Kobayashi
	Paterina sp.
	Poliella germana (Resser)
	Ptarmiganoides communis (Resser)
	Ptarmiganoides exigua (Resser)
	Zacanthoides alatus (Resser)

[6] The reported *Kochaspis*, however, is considered by A. R. Palmer (written commun., June 18, 1969) to be a misidentified *Albertelloides*.

[7] The assemblage zones are more useful than suggested by the list because *Prozacanthoides* and *Kochaspis* are misidentified and because lax identifications of *Poulsenia* are not stratigraphically definitive, according to A. R. Palmer (written commun., June 18, 1969).

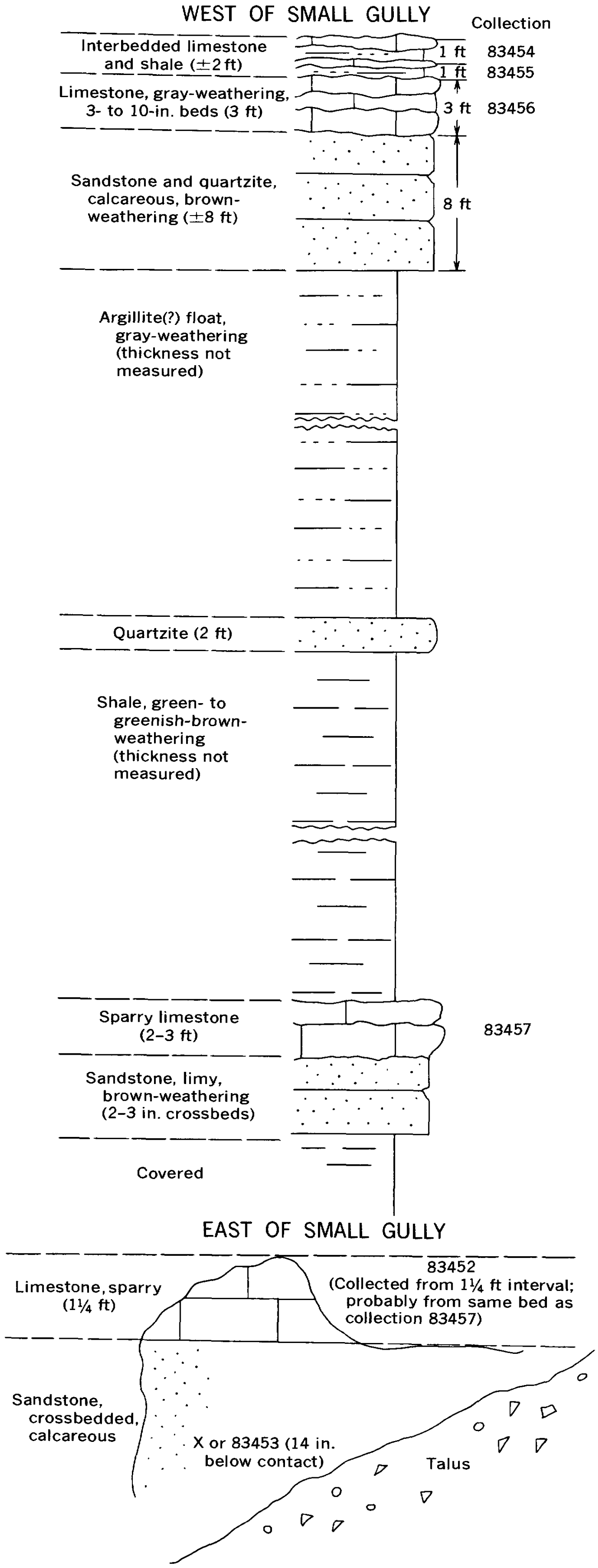


FIGURE 6.—Horizons of trilobites collected from the Twin Knobs Formation on the north side of Two Mile Canyon in the Malad Range. (Sketches provided by W. H. Fritz.)

Collection loc. No.

83457 *Albertelloides* sp.
Caborcella granosa (Resser)
Kootenia convoluta Resser
Oryctocephalus maladensis Resser
Pagetia resseri Kobayashi
Ptamiganoides exigua (Resser)
Zacanthoides sp.

83456 *Albertella*? sp.
Albertelloides sp.
Amecephalus? sp.
Caborcella granosa (Resser)
Kootenia convoluta Resser
Oryctocephalites sp.
Oryctocephalus maladensis Resser
Pagetia resseri Kobayashi
Paterina sp.
Ptarmiganoides lepida (Resser)
Ptarmiganoides? sp.
Zacanthoides alatus (Resser)

83455 *Albertelloides* sp.
Caborcella granosa (Resser)
Helcionella sp.
Kootenia convoluta Resser
Pagetia resseri Kobayashi
Poliella germana (Resser)
Ptarmiganoides exigua (Resser)
Zacanthoides sp.

83454 ?*Alokistocarella occidens* Resser
Caborcella? sp.
Helcionella sp.
Ogygopsis typicalis (Resser)
Pachyaspis longa? Fritz
Pachyaspis typicalis Resser
Pagetia maladensis Resser
Pagetia rugosa Rasetti
Peronopsis lautus (Resser).

Remarks.—These collections come from the approximate location specified by Resser (1939b, p. 17) as the type locality of the "*Ptarmigania*" strata. It was Resser's first understanding from Walcott's notes (in Resser, 1939b, p. 10, 17) that these fossiliferous strata consist of a 6-foot bed of limestone. After describing the "*Ptarmigania*" faunule, he learned from Deiss (in Resser, 1939b, p. 9) that the locality consists of "60 feet of impure limestone containing beds of pure crystalline limestone with the *Ptarmigania* fauna." Later, Rasetti (1951, p. 94; 1966, p. 510) rightly pointed out that near the top of the "Langston" Formation [Twin Knobs Formation of this report] at Two Mile Canyon two distinct faunules exist and that these faunules had been combined in Resser's report. Three faunules were found at Two Mile Canyon. The oldest (GSC colln. loc. 83453; faunule 1) has not been recorded in the literature on this region. The next youngest faunule (GSC colln. locs. 83452, 83455, 83456, 83457; faunule 2) furnished most of the forms described as the "*Ptarmigania*" faunule by Resser. The youngest faunule (GSC colln. loc. 83454; faunule 3) is the one that Resser intermixed with the "*Ptarmigania*" faunule, as Rasetti has pointed out. Since the first two faunules contain *Albertella*, they can safely be placed in the *Albertella* zone. The youngest faunule is probably very close to the boundary between the *Albertella* and the next younger, *Glossopleura* zone. I presently favor placing this fauna in the oldest part of the *Glossopleura* zone, but definite placement must await more work on faunules of this age.

The *Ptarmigania* fauna found in limestone directly below the Lead Bell Shale at Oneida Narrows near Cleveland includes the genera *Agnostus*, *Caborcella* (same as Resser's *Poulsenia*), *Dolichometopsis*, *Kochaspis*, *Kootenia*, *Olenoides*, *Oryctocephalites*, *Pagetia*, *Ptarmigania*, and *Ptarmiganoides* (Bright, 1960, p. 42–43). Although this limestone was assigned by Bright to the Naomi Peak, it probably represents the top of the Twin Knobs Formation, for we have observed limestone layers more than 40 feet below the top of the Brigham as mapped.

Fossils have been found at several horizons within the Twin Knobs Formation at Two Mile Creek in the Portneuf Range. *Ogygopsis* is present within the upper 22 feet of the unit, according to Holmes (1958, p. 24). Limestone 200–250 feet below the formation top contains *Pagetia*, *Chancia*, *Ogygopsis*, *Zacanthoides* (same as Resser's *Prozacanthoides*), *Caborcella*, *Olenoides*, *Alokistocarella*, *Kochiella*, and *Kochaspis*, according to Bright (in Storey, 1959, p. 20, 26). A claystone directly below, in about the middle of the formation, contains *Zacanthoides* and *Elrathia* (Storey, 1959, p. 26). Limestone at the base of the formation is reported (Holmes, 1958, p. 25) to contain *Alokistocarella* and *Prozacanthoides*. The collections most probably represent the upper part of the *Albertella* zone, allowing for some misidentifications of the difficult trilobites.

Fossils probably equivalent to those composing the *Ptarmigania* fauna have also been found in a limestone lens 150 feet below the top of the Brigham in the Nelson Creek area of the Soda Springs quarangle. Genera present are *Athabaskia*, *Chancia*, *Dolichometopsis*, and *Pagetia*. The limestone lens may represent an easternmost remnant of the Naomi Peak Tongue of the Twin Knobs Formation in the inner detrital belt (pl. 7).

The *Ptarmigania* fauna is assigned in all recent studies to the upper part of the *Albertella* zone. The Twin Knobs Formation and its Naomi Peak Tongue, therefore, are of early Middle Cambrian age. Limestone beds in these units pinch out eastward and intertongue with the uppermost part of the Brigham Quartzite. The underlying Brigham, therefore, which is of Precambrian to late Early Cambrian age in the Portneuf Range, includes beds as young as early Middle Cambrian in the Bear River Range (pl. 7).

MIDDLE MIDDLE CAMBRIAN

Many, but not all, of the "Spence faunas" previously reported represent the *Glossopleura* zone. The *Glossopleura* zone is well represented by collections from the lower part of the Lead Bell Shale, from the Spence Tongue, and by sparse collections from the High Creek Limestone and from thin tongues of other lithology in the Langston Dolomite.

Genera collected from the lower and middle parts of the type Lead Bell, described earlier in this paper, include *Oryctocephalus*, *Peronopsis*, *Ogygopsis*, *Elrathina?*, *Oryctocara*, *Clappaspis*, *Clavaspidella?*, *Kootenia?*, and *Bathyuriscus*.

Genera found in the lower part of the Lead Bell Shale at Oneida Narrows near Cleveland include "*Agnostus*," *Pagetia*, *Oryctocephalus*, *Oryctocara*, and *Ogygopsis* (Bright, 1960, p. 47).

Numerous trilobites have also been collected by W. H. Fritz from the Lead Bell Shale and underlying rocks at Copenhagen Canyon, sec. 26, T. 12 S., R. 42 E., in the Bear River Range (fig. 7). These Geological Survey of Canada collections have been identified by Dr. Fritz (written commun., Apr. 17, 1969) as follows (number in parentheses following locality number is footage above top of Brigham Quartzite):

Collection loc. No.	
83385(−20)	Trilobite fragments (Float from upper part of Brigham Quartzite 1 mile north of section)
83386(58)	*Albertelloides dispar* (Resser) *Caborcella* aff. *C. granosa* (Resser) *Caborcella?* cf. *C.? dispar* (Resser) *Kootenia* sp. *Paterina* sp. *Ptarmiganoides* sp. *Ptarmiganoides propinqua* (Resser)
83387(59)	*Corynexochides?* sp. *Helcionella* sp. *Hyolithes* sp. *Onchocephalus* sp. *Zacanthoides idahoensis* Walcott
83388(71)	*Corynexochides?* sp. *Ehmaniella?* sp. *Helcionella* sp. *Hyolithes* sp. *Kootenia brevispina* Resser *Onchocephalus* sp. *Oryctocephalites* sp. *Zacanthoides* sp.
83389(74)	*Acrothele* sp. cf. *Alokistocarella* sp. *Amecephalus laticaudum* (Resser) *Kochina?* sp. *Kootenia idahoensis* Resser *Kootenia* cf. *K. libertyensis* Resser *Pagetia fossula* Resser *Pagetia* cf. *P. rugosa* Rasetti *Peronopsis bonnerensis?* (Resser) *Zacanthoides* aff. *Z. alatus* (Resser)

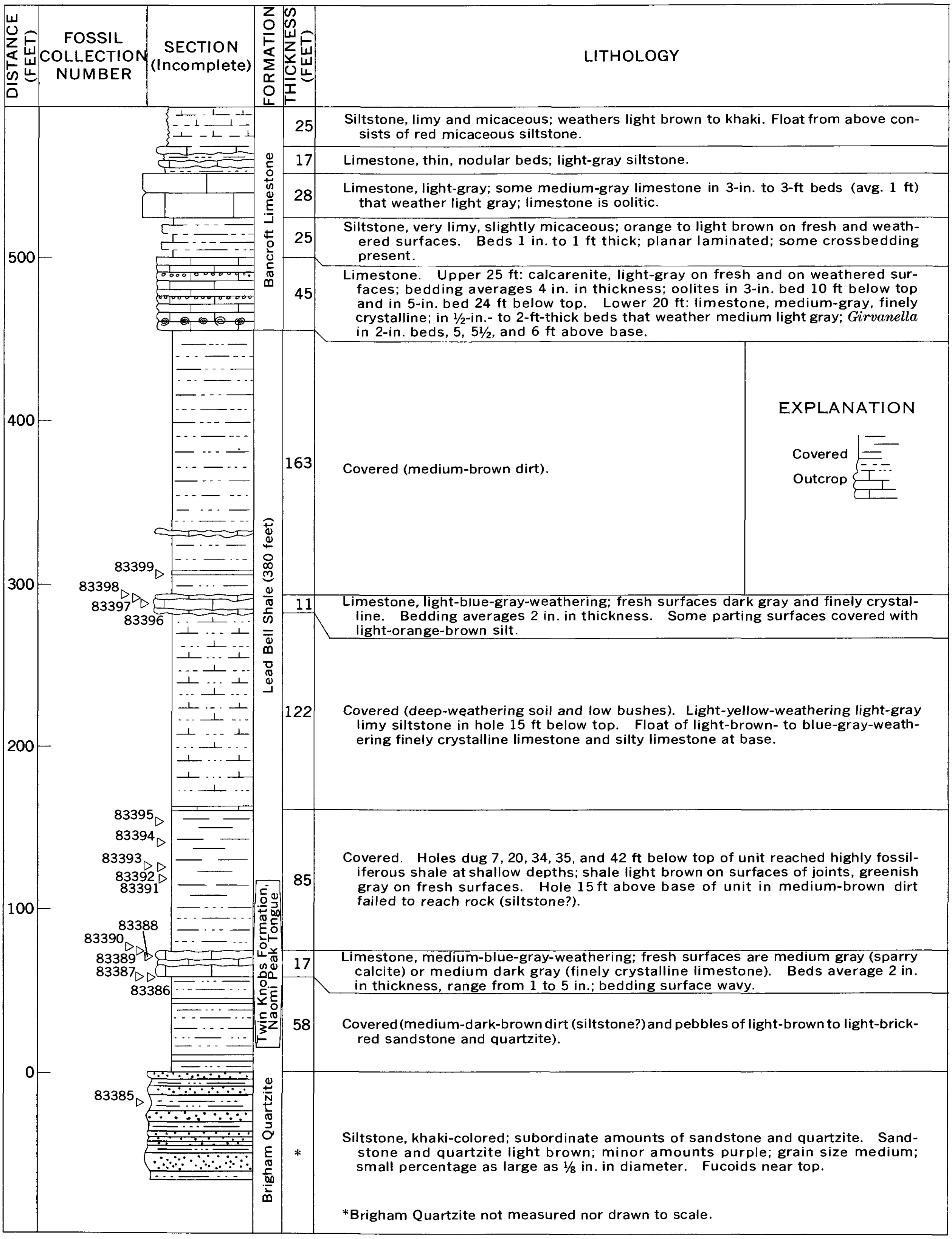


FIGURE 7.—Horizons of trilobite collections from the Lead Bell Shale and adjoining units measured by W. H. Fritz (written commun., Apr. 17, 1969) at Copenhagen Canyon, sec. 26, T. 12 S., R. 42 E., in the Bear River Range. Distances measured from top of Brigham Quartzite.

Collection loc. No.

83390 (76) *Acrothele* sp.
Amecephalus idahoense? (Resser)
Amecephalus laticaudum (Resser)
Athabaskia? sp.
Corynexochides? sp.
Helcionella sp.
Kootenia crassa Fritz
Kootenia idahoensis Resser
Micrometra sp.
Pagetia fossula Resser
Peronopsis bonnerensis (Resser)
Zacanthoides idahoensis Walcott

83391 (118) *Bythicheilus* sp.
Pagetia fossula Resser
Pagetia rugosa? Rasetti
Peronopsis bonnerensis (Resser)
Spencia typicalis Resser
Zacanthoides typicalis? (Walcott)

83392 (125) *Amecephalus* sp.
Bythicheilus typicum Resser
Chancelloria sp.
Chancia? sp.
Ehmaniella spencei (Resser)
Hyolithes sp.
Pagetia fossula Resser
Peronopsis bonnerensis Resser
Spencia typicalis Resser

83393 (126) *Bythicheilus* sp.
Ehmaniella spencei (Resser)
Pagetia fossula Resser
Spencia typicalis Resser
Zacanthoides idahoensis? Walcott

83394 (140) *Acrothele* sp.
Amecephalus spencense? (Resser)
Athabaskia? sp.
Bythicheilus sp.
Pagetia fossula Resser
Peronopsis bonnerensis (Resser)
Spencia typicalis Resser

83395 (153) *Pagetia fossula* Resser
Peronopsis bonnerensis (Resser)
Spencia typicalis Resser
Zacanthoides typicalis? (Walcott)

83396 (286) *Amecephalus punctatum*? (Resser)
Zacanthoides sp.

83397 (291) *Amecephalus punctatum* (Resser)
Arellanella sp.
Athabaskia bithus (Walcott)
Diraphora sp.
Pagetia fossula Resser
Paterina sp.
Zacanthoides sp.

83398 (292) cf. *Amecephalus* sp. or *Alokistocare* sp.
Athabaskia? sp.
Diraphora sp.
aff. *Pagetia fossula* Resser
Peronopsis sp.
Zacanthoides sp.

Collection loc. No.

83399 (306) *Amecephalus* sp.
Arellanella sp.
Athabaskia bithus (Walcott)
Diraphora sp.
Kootenia sp.
aff. *Pagetia fossula* Resser
Spencia sp.
Zacanthoides sp.

Remarks.—In the Copenhagen Canyon section (see fig. 7), the lowest locality shown (GSC colln. loc. 83385) is not in place. The position of this locality is correlated from the spot where float was collected near the top of the Brigham Quartzite 1 mile north of the measured section. The float contains indeterminant trilobite fragments that suggest a Middle Cambrian age and thus support Walcott's (1908a, p. 9) Middle Cambrian assignment for the upper part of the Brigham. This assignment has been followed by Burling (1914, p. 10), Mansfield (1927, p. 53), Richardson (1941, p. 8), Deiss (1938, p. 1119), and Coulter (1956, p. 7), but not by Williams and Maxey (1941, p. 277) and Williams (1948, p. 1132).

Collections from GSC colln. locs. 83386–833868 belong to the late *Albertella* zone. Collections from the immediately overlying strata, GSC colln. locs. 83389 and 83390, contain fossils that I would tentatively place in the earliest part of the *Glossopleura* zone.

Shale samples from GSC locs. 83391–83395 contain the same faunule as found in samples from the type Spence (GSC colln. locs. 83379–83384, Resser 1939a). The lithology of both sites is the same. Lochman-Balk (1956, fig. 10) has correctly placed the Spence faunule in the *Glossopleura* zone.

The youngest faunule collected (GSC colln. locs. 83396–833969) in the Cophenhagen Canyon sections can also be placed in the *Glossopleura* zone.

Collections from the type locality of the Spence Tongue of the Lead Bell Shale are also assigned to the *Glossopleura* zone. Genera present are "*Agnostus*," *Alokistocare*, *Bythicheilus*, *Bathyuriscus*, *Chancia*, *Elrathina*, and *Clappaspis* (Maxey, 1958, p. 656). The same genera, with the exception of *Bythicheilus*, as well as the genera *Clavaspidella*, *Olenoides*, *Oryctocephalus*, *Pachyaspis*, *Pagetia*, *Spencia*, and *Ogygopsis*, are also present in the Spence Tongue at High Creek (Maxey, 1958, p. 654). Most of these genera are also represented in collections from the Spence Tongue at Calls Fort (Maxey, 1958, p. 662).

Additional fossils were collected from the type Spence at Spence Gulch by W. H. Fritz in 1966. Although not tied to specific stratigraphic horizons, the Geological Survey of Canada collections, in ascending order, are identified (written commun., Apr. 17, 1969) as follows:

Geological Survey of Canada
Collection loc. No.

83379 *Acrothele* sp.
Athabaskia sp.
Bythicheilus typicum Resser
Hyolithes sp.
Pagetia fossula Resser
Peronopsis bonnerensis (Resser)
Spencia typicalis Resser

Collection loc. No.

83380 *Acrothele* sp.
Amecephalus laticaudum (Resser)
Amecephalus punctatum (Resser)
Chancia coriacea (Resser)
Pagetia fossula Resser
Peronopsis bonnerensis (Resser)
Spencia typicalis Resser

83381 *Bythicheilus typicum* Resser
Diraphora sp.
Pagetia fossula Resser
Peronopsis bonnerensis (Resser)
Spencia typicalis Resser
Echinoderm fragment

83382 *Amecephalus idahoense* (Resser)
Amecephalus punctatum (Resser)
Nisusia sp.
Pagetia fossula Resser
Peronopsis bonnerensis (Resser)
Spencia typicalis Resser
Zacanthoides idahoensis Walcott

83383 *Amecephalus punctatum* (Resser)
Bythicheilus typicum Resser
Hyolithes sp.
Micrometra sp.
Pagetia fossula Resser
Peronopsis bonnerensis (Resser)
Spencia typicalis Resser
Zacanthoides idahoensis Walcott

83384 *Amecephalus punctatum* (Resser)
Zacanthoides sp.

Remarks.—See previous remarks under Copenhagen Canyon Section.

The Spence Tongue is also present beneath the High Creek Limestone, previously assigned to the Langston in the Egbert Canyon area, in the Soda Springs quadrangle and contains fossils from the *Glossopleura* zone. Genera identified, as cited previously in this paper, include *Alokistocare*, *Bathyuriscus*, *Ehmaniella?*, *Elrathia*, *Oryctocara*, *Pagetia*, *Peronopsis*, *Spencia*, and *Zacanthoides*.

Few fossils have been found in the High Creek Limestone and in the Langston Dolomite. One collection from limestone beds 85 feet below the top of the Langston at the Left Fork of Blacksmith Fork Canyon included *Glossopleura* and *Glyphaspis?* (Maxey, 1958, p. 657).

Glossopleura zone trilobites have also been reported from the lower part of the Ute Limestone at several localities. Rock-stratigraphic assignments at each of these places seem to us to be equivocal. For example, the genera *Glossopleura*, *Kootenia*, and *Zacanthoides* are present in a 4-foot shale unit placed at the base of the Ute Limestone at Calls Fort (Maxey, 1958, p. 661). The shale unit overlies a moderately thin dolomite unit, properly assigned to the Langston, but is overlain by a unit of thick-bedded limestone that we believe is more properly assigned to the High Creek Limestone than to the Ute (pl. 6). No moderately thick unit of shale, representing the Cub Tongue of the Lead Bell Shale, is present in the Calls Fort section to mark the boundary between the High Creek and Ute Limestones. Perhaps the top of the thick-bedded limestone should be used as the contact.

LATE MIDDLE CAMBRIAN

Collections of fossils that represent the *Bathyuriscus-Elrathina* zone are sparse, and those taken from rocks beneath the Blacksmith Limestone contain comparatively few forms. The collections have been made in the upper part of the Lead Bell Shale, the Cub Tongue of the Lead Bell, the Bancroft Limestone, and the Ute Limestone.

The Lead Bell Shale, at its type locality, contains trilobites 25 feet below the top of the unit. These fossils are species of *Elrathina* and *Peronopsis* assigned to the *Bathyuriscus-Elrathina* zone. Collections from the type Lead Bell are too sparse to indicate the position of the contact between the *Glossopleura* and *Bathyuriscus-Elrathina* Assemblage Zones; it likely lies in the upper third of the formation.

The basal part of the Ute Limestone at its type locality in Blacksmith Fork Canyon consists of shale assigned here to the Cub Tongue of the Lead Bell Shale. Trilobites found in this unit include *Elrathina?* (Maxey, 1958, p. 657) and other forms assigned to the *Bathyuriscus-Elrathina* zone (A. R. Palmer, written commun., May 28, 1964). Genera previously reported from the basal part of the type Ute included *Alokistocare*, *Elrathina?*, *Glossopleura*, and *Kochina* (Deiss, 1938, p. 1114). *Glossopleura* was also collected from within 6 inches of the top of the High Creek Limestone at High Creek, according to A. R. Palmer (written commun., June 18, 1969). Thus, the contact between the *Glossopleura* and *Bathyuriscus-Elrathina* Assemblage Zones lies very close to the contact between the High Creek Limestone and Langston Dolomite below and the Ute Limestone above.

The precise relation of the rock-stratigraphic units described here to generalized units recognized in the Bannock Range near Pocatello (W. J. Carr and D. E. Trimble, written commun., 1969) is not known. In the Bannock Range, a shale unit about 100 feet thick lies above several hundred feet of thin-bedded limestone. These units may be counterparts of the Cub Tongue of the Lead Bell Shale and the underlying High Creek Limestone. The presence of *Bathyuriscus-Elrathina* zone trilobites in the shale unit supports this interpretation but is hardly an adequate basis for the application of rock-stratigraphic names.

Genera from the middle and upper parts of the Ute Limestone include *Olenoides* and *Alokistocare* at Blacksmith Fork Canyon (Maxey, 1958, p. 657), at High Creek (Maxey, 1958, p. 653), and at Calls Fort, where *Ehmaniella?* is also present. *Ehmaniella* is also present in the Ute of the Nelson Creek area in the Soda Springs quadrangle. These are *Bathyuriscus-Elrathina* zone forms.

At its type locality in the Bancroft quadrangle, only *Alokistocarella* has been found in the Bancroft Limestone. Farther south, however, at Oneida Narrows near Cleveland, the Bancroft contains *Kootenai*, *Olenoides*, and *Elrathina?* (Bright, 1960, p. 61), all assigned to the *Bathyuriscus-Elrathina* zone.

CORRELATIONS

The faunal evidence reviewed above is consistent with and supports the rock-stratigraphic classification proposed in this report. The relation of the trilobite assemblage zones to rock units is shown on plate 7.

A summary by W. H. Fritz (written commun., Apr. 17, 1969) of the regional relations of his newly reported collections is shown in figure 8 and is described as follows:

> The species of *Albertella* found in the oldest collection (faunule 1) suggests, but does not prove, that it belongs to the older part of the *Albertella* zone. Similar species of *Albertella* are known from the upper part of the Pioche Shale in the Pioche mining district and the adjacent Highland Range, Nev., and from the Arroyos Formation of northwestern Sonora, Mexico.
>
> Faunule 2 is reported (Williams and Maxey, 1941, p. 279) to correlate with the lowest part of the Langston Formation near the type locality at Blacksmith Fork, Utah. It also correlates with the lower half of the upper member of the Pioche Shale, as described by Fritz (1968, text fig. 1), from the Campbell Ranch section of the northern Egan Range, Nev. Late *Albertella* faunules of the same age are also known from the Gordon Shale, of Montana (Walcott, 1917, p. 7) and adjacent British Columbia and Alberta (Fritz and Norris, 1965). At its more westerly exposures, the upper part of the Gordon contains a *Glossopleura* fauna, and the entire Gordon becomes younger and belongs to the *Glossopleura* zone at its eastern exposures (Lochman-Balk, 1956, p. 624, fig. 14). Other strata that belong to the late *Albertella* zone are present in the Rennie Shale of northern Idaho (Resser, 1938), and the Ross Lake Shale Member within the Cathedral Formation of Alberta and British Columbia (Walcott, 1917, p. 4).
>
> Faunule 3 has what I would consider an approximate equivalent in the upper member of the Pioche Shale at the Campbell Ranch section at Fritz' localities 17 and 18 (1968, text fig. 1).
>
> Williams and Maxey (1941, p. 279–281) have correlated the Spence Shale Member (faunule 4) with the lower barren dolomite member of the Langston Formation at its type locality. They believe this member grades northward and westward into a unit that has limestone at the base that bears the "*Ptarmigania*" faunule (faunule 2), and shale at the top that is equivalent to the Spence Shale Member. The presence of *Glossopleura*-zone fossils in the middle member of the Langston at its type locality (Walcott, 1908b, p. 198) and 7 miles to the south (Rigo, 1968, p. 46) adds credibility to the correlation by Williams and Maxey.
>
> The Spence faunule closely resembles a part of the fossil assemblage illustrated by Resser (1938) from the Rennie Shale and Lakeview Limestone of northern Idaho. The resemblance is with the *Glossopleura*-zone fossils illustrated by Resser. Illustrated also are late *Albertella*-zone fossils, such as *Albertella sampsoni* Resser and *Vanuxemella idahoensis* Resser, which correlate with the "*Ptarmigania*" faunule (faunule 2).
>
> The youngest faunule collected from the Lead Bell Shale at Copenhagen Canyon section (faunule 5), can also be assigned to the *Glossopleura* zone. At present, a close correlation with this faunule is difficult to make. The nearest lithologic units bearing fossils assigned to this zone are the upper members of the type Langston (Walcott, 1908b, p. 198, 199; Williams and Maxey, 1941, p. 279). Other well-known formations that partly or wholly belong in this zone are the Chisholm Shale, Ophir Formation, and Gordon Shale.

BLACKSMITH LIMESTONE

Although we have been concerned in this report primarily with the rocks beneath the Blacksmith Limestone in southeastern Idaho, discussion of the Blacksmith, however brief, can hardly be omitted, for several reasons. First, some of the accompanying illustrations have required the use of the top of the Blacksmith, or the base of shale in the Bloomington Formation, as a datum because it is the most consistently recognized rock boundary in the sequence. Second, discussions of the tops of the Bancroft and Ute Limestones have required consideration of the Blacksmith. Finally, inconsistencies in the use of the term Blacksmith merit discussion, even though we offer no solution to the problem.

BANCROFT AND SODA SPRINGS QUADRANGLES

Rocks assigned to the Blacksmith Limestone in the Bancroft quadrangle consist dominantly of cliff-forming medium- to thick-bedded and massive limestone. The limestone is mainly mottled or laminated, dark to medium gray, and subaphanitic with some beds ranging to medium grain size. Mottles and laminae of silty limestone weather to yellow, pink, and tan. Beds of oolitic and *Girvanella*-bearing limestone are scattered throughout the formation. Although a unit of light-gray to buff dolomite about 10 feet thick was found in the upper part of the formation at one locality, counterparts at other localities are light-colored magnesian limestone. The formation, as mapped, is about 700–900 feet thick. Diagnostic fossils were not found, but irregular small protuberances of relatively resistant white calcite on many weathered surfaces, characteristic of the formation, are interpreted to have formed by recrystallization of fossils.

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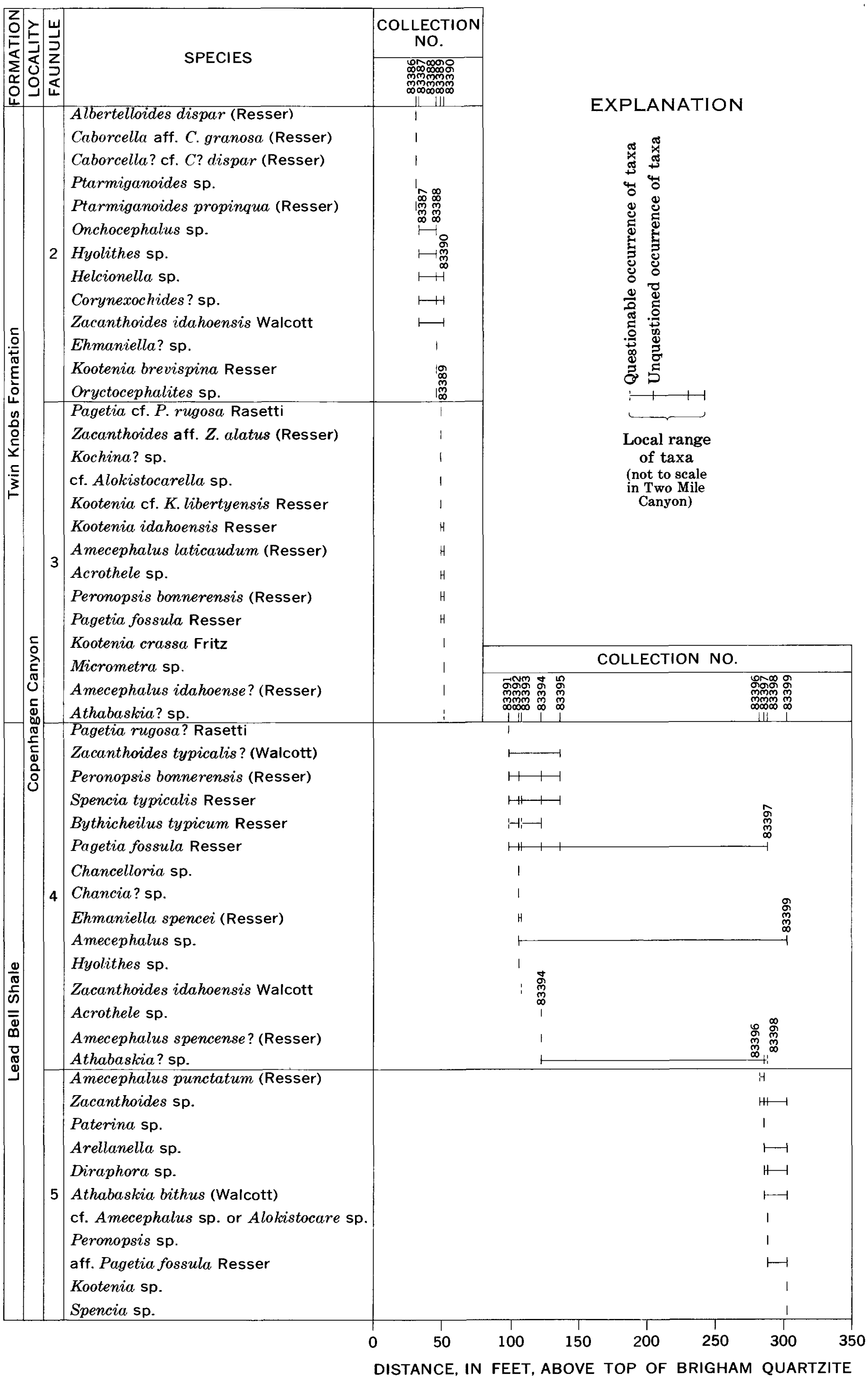

FIGURE 8.—Checklist of faunules collected by W. H. Fritz at Copenhagen Canyon and Two Mile Canyon.

FORMATION	LOCALITY	FAUNULE	SPECIES	83453	83452	83457	83456	83455	83454
Twin Knobs Formation	Two Mile Canyon	1	*Albertella* cf. *A. proveedora* Lochman	X					
			Kootenia sp.	X					
			Onchocephalus sp.	X					
			Poliella? sp.	X					
		2	*Alokistocare*? sp.		X				
			Chancia venusta (Resser)		X				
			Ptarmiganoides communis (Resser)						
			Kootenia convoluta Resser		X	X	X	X	
			Kootenia brevispina Resser		X				
			Oryctocephalus maladensis Resser		X	X	X		
			Paterina sp.		X		X		
			Helcionella sp.		X			X	
			Poliella germana (Resser)		X			X	
			Ptarmiganoides exigua (Resser)		X	X		X	
			Zacanthoides alatus (Resser)		X		X		
			Albertelloides sp.		X	X	X	X	
			Caborcella granosa (Resser)		X	X	X	X	
			Pagetia resseri Kobayashi		X	X	X	X	
			Albertella? sp.					X	
			Amecephalus? sp.					X	
			Oryctocephalites sp.					X	
			Ptarmiganoides lepida (Resser)					X	
		3	*Alokistocarella occidens* Resser						X
			Caborcella? sp.						X
			Helcionella sp.						X
			Ogygopsis typicalis (Resser)						X
			Pachyaspis typicalis Resser						X
			Pagetia maladensis Resser						X
			Pachyaspis longa? Fritz						X
			Pagetia rugosa Rasetti						X
			Peronopsis lautus Resser						X

Rocks assigned to the Blacksmith in the Egbert Canyon area of the Soda Springs quadrangle resemble those in the Bancroft quadrangle and are about 800 feet thick. In the Nelson Creek area, however, units of thick- to medium-bedded medium- to light-gray dolomite are present near the middle of the formation. The units of dolomite are 100–150 feet thick, and the formation is 800–900 feet thick.

Criteria for recognizing the base of the Blacksmith are mentioned in the discussions of the tops of the Bancroft and Ute Limestones. The top of the Blacksmith is placed at the base of the lowest shale in the overlying Bloomington Formation.

MEANING AND PROBLEMS OF THE BLACKSMITH

PREVIOUS USAGE

DEFINITION

The Blacksmith Formation was defined for exposures in Blacksmith Fork Canyon and described as "gray arenaceous limestone in massive layers" (Walcott, 1908a, p. 7). A subsequent description of the type section by Walcott (1908b, p. 195) added little more than colors ("steel gray," "lead-gray," and "dove-gray") for the 570-foot unit measured. Thus, the two features stressed in the original description are the arenaceous appearance and the thick bedding.

EMENDED DEFINITION

Later examination of the type section led Deiss (1938, p. 1121) to designate the unit the Blacksmith Dolomite, because it consists overwhelmingly of nearly pure dolomite. "Arenaceous beds," he added, "were not encountered, but the dolomite weathers to sugary surfaces which superficially appear sandy." Consequently, Deiss (1938, p. 1121) emended the definition of the Blacksmith, stressing that it consists dominately of thick-bedded dolomite, although it includes interbedded magnesian limestone only 450 feet thick, and that it is the resistant rock unit between the weaker Ute Limestone below and Bloomington Formation above.

SUBSEQUENT USAGE

The various features stressed in early definitions and additional observations at various localities have led to the use of different criteria for recognition of the Blacksmith. One problem is that contacts for the formation differ on the basis of the criterion stressed.

Dolomitic composition is stressed as essential to the meaning of the term Blacksmith by Williams (1948, p. 1133), Maxey (1958, p. 672), Holmes (1958, p. 29), Storey (1959, p. 28), and Rigo (1968, p. 56), although all include some limestone beds in the formation. The absence of dolomite from the Portneuf Range led Maxey (1958, p. 672) to indicate that the Blacksmith was not recognized near Lava Hot Springs.

Thick bedding is stressed in descriptions of the Blacksmith by Mansfield (1927, p. 55), Coulter (1956, p. 10), Bright (1960, p. 70), and by us (this report).

Resistance to weathering, undoubtedly related in part to thickness of bedding, is stressed in the discussions by Williams (1948, p. 1133), Coulter (1956, p. 12), Murdock (1961, p. 21), and Keller (1963).

Color also has been used as a basis for recognizing the Blacksmith by Bright (1960, p. 54) and Armstrong (this report). The Blacksmith is regarded as dominantly gray limestone, whereas tans and pinks characterize the underlying Ute.

SOME OBSERVATIONS

REGIONAL RELATIONS

The areal distribution of the various rocks that have been assigned to the Blacksmith resembles the areal relation of the Langston Dolomite to the High Creek Limestone. In easternmost sections which consist dominantly of dolomite, Blacksmith Dolomite is used; in sections to the west which consist of limestone, Blacksmith Limestone is used. The dolomite pinches out westward. Thus, an extensive middle carbonate belt is suggested, with an inner part composed dominantly of dolomite and an outer part composed dominantly of limestone.

VERTICAL RELATIONS

The distribution of dolomite in the various sections indicates clearly that the base of the lowest dolomite climbs section from east to west. The top of the highest dolomite beneath the Bloomington descends from east to west. Thus, the contacts of the dolomite occur at different stratigraphic levels from place to place.

Data are inadequate to determine whether the contacts defined by other criteria are at nearly the same stratigraphic level from place to place, but we doubt it. The change from thin to thick bedding, for example, no doubt also reflects depositional environments which shifted with minor transgressions and regressions. Thus, this change may also cross isochronous surfaces although, curiously enough, it seems to do so at a far lower angle than the change from limestone to dolomite.

The top of the Blacksmith or the base of the Bloomington Formation, although among the most consistently recognized contacts in the region, may also be placed inconsistently here and there. At most localities the contact is placed at the base of the lowest shale assigned to the Bloomington. In a few sections the contact is placed between thick-bedded limestone or dolomite below and thin-bedded argillaceous limestone above. The dominance of shale in the Bloomington, of course, suggests another major transgression of the outer detrital belt, and the transgression likely was not instantaneous across the entire region. The base of the Bloomington, therefore, is undoubtedly not isochronous and probably rises to the east.

POSSIBLE NOMENCLATURAL CHANGES

The relation of various rock changes to inferred isochronous surfaces has no bearing, of course, on the definition of rock-stratigraphic units. We believe our knowledge of the rocks is inadequate to propose nomenclatural changes here. The distribution of the many kinds of rock called limestone, for example, has not been ascertained. Nevertheless, some observations may be appropriate.

Our redefinition of the Langston clearly is consistent with Deiss' (1938, p. 1121) and Maxey's (1958, p. 672) restriction of the term Blacksmith to dolomite. If this alternative is chosen by later workers for the Blacksmith, then a new name will be needed for the thick-bedded limestones that overlie the Bancroft and Ute Limestones. A tongue of this new limestone unit might then be used to describe the presence of limestone above dolomite, as in the Two Mile Creek area of the Portneuf Range.

The change from thin-bedded limestone below to thick-bedded limestone above is not so sharp and evident that it is mappable at some localities. Thus, at such places another name, a more inclusive one, may be needed for all the limestones above the Lead Bell Shale and below the Bloomington.

Detailed studies of the rocks may, of course, suggest still other bases for revision of formal rock nomenclature.

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