Ordovician and Older Rocks of the Bayhorse Area, Custer County, Idaho

U.S. GEOLOGICAL SURVEY BULLETIN 1891

Ordovician and Older Rocks of the Bayhorse Area, Custer County, Idaho

By S. W. HOBBS and W. H. HAYS

Detailed descriptions and columnar sections of the major stratigraphic units that comprise Ordovician and older strata of unknown age in a structurally complex area

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DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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UNITED STATES GOVERNMENT PRINTING OFFICE: 1990

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Hobbs, S.W. (Samuel Warren), 1911—
Ordovician and older rocks of the Bayhorse area, Custer County, Idaho / by S.W. Hobbs and W.H. Hays.
p. cm.— (U.S. Geological Survey bulletin ; 1891)
Includes bibliographical references.
Supt. of Docs. no.: I 19.3:1891
1. Geology, Stratigraphic—Ordovician. 2. Geology—Idaho—Custer County. I. Hays, William Henry, 1922— . II. Title. III. Series.
QE75.B9 no. 1891
[QE660]
557.3 s–dc20 89–600226
[551.7'31'0979672] CIP

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FIGURES

Ordovician and Older Rocks of the Bayhorse Area, Custer County, Idaho

By S.W. Hobbs *and* W.H. Hays

Abstract

More than 40,000 ft of strata that range in age from Late Proterozoic(?) to Mississippian comprise the pre-Tertiary sedimentary section in the Bayhorse area, Custer County, Idaho. Of these rocks, the Middle Ordovician and younger rocks are well dated and most are easily correlated with similar strata that are widely distributed to the east and south of the Bayhorse area. Lower(?) Ordovician and older strata are restricted in known occurrences to the general Bayhorse area and represent tectonically isolated segments of a variety of rock types that were formed in diverse sedimentation regimes and later juxtaposed during a complex structural evolution. These diverse strata are divided, for purpose of description, into five groups based on distinctive lithologies or structural settings. At least two of these groups are allochthonous; others may be. The environment of deposition, original extent, thickness, age, and correlation of these different groups of strata that comprise the Early(?) Ordovician and older part of the stratigraphic section in the Bayhorse area are major problems of central Idaho geology.

The late Middle and Late Ordovician Saturday Mountain Formation and the underlying Middle Ordovician Kinnikinic Quartzite, have type localities within the Bayhorse area and were deposited in a geosynclinal-margin depositional site. These units are widely recognized to the east of the Bayhorse area where they were deposited in a platform or cratonic depositional site. The Middle Ordovician Ella Dolomite that lies beneath the Kinnikinic Quartzite may occur at several places beyond the Bayhorse area as recrystallized remnants in the igneous and metamorphic terranes to the southwest and northwest. A thick heterogeneous sequence of quartzite, conglomerate, siltite, and minor dolomite, collectively named the Clayton Mine Quartzite, disconformably underlies the Ella Dolomite and is the basal unit of an allochthonous sequence of unknown displacement.

This allochthon rests on a sequence that comprises, from top to bottom, the Ramshorn Slate, Bayhorse Dolomite, Garden Creek Phyllite, and the basal dolomite of Bayhorse Creek. No basal contact of this sequence is exposed. These strata are considered to be Early Ordovician or Late Cambrian.

An area of Middle Cambrian and older strata that is isolated by faults and Tertiary volcanic rocks probably underlies the known allochthonous sequences and may also be allochthonous. Fissile shale, massive quartzite, massive dolomite, laminated calcareous siltstone and thick-bedded, cross-laminated feldspathic quartzite comprise these strata.

Quartzite, conglomerate, and siltstone containing minor amounts of interlayered dolomite occur in the northeast part of the Bayhorse area and are considered to be the oldest group of strata known in the map area; they are probably Late Proterozoic(?) and early Paleozoic (Ordovician?).

INTRODUCTION

The Bayhorse area in east central Custer County, Idaho is a part of the large, rough, mountainous area that occupies most of the State north of the Snake River Plain. Figure 1 shows the major geographic features of the area. Elevations range from 5,000 ft to over 10,000 ft, and most of the valleys that dissect the area are narrow and steep sided. Although some of the lower lands are open, grass-covered, and semiarid, most of the mountainous parts are heavily forested. The Salmon River, that heads in the southwest corner of Custer County, flows through the Bayhorse area and together with its major tributaries provides the major routes for roads from the town of Salmon to the north and the Wood River district and the Mackay area to the south.

The Bayhorse mining district, that was discovered in 1877, was the impetus for early settlement, and mining is still a major occupation although small farms, cattle ranches, lumbering, and recreation add to the economy. The town of Challis, in the northern part of the Bayhorse area, is the County seat of Custer County and the business and supply center of the area.

The geology of the Bayhorse area is central to an understanding of the lower Paleozoic stratigraphy of east-central Idaho, and thereby, to a rational inter-

Manuscript approved for publication, April 20, 1989.

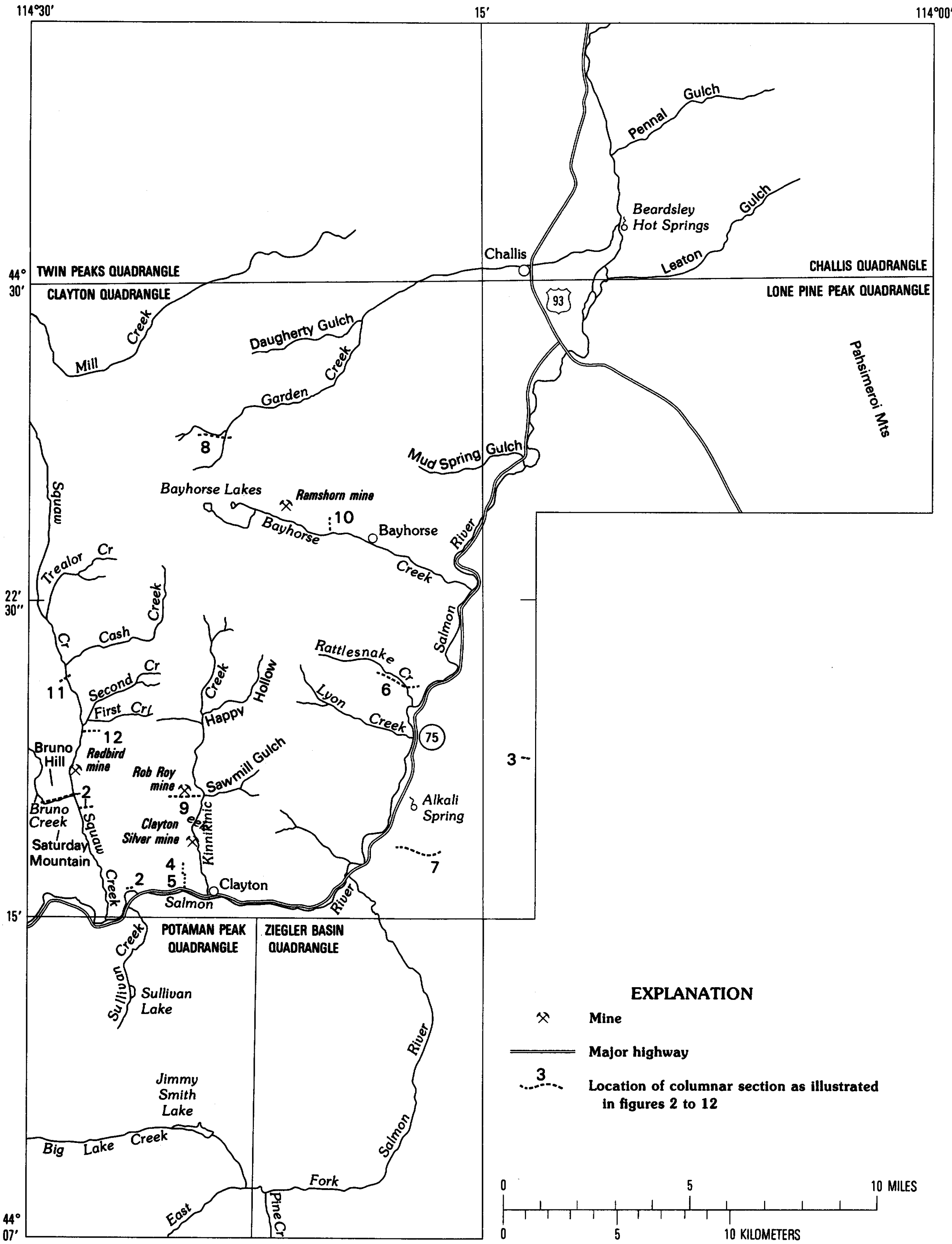


Figure 1. Index map showing location and major geographic features of the Bayhorse area, Custer County, Idaho.

pretation of the complex structural history of the area. Within this area, more than 40,000 ft of strata that range in age from Late Proterozoic to Mississippian compose the pre-Tertiary sedimentary section. The stratigraphic record includes evidence of two constrasting depositional environments in the geologic evolution of the area—one resulted in the deposition of several Middle Ordovician and younger formations that are easily correlated for long distances to the east and south beyond their type localities in the Bayhorse area; the other resulted in a number of rock units of Ordovician(?) and older age for which there are no known, or only suggestive, correlatives outside the Bayhorse area. These latter rock units are exposed in relatively restricted, and in some cases tectonically isolated, localities and appear to be of widely divergent origins and probably represent not only drastic differences in basins of deposition and source terranes but also the physical telescoping of different facies along major thrust faults. These thrusts were displaced by normal faults, and the resulting complex structure produced the tectonic isolation of several of the stratigraphic units. The problems of identity and correlation of many units are augmented by the sparsity of fossils and by an extensive cover of Eocene Challis Volcanic Group, thick Tertiary basin-fill deposits, and Quaternary deposits all of which physically isolate many exposures of the section.

This report is an attempt to identify and describe all rock units suspected or known to be of Ordovician age or older, to place them as nearly as possible in their proper stratigraphic position, and to suggest correlation with other units beyond the Bayhorse area wherever justified. Although much has been learned and new ideas have been documented, this report is for the most part a litany of problems. The recognition of the problems here may be a first step toward their ultimate solution.

SUMMARY OF EARLIER WORK

Interest in the geology of the Bayhorse area began with the discovery of gold, silver, lead, zinc, and copper during the decade from 1870 to 1879. Early reports by Eldridge (1895), Bell (1900, 1901), Lindgren (1900, p. 75–256), and Umpleby (1911, 1913a, b) focussed mainly on the history and potential of the mining districts, but these reports also included some of the first recorded discussions of the general geology, stratigraphy, geologic history, and geologic problems. This work was followed in a few years by more extensive and detailed general studies in the Sawtooth quadrangle and Mackay district by Umpleby (1915, 1917), in the Wood River region by Umpleby, Westgate, and Ross (1930), and in the Casto quadrangle by Ross (1934b). These areas, although peripheral to the Bayhorse area, provided an opportunity for more detailed study of many of the stratigraphic units that have become the object of this report. C.P. Ross, who worked for several years in these surrounding areas, turned his attention to the Bayhorse region in 1927–1930, and the resulting U.S. Geological Survey Bulletin 877 (Ross, 1937) is the firm base on which all subsequent work has been built. Later work in the Borah Peak quadrangle by Ross (1947) and the Doublesprings quadrangle by Mapel and others (1965) added more valuable information to the stratigraphic story. Other papers on specific formations or special problems of correlation and age, notably those by Churkin (1962), C.P. Ross (1960, 1961, 1962a), Mapel and Sandberg (1968), Hobbs, Hays, and Ross (1968), and Oaks and others (1977) clarified and refined various parts of the stratigraphic story.

STRATIGRAPHIC PROBLEMS AND RECOGNIZED ROCK SEQUENCES

A straight-forward chronological description of the numerous units in the report area would be difficult and potentially misleading. Geologic mapping and related investigations into the stratigraphic succession, structural patterns, and the geologic evolution of the Bayhorse area have resulted in the delineation of five groups of strata, each of which is internally consistent as to rock types, stratigraphic succession, age, and structural setting. For the most part, however, temporal and stratigraphic relations between these groups are ambiguous. Excellent paleontological data from some parts of the section contrasts with the complete lack of data or only equivocal results from other rock sequences or from other parts of the same rock group.

The distribution of the rock units described in this report and their structural and stratigraphic relations are shown on U.S. Geological Survey Map I–1882, Geologic map of the Bayhorse area, central Custer County, Idaho (Hobbs and others, 1990), and Geologic map of the Challis quadrangle, Custer County, Idaho (McIntyre and Hobbs, 1978). Plate 1 is a simplified map of the western and central part of the Bayhorse area and the immediate environs that shows the distribution of the Ordovician and older rocks, delineates the five rock groups, and shows the formational units in each group. In this report we describe the five rock groups from the best known to the least well known, and, where ages are known, each group of rocks is described from youngest to oldest. If age is indeterminate, the groups of rocks are described from top to bottom. This sequence is the reverse of the usual practice of describing stratigraphic units from oldest to youngest, but it is considered preferable in such an unknown, complex, and isolated stratigraphic terrane. Reference to U.S. Geological Survey Map I–1882 during the reading of this report will provide more accurate locations of occurrences referred to in the text, and will alert the reader to possible alternate interpretations that could result from as yet unknown structural complexities. Certain parts of the sequence, especially the quartzites and other strata closely related to them, were described in an earlier publication (Hobbs and others, 1968), and, where appropriate, these descriptions will be the basis for the expanded and more detailed descriptions in this report.

KNOWN ORDOVICIAN STRATA OF THE BAYHORSE AREA

A sequence of strata that includes the Saturday Mountain Formation, Kinnikinic Quartzite, and Ella Dolomite has been well dated from fossil evidence as Middle and Upper Ordovician. Two other units, the carbonate of Cash Creek area (Occ) and the black carbonaceous graptolite-bearing shale and argillite (Op), that are physically separated from the above sequence, are documented to be of Ordovician age but could not be dated more specifically. The distribution of these strata in the Clayton and Lone Pine Peak quadrangles is shown on plate 1. Minor extensions of these units have been mapped to the south and west of the map boundaries, and Saturday Mountain and Kinnikinic lithologies have been identified as far east as the Beaverhead Mountains along the Montana border and south to the Snake River Plain.

Saturday Mountain Formation

The Saturday Mountain Formation was named by Ross (1934a) from a ridge in the southwestern part of what is now the Clayton 15-minute quadrangle of this report on whose lower eastern slopes the strata are well exposed. In subsequent publications Ross (1937, 1947, 1961, 1962b) further described the character, distribution, and age of the unit, and he speculated on its nature and the reasons for facies changes and variations of thickness. Our more recent work has resulted in minor refinements in distribution, general character, and age of the Saturday Mountain Formation and has clarified the role of structure as related to facies changes.

At its type locality, the Saturday Mountain Formation crops out along or near both sides of lower Squaw Creek in the southwestern part of the Clayton quadrangle. Other exposures occur as intermittent outcrops along a narrow north-trending band about 2 mi (3.2 km) east of the west edge of the Lone Pine Peak quadrangle, and as two small exposures—one east of the north end of the main band, and the other in the northeast part of the Lone Pine Peak quadrangle. The total area of exposure is less than 6 mi^2 (15.5 km^2). Because complex folding and faulting have disrupted the strata in this part of the Bayhorse area, there is no place in the Clayton quadrangle where an uninterrupted stratigraphic section is exposed. As a result the thickness for the Saturday Mountain Formation in the type locality can only be estimated by piecing together a fragmented section. Between 3,000 and 4,000 ft (915–1220 m) of the Saturday Mountain Formation probably occurs in the Squaw Creek locality; some duplication may occur and parts of the section may be cut out along the numerous faults that offset the strata. A well-exposed section in sec. 4, T. 11 N., R. 19 E., Lone Pine Peak quadrangle, displays the nearly complete uninterrupted thickness of the Saturday Mountain Formation in the eastern part of the Bayhorse area. However, this exposure differs from the exposure on Squaw Creek, in that here it is only 1,000 ft (300 m) thick, contains no shale intervals, and is almost wholly dolomite.

Character

The general description by Ross (1934a, 1937, 1962b) of the lithologies that comprise the Saturday Mountain Formation provides a sound basis on which to build a more complete picture by the addition of new information from our more detailed study. In his paper on "Stratified Rocks in South-Central Idaho," Ross (1962b, p. 32) described the Saturday Mountain Formation as follows:

> In the vicinity of Squaw Creek in the Bayhorse quadrangle the formation is composed dominantly of more or less shaly dolomite and magnesian limestone, most of which contains enough carbonaceous matter to be black or nearly so on fresh fracture. In this vicinity many of the beds are more argillaceous than is common at the same horizon in other localities. The fine-grained, carbonaceous and argillaceous beds are commonly banded and more or less fissile, locally ripple marked, and some contain rounded pebbles (sic) of quartz and quartzite about 0.1 mm in diameter, but in most of the argillaceous beds quartz grains are only about 0.02 mm in diameter.*** *** In most other localities, the more argillaceous beds are absent, and the formation is composed of somewhat thin-bedded, dark-gray, locally rusty, dolomitic limestone. The strata are distinguished from the Laketown Dolomite where that unit overlies them by a more rusty appearance, somewhat darker color, and greater tendency to weather into slabs. The thickness is about 3,000 ft.

The emphasis Ross placed on the presence of argillaceous beds and impurities in the carbonate layers is well justified. Figure 2 is a composite columnar section that includes the major lithologies of the Saturday Mountain Formation along Squaw Creek in the western area of occurrence. Because of poor exposures and structural complexity, the location of the argillaceous zones and layers of impure dolomite in the stratigraphic section may be imprecise, and parts of the section may be repeated or omitted.

The base of the section where exposed along its north-trending contact with the underlying Kinnikinic Quartzite in sec. 22, T. 11 N., R. 17 E. (See Hobbs and others, 1990), about 1 mi east of the mouth of Squaw Creek is in part faulted and sheared subparallel to the contact, but there is no evidence of major disruption of the stratigraphic section. South of the Salmon River at this locality, black sandy shale or siltstone of the Saturday Mountain Formation is in sharp conformable contact with vertically dipping, clean, white Kinnikinic Quartzite. The black shale contains a well preserved fauna that has been identified as probably late Middle Ordovician (Hobbs and others, 1968, p. J11–J12). A few tens of feet above the contact the shale becomes slightly dolomitic and weathers into small buff or yellowish-gray plates and chips that are black on fresh surface. At about 35 ft (10.7 m) farther from the contact, and for some distance beyond, dip-slip deformation, probably related to faulting or shearing along the Kinnikinic contact, has produced a wide zone of pencil slate in which the horizontal *B* axes are parallel to the north-trending contact. Farther up section, the siltstone grades into limy siltstone that weathers buff to light reddish brown. The limy siltstone within several hundred feet grades into a dark-gray silty limestone that weathers into buff or light-yellow chips and plates, and includes increasing amounts of dark-blue-gray limestone that predominates toward the west end of the outcrop. Even though this lower part of the Saturday Mountain Formation is somewhat sheared and possibly faulted along planes parallel to the contact, the general sequence strongly suggests a transition over a distance of several hundred feet from black shale at the base up section through a fine sandy or silty zone to an impure limestone. On the north side of the Salmon River at this locality, the basal contact shows similar relations and more than 1,200 ft (365 m) of platy, yellow-buff-weathering, medium-dark-gray, silty limestone; and dolomitic limestone is exposed westward and up section from the basal transition zone. This exposure terminates on the west against a vertical fault boundary with the Cambrian, Devonian, and Mississippian Salmon River assemblage.

Strata on both sides of the lower reaches of Squaw Creek and west of the fault mentioned previously probably lie above the basal limestone part of the section described in the preceding paragraph, but their exact relation is indeterminate because of faulting and the extensive cover of the Challis Volcanic Group and recent colluvium. Along the east side of Squaw Creek about 3 mi from its mouth and presumably next above the basal shale-limestone sequence described, is an indeterminate thickness of probably no more than several hundred feet of medium-bedded, dark-gray, erratically mottled, fine-grained, slightly fetid dolomite that contains scattered crinoid columnals and horn corals. This dolomite is locally laced with white carbonate veinlets and generally weathers to a dark-gray, rather hackly or granular surface. Some fine sand and silt occur as local impurities, but much of the dolomite is quite pure. Scattered carbonaceous material imparts the dark color. This interval of the Saturday Mountain Formation has many attributes of the Fish Haven Dolomite with which it is probably in part correlative (Churkin, 1963). Strata above the fetid dolomite on the east side of Squaw Creek are medium-bedded, sandy or silty dolomite and minor dolomitic limestone. The color on fresh surface is medium dark to light gray, and much of the rock weathers into rough slabs and small blocks that locally are mottled pink or yellowish gray. This part of the section terminates upslope to the east against a steeply dipping north-trending fault that juxtaposed the Saturday Mountain dolomite with platy, impure limestone of Late Ordovician or Early Silurian age.

Parts of the Saturday Mountain Formation above the black fetid dolomite are exposed in a west-dipping sequence of strata on the west side of Squaw Creek and along the north side of Bruno Creek for more than a mile westward from its mouth. This sequence is fully exposed in the conical hill that is bounded by Squaw Creek on the east and by Bruno Creek on the south and west. Although this part of the section is separated from the fetid dolomite by the valley of Squaw Creek, the stratigraphic gap is probably small. Thrust and normal faults displace the section as exposed along Bruno Creek and make the true thickness and stratigraphic sequence uncertain.

The stratigraphically lowest outcrop of this part of the section lies at the mouth of Bruno Creek and on the east side of the Bruno Creek road immediately before the road turns west into the Bruno Creek canyon. This outcrop, at creek level, consists of a resistent ledge of dolomitic quartzite as much as 30 or 40 ft (10 or 12 m) thick that is overlain at road level by a few feet of black crystalline dolomite. In the west bank of the road above the dolomite, is a black, fissile, and brittle shale that contains a well-preserved graptolite fauna of Late Ordovician age. This fossiliferous horizon extends along Squaw Creek south from the mouth of Bruno Creek and also occurs to the east across Squaw Creek. It has produced a varied fauna including brachiopods and trilobites (Churkin, 1962, 1963; Ross, R.J., Jr., 1961; Ross, R.J., Jr., and Berry, 1963). The fossiliferous black shale, about 20 ft (6 m) thick, grades upward into approximately 200 ft (60 m) of medium-dark-gray to light-grayish-green, fissile and slightly calcareous shale and siltstone.

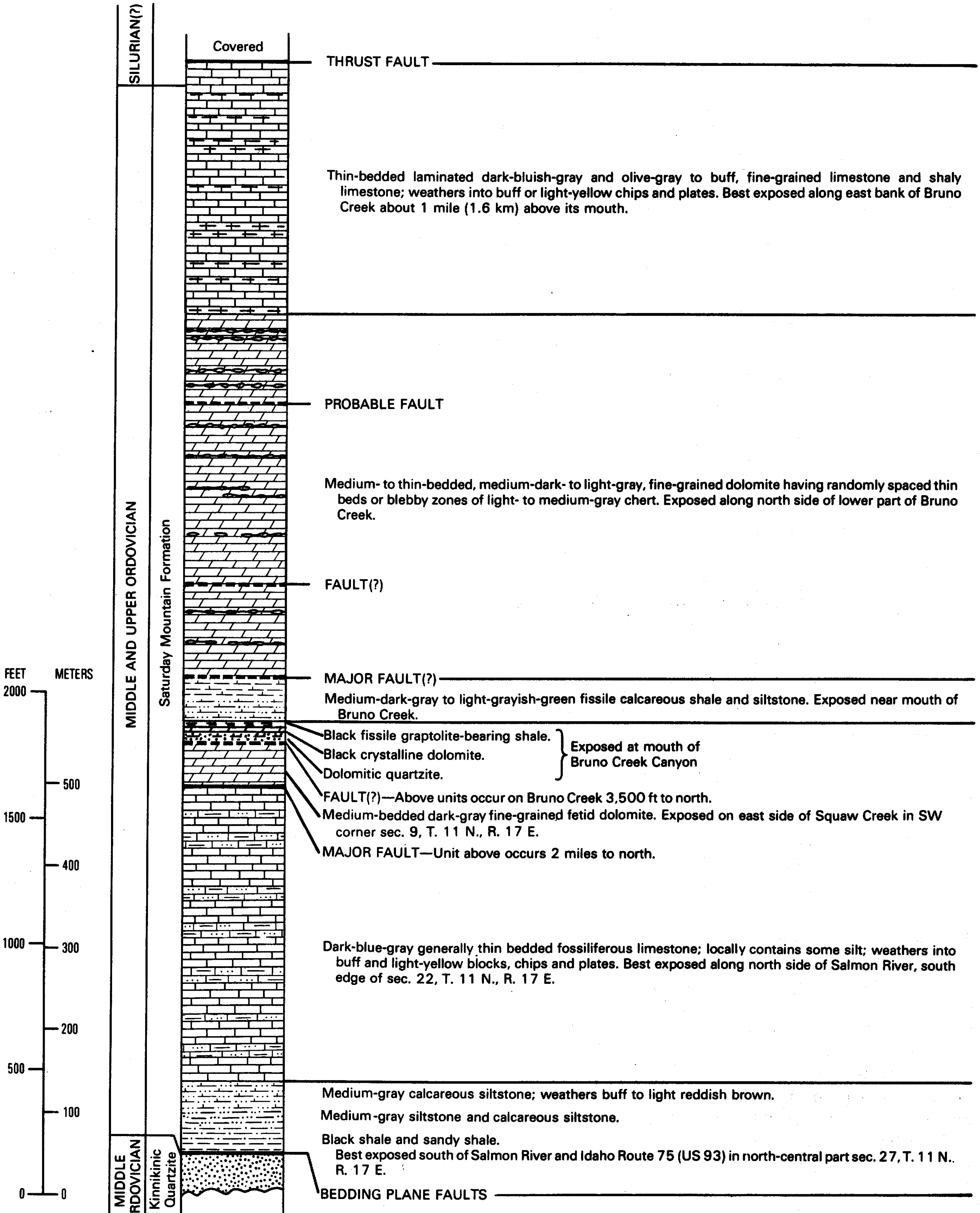
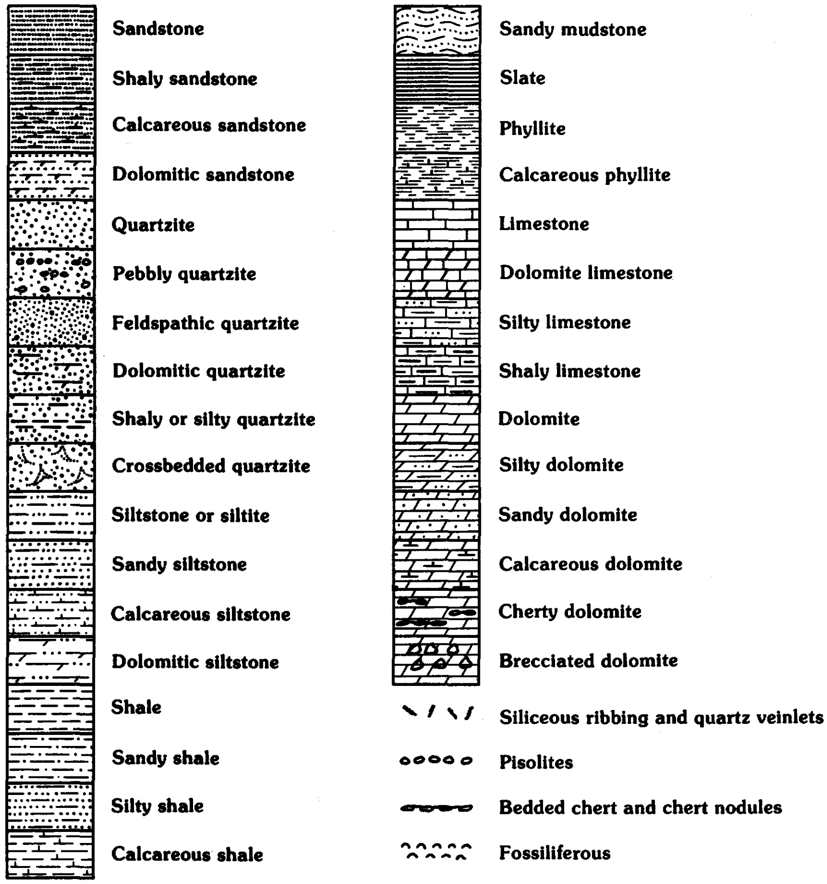


Figure 2 (above and facing page). Composite columnar section of the Saturday Mountain Formation along lower Squaw Creek valley. Some duplication or deletion of the formation probable across faults. See page 7 for explanation of lithologic symbols used in figures 2 through 12.

EXPLANATION OF LITHOLOGIC
SYMBOLS FOR COLUMNAR SECTIONS
(For figures 2 through 12)



The limy shale and siltstone interval is faulted at its west boundary against an intermixed sequence of medium-thick-bedded light-creamy dolomite, local chert layers, and areas of massive chert and minor dolomite. Some of the dolomite is sandy, and locally contains thin interbeds of platy shale and shaly limestone. The steeply dipping, sharply cross-cutting contact with the shale and siltstone interval, the mixture of rock types, and the localized occurrence of thick distorted chert masses, quartz veining, and in-faulted blocks whose stratigraphic position is indeterminate all mark a major fault zone. From this broad disturbed zone westward to beyond the crest of Bruno Hill the strata are medium- to thin-bedded, medium-dark- to light-gray, fine-grained dolomite with variably spaced thin beds or strings of elongate pods of light- and medium-gray chert. This part of the section is estimated from map measurement to be about 2,000 ft (600 m) thick but may be thickened by faulting. West of the hill crest, the cherty dolomite is overlain by more than 1,000 ft (300 m) of laminated, dark-bluish-gray and olive-gray to buff slightly impure to shaly, fine-grained limestone. This unit weathers to buff or light-yellow chips and plates. Some platy layers split into nearly paper-thin sheets along bedding. Good exposures of this limestone occur at road level along Bruno Creek on the west side of Bruno Hill.

An aberrant unit at least several hundred feet thick occurs on the lower south slopes of Bruno Hill about 0.6 mi upstream from the mouth of Bruno Creek. It continues across the creek into the steep, heavily wooded canyon wall where it is concealed beneath an allochthon of highly folded and imbricated strata that have been given the informal name of Salmon River assemblage (Hobbs, 1985a). This assemblage has yielded sparse fossils that range in age from Cambrian to Mississippian, but the stratigraphic position of the dated beds within the highly folded and imbricated allochthon is unknown, and the characteristics of these beds are herein not described.

The aberrant unit that seems to be a part of and within the Saturday Mountain Formation below the Salmon River assemblage consists of brownish-gray medium-bedded dolomitic sandstone that weathers to a rich brown. The talus from these strata tends to be blocky, and locally the rock shows much internal slump contortion. Although these beds have the same general structure as the major part of the Saturday Mountain Formation, and seem to be conformable within it, they cannot be traced much beyond the area described and their relation to the formation was not determined. The general lithology and color of the unit are more like strata of the Silurian Roberts Mountains Formation that overlies the Saturday Mountain Formation at places along Squaw Creek in the Clayton quadrangle, and in the Lone Pine Peak quadrangle (Hobbs and others, 1990; Hays and others, 1990). These aberrant beds along Bruno Creek may be a thrust slice of the Roberts Mountains Formation within the Saturday Mountain Formation. In summary, structural complications, the limited area of outcrop, and a lack of information by which to date the strata preclude identification of the unit with certainty.

In the Lone Pine Peak quadrangle, strata of Saturday Mountain Formation age differ significantly in both composition and thickness from those in the type locality. This facies of the formation is most continuously exposed as a nearly complete section in the western half of sec. 4, T. 11 N., R. 19 E. (See Hobbs and others, 1990.) Although the base of the sequence is covered and the upper contact is faulted, the section seems to be nearly complete and is similar to other less well exposed sections to the north where the actual contacts can be seen. This section has been measured and studied in detail by W.H. Hays and others (1980, p. 6, 7, 16–20), and a generalized columnar section is given in figure 3. For the most part, it consists of a medium- to thick-bedded, medium-dark- to medium-gray, microgranular to very fine grained, moderately pure dolomite that is locally laminated and commonly silty or sandy in the lower part. Chert is present not only in scattered intervals mostly as nodules and discontinuous layers, but also as fairly continuous thin layers near the top. The strata are very resistant to erosion and characteristically form ledges and cliffs that weather medium dark to medium light gray or yellowish gray and light brownish gray at the sandy basal part. Although this section is not completely exposed, its thickness is between 900 and 1,000 ft (275 and 300 m).

Differences in composition and thickness of the Saturday Mountain Formation across the Bayhorse area were recognized by Ross (1937, p. 19–20) and alluded to in other reports that describe the unit in the Borah Peak quadrangle and southern Lemhi Range to the east of the Bayhorse District (Ross, 1947, p. 1105; 1961, p. 204). Brief descriptions of the unit in the Doublesprings Pass quadrangle (Mapel and others, 1965) and in the Hawley Mountain quadrangle (Mapel and Shropshire, 1973) also to the east of the Bayhorse area, are compatible with the composition of the unit in the Lone Pine Peak quadrangle and other localities east of it.

The drastic change in the Saturday Mountain Formation within a distance of about 12 mi (20 km) could result from an abrupt facies change, but the continuity of the eastern facies at all known localities far to the east and southeast without further significant variation makes such a change over a relatively short distance difficult to explain. Separation of the two facies in the Bayhorse area by a major thrust fault provides an alternative interpretation—the original distance between the two facies has been reduced by tectonic shortening and telescoping by thrusting from the west (Hobbs and others, 1990).

Age

The thick section of Saturday Mountain Formation along Squaw Creek yielded faunas from numerous localities that give ages ranging from late Middle to Late Ordovician. Though the extensive disruption of the section by folding and faulting precludes the reconstruction of a definitive and continuous stratigraphic section, the variety of lithologies from which ages have been obtained and the various faunas that roughly span the interval from late Middle through Late Ordovician makes it plausible to infer that this section is reasonably complete. The Squaw Creek section may also include some Lower Silurian beds in its uppermost exposures. The thinner section of nearly continuous carbonate strata studied by Hays and others (1980) in the Lone Pine Peak quadrangle yielded numerous fossil collections that give an age of late Middle through Late Ordovician and include a few meters of strata of Silurian age at the top.

Kinnikinic Quartzite

The Kinnikinic Quartzite was named by C.P. Ross (1934a) from extensive exposures of quartzitic rocks along the lower reaches of Kinnikinic Creek in the Clayton quadrangle. This unit, first defined during reconnaissance mapping of the Bayhorse area, has been subject in recent years to more detailed study that has lead to redefinition and subdivision. Ketner (1964), during his general study of the origin of Ordovician quartzites in the Cordilleran miogeosyncline, first recognized that the Kinnikinic as defined by Ross should probably be subdivided, and he suggested that it is composed of an upper undoubted Ordovician unit and an underlying Cambrian and Precambrian(?) sequence possibly equivalent to quartzite strata in northern Utah. Our early work in the Bayhorse area supported Ketner's suspicions in part as it became apparent that only the upper part of the very thick sequence of quartzites in the Bayhorse area was correlative with an extensive sheet of Middle Ordovician, relatively pure, fine-grained

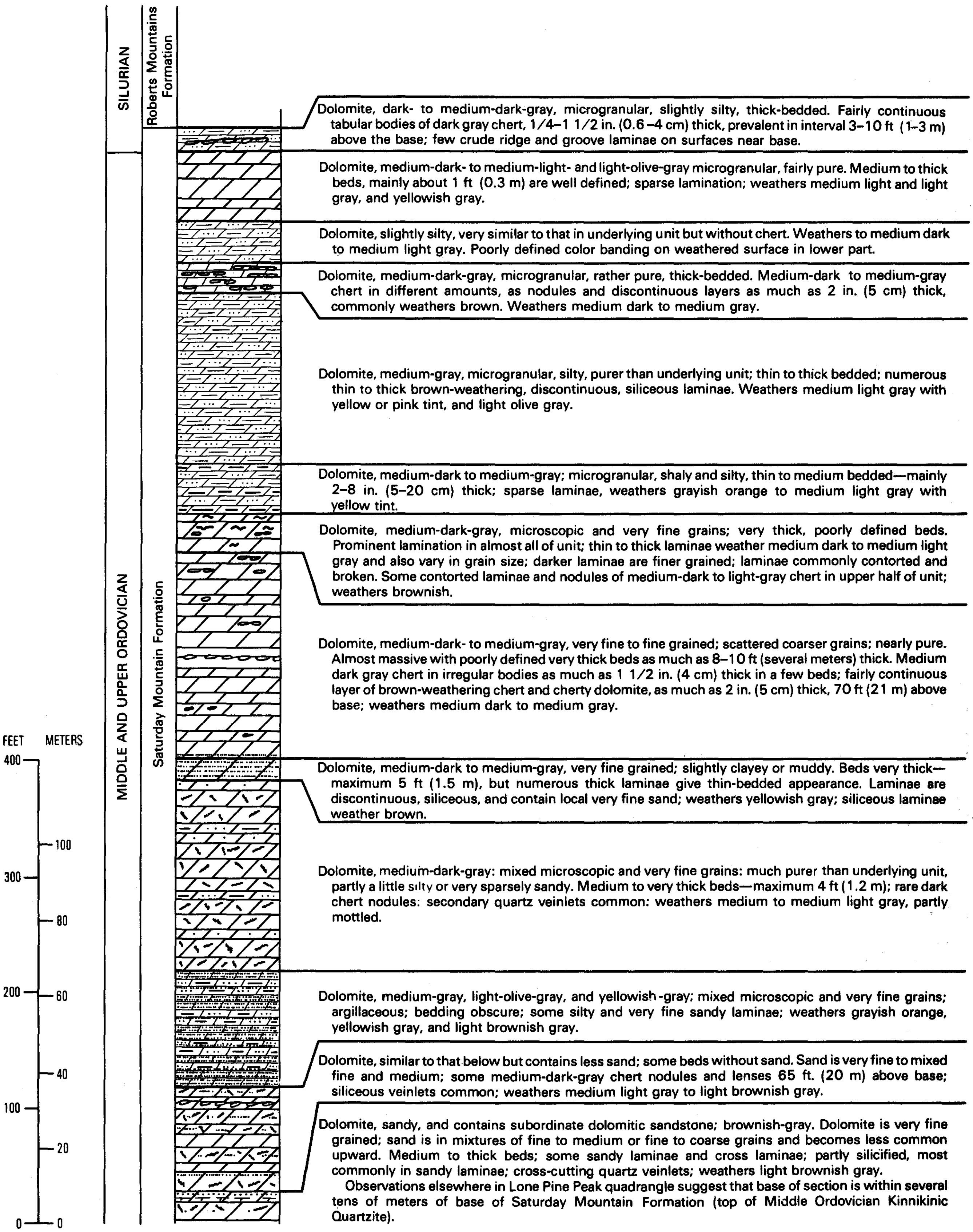


Figure 3. Measured columnar section of the Saturday Mountain Formation in the southwestern part of the Lone Pine Peak quadrangle (W½ sec. 4, T. 11 N., R. 19 E.), Bayhorse area, Custer County, Idaho (Hays and others, 1980). See page 7 for explanation of lithologic symbols used in this figure.

quartzite that is now called Kinnikinic over wide areas to the east and southeast of the type locality (Hobbs and others, 1968). Detailed studies by James and Oaks (1977), and by Oaks and James (1980) on the Kinnikinic as now redefined led to a refinement of stratigraphic detail and the establishment of a more characteristic, complete, and structurally undisturbed reference section near Arco, Idaho. The lower part of Ross's original Kinnikinic has been subdivided into at least six units of probable Early Ordovician, Cambrian, and possibly Precambrian age.

Distribution

Kinnikinic Quartzite as now defined has very limited distribution in the Bayhorse area. Most extensive exposures are in a discontinuous line of outcrop parallel to and about a mile east of the lower 4 mi (6.4 km) of Squaw Creek; an extension of these outcrops continues southward across the Salmon River and into the Potaman Peak quadrangle for an additional 1.5 mi (2.5 km) along the east side of Sullivan Creek. About 5 mi (8 km) due north of the lower Squaw Creek exposure is a small isolated outcrop of Kinnikinic that is clearly an extension of the same unit. A short distance to the west of the Clayton quadrangle, in the Thompson Creek 7½-minute quadrangle, another small exposure is in the headwaters of Bruno Creek. A series of outcrops along State Highway 75 (formerly U.S. 93) on the north side of the Salmon River, about 2 mi (3.2 km) west of the town of Clayton, has been designated the reference section for the Kinnikinic Quartzite (Hobbs and others, 1968).

Other Kinnikinic Quartzite outcrops are in the central part of the Bayhorse area east of the Salmon River between the mouth of the East Fork at the south and Mud Spring Gulch at the north. Part of these mark the leading edge of a major thrust fault near Alkali Springs in sections 12 and 13, T. 11 N., R. 18 E. (See Hobbs and others, 1990), about 2.5 mi (4 km) east-northeast of the mouth of the East Fork. Other outcrops parallel the Saturday Mountain Formation east of Germer Basin in the west-central part of the Lone Pine Peak quadrangle.

Character

The Kinnikinic Quartzite has been described by various workers from different points of view. Ross (1934a) who formally named it for rocks in the Bayhorse area, was apparently influenced in his description by similar quartzites in the Lost River and Lemhi Ranges that were described originally by Umpleby (1917), and Shenon (1928), and that are overlain by Upper Ordovician dolomites in the same way that the Kinnikinic is overlain by the Saturday Mountain Formation in the Bayhorse area. The quartzites at these more easterly localities were considered by Ross to be probably equivalent to the quartzites near Bayhorse. The following description of the Bayhorse area reference section for the Kinnikinic Quartzite is from the report of James and Oaks (1977).

> The Kinnikinic Quartzite is a silica-cemented, supermature quartz arenite. Although predominantly fine- to medium-grained, it is locally coarse-grained or even very coarse-grained. In the type area it is generally very fine to fine-grained, and contains shaly interbeds near the middle. Rarely, dolomite cement is present. Where sedimentary structures are visible, the Kinnikinic exhibits chiefly parallel laminae within thin to medium parallel bedding. Less commonly, medium to thick beds contain medium- to high-angle cross-laminae. Small-scale ripples and shallow scours are rare. Although found in only six sections, *Skolithos* is the predominant trace fossil, and is concentrated within distinct zones. Grains, more than 99 percent quartz, are chiefly rounded to well-rounded and moderately to well-sorted. Silica cement gives the unit its characteristic vitreous appearance.
>
> Fresh surfaces of Kinnikinic usually are white (N9) to very light gray (N8), but colors range to yellowish gray (5Y 8/1), pinkish gray (5YR 8/1), and even yellowish brown (10YR 5/4). * * * From middle distances, the Kinnikinic usually appears white to light brown in color.

The original reference section in the Bayhorse area is somewhat atypical, as shown by Oaks and James (1980), who divided the formation there into three members, the middle of which contains an anomalous amount of dark shaly beds that are sparse or absent in the eastern counterparts of the unit. A second reference section proposed by Oaks and James (1980) near Arco, Idaho, about 70 mi (112 km) to the southeast, contains no shale interbeds. James and Oaks (1977, p. 1499) proposed that the Bayhorse section—one of the most westerly exposures—probably represents an outer-shelf facies where interfingering argillaceous beds might be expected. Further support of this hypothesis comes from our structural interpretation of the Bayhorse area whereby the Kinnikinic Quartzite of the original reference section is part of a thrust plate that has been moved from the west and consequently from an even more westerly site of deposition. A distinctive and different lithology is thereby expectable.

Age

The Kinnikinic Quartzite is underlain by the Ella Dolomite that is early Middle Ordovician in age on the basis of good fossil evidence, and the Kinnikinic is overlain by the Saturday Mountain Formation whose lower beds are late Middle Ordovician. These ages restrict the Kinnikinic Quartzite in this area to the Middle Ordovician.

Ella Dolomite

The Ella Dolomite, first named informally in a thesis by Patten (1948), was formally adopted by Hobbs and others (1968) for a sequence of dolomitic strata at least 700 ft (210 m) thick that lies in apparent conformity below the Kinnikinic Quartzite near Clayton in the Bayhorse area, and rests on the Clayton Mine Quartzite along a disconformity or low-angle unconformity. The general features, distribution, and characteristics of the Ella Dolomite are described by Hobbs and others (1968), and the salient parts of this description (p. J12–J14) are paraphrased below and a measured columnar section is illustrated in figure 4.

Distribution

A minimum of 700 ft (215 m) of massive dolomite and sandy dolomite lies below the Kinnikinic Quartzite in the anticline along the Salmon River canyon west of the town of Clayton. The beds in this fold bend down sharply into the nearly vertical east limb of the anticline and form spectacular exposures along the west side of Kinnikinic Creek between a point near its mouth at Clayton and the Clayton Silver mine abut 1.5 mi (2.4 km) upstream. Some of these steeply dipping beds are also exposed along the road that follows the east side of Kinnikinic Creek.

The most complete, best exposed, and least disturbed section is that of the nearly flat-lying beds on the crest of the anticline, high on the cliffs that form the north wall of the canyon west of Clayton. This stratigraphic section has been designated the type section (Hobbs and others, 1968) and its general characteristics are shown in figure 4. The dolomite is also exposed in the south wall of the Salmon River canyon in the west limb of the anticline and extends southward as a discontinuous band of outcrops for several miles on the east side of the valley of Sullivan Creek to a point where the dolomite is covered by landslide debris and Challis Volcanics.

Small isolated outcrops of dolomite that probably correlate with the Ella Dolomite occur for several miles to the north-northwest of the type section in a gently rolling area between 7,000 and 7,200 ft (2,100 and 2,200 m) in altitude that is mantled in large part by volcanics of the Challis, extensive talus, landslides, and colluvium. A thin fault slice of Ella Dolomite is exposed at an altitude of 9,000 ft (2,750 m) on the sharp crest of the quartzite ridge west of Kinnikinic Creek and about 1.5 mi (2.5 km) north of the Clayton Silver mine (Hobbs and others, 1990). Middle Ordovician dolomite crops out at intervals for several miles along a north-trending line east of the Salmon River and the East Fork of the Salmon River. These strata are part of the thick, overturned leading edge of a major allochthon and most likely are tectonically thinned and disturbed. Similarity of lithology and stratigraphic position between the Kinnikinic Quartzite and the Clayton Mine Quartzite assures the correlation of this dolomite with the type section of the Ella Dolomite.

A small exposure of the Ella Dolomite is in the upper reaches of Trealor Creek in the west-central part of the Clayton quadrangle, and faulted segments of dolomitic strata east and northeast of Germer Peak have been confirmed from fossil evidence to be equivalent to the type Ella Dolomite (pl. 1).

Ella Dolomite has been definitely dated and delineated only in the Bayhorse area. However, in the Pioneer Mountains east of Ketchum, Idaho, nearly 40 mi (64 km) south-southeast of Clayton (Dover, 1981), and on Loon Creek about 30 mi (48 km) to the northwest of Clayton (Ross, 1934b), metamorphic sequences occur as roof pendants or as wallrock adjacent to the Idaho batholith and contain white or light-tan granular dolomitic marble that is almost certainly equivalent to the type Ella Dolomite. In both places, the marble is overlain by fine-grained quartzite that probably is Kinnikinic and underlain by coarse-grained feldspathic quartzite that is in most respects analogous to the Clayton Mine Quartzite that underlies the Ella Dolomite in the Bayhorse area. These two occurrences are nearly on regional strike with the Bayhorse Ella and are probably in a similar structural setting.

East of the Bayhorse area, no Ella Dolomite has been identified but a rather extensive sandy dolomite is present beneath the Kinnikinic Quartzite for about 35 mi (56 km) in the southern part of the Lemhi Range, and similar sandy dolomite has been found in the Lost River Range (Buetner and Scholten, 1967; James and Oaks, 1977). These sandy dolomites may be in part an eastern equivalent of the Ella Dolomite of the Bayhorse area.

Character

The Ella Dolomite is a sequence of dominantly medium- to thick-bedded dolomite, most of which contains some silt and fine sand, usually in thin laminae that show as fine ribbing or a hackly texture on weathered surfaces; laminae are not obvious on fresh fractures. Most of the dolomite is fine grained, but some portions as much as 25 ft (7.6 m) thick are medium to coarsely crystalline. Color generally is medium to medium dark gray, commonly with a brown or tan cast, but some layers are lighter gray, and some are dark gray to almost black. Weathered surfaces are predominantly tan, brown, or yellowish gray. Some layers near the base have a coarsely crystalline texture, a dark-gray color, and weather to deep brown. This basal zone has proved useful as a marker bed.

Locally, about 230 ft (70 m) above the base of the Ella, a 20- to 30-ft-thick (6–9 m) sequence of beds

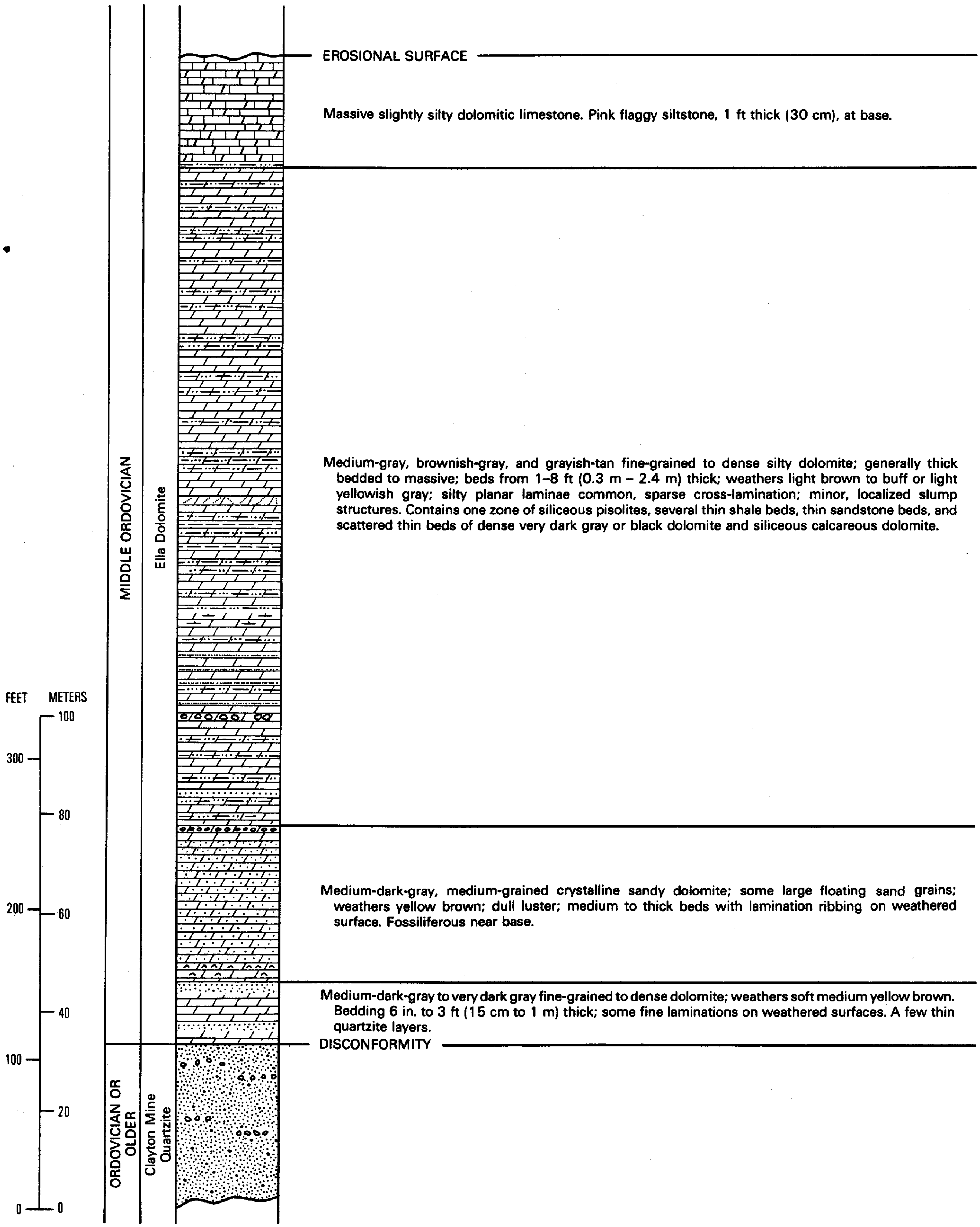


Figure 4. Measured columnar section of the Ella Dolomite at its type locality, E½ sec. 23, T. 11 N., R. 17 E., near the southern border of the Clayton 15-minute quadrangle, Bayhorse area, Custer County, Idaho. See page 7 for explanation of lithologic symbols used in this figure.

consists of fine-grained quartzite, sandy dolomite, and some replacement chert. One highly silicified zone has a pisolitic appearance that may have resulted from the replacement of subspherical algal structures by silica. Microlayered siliceous laminae may also have resulted from the replacement of algal structures.

Age

Brachiopods and conodonts from a sequence of dark-gray dolomite near the base of the type section of the Ella Dolomite and conodonts from dolomite about 450 ft (137 m) above the base were determined by R.J. Ross, Jr., and J.W. Huddle of the U.S. Geological Survey to be of probable early Middle Ordovician age; we thus assign the Ella Dolomite to the Middle Ordovician (Hobbs and others, 1968, p. J14–J15). The narrow sliver of Ella that crops out northwest of the Clayton Silver mine on the 9,000-ft (2,750-m) high ridge is much like the lower part of the measured section and contains poorly preserved fossil fragments that are similar to those described for the type section.

Carbonate of Cash Creek Area

Two exposures of dolomite, each less than 0.1 mi^2 (0.25 km^2) in area, crop out to the east and west of Squaw Creek about 7 mi (11.3 km) north of the Salmon River (pl. 1). One exposure is about a half mile west of Squaw Creek from a point nearly 1 mi (1.6 km) south of the mouth of Cash Creek. The other and larger exposure is east of Squaw Creek and on the north side of Cash Creek about 2 mi (3.2 km) from its mouth.

Character

The carbonate of the Cash Creek area is a somewhat silty, light- to medium-light-gray or pale-yellowish-brown, fine-grained dolomite containing some very fine sand. On weathered surfaces the rocks range from medium tan to dark grayish yellow or medium to deep brown. In places the dolomite is slightly recrystallized and nearly pure white; elsewhere, it is medium dark gray and very fine grained. For the most part the strata are medium to thick bedded and locally massive, but near the base they tend to be medium to thin bedded and to include more fine sand and silt.

The basal contact of the dolomite is probably a disconformity or a low- angle unconformity. Exposures are poor, and the accessible contact is limited; at one place west of Squaw Creek the dolomite rests with apparent conformity on Cash Creek Quartzite of Middle or Lower Cambrian age and, within a thousand feet along strike, on a Middle Cambrian shale that stratigraphically overlies the Cash Creek Quartzite. These two localities are on a near planar erosion surface on which the dolomite was deposited. What appears to be a pre-dolomite steeply dipping cross-fault separates the two localities. At the exposure east of Squaw Creek the dolomite beds rest on and seem to be conformable with rather thin remnants of the Middle Cambrian shale. The relations at both dolomite outcrops indicate a situation wherein Ordovician dolomite was deposited upon an eroded surface cut across Middle Cambrian strata that had been uplifted, locally faulted, but not notably folded during Late Cambrian or possibly Early Ordovician time.

This dolomite is overlain in both outcrop localities by heterogeneous quartzites of unknown age, and the contact, wherever seen, is a major thrust fault that is marked by brecciation and disruption of both units, gossan zones, and slickensides. At least 700 ft (215 m) of dolomite is exposed in Cash Creek, but a thrust fault at the top makes determination of its original thickness impossible. Because of the fragmentary nature of the fossil record and the nondefinitive stratigraphic and structural relations to the underlying Middle Cambrian shales and the overlying quartzite allochthon we are unable to relate this dolomite unequivocally to any of the other better known carbonate units within or beyond the Bayhorse area.

Age

The dolomite was deposited on Middle Cambrian beds. A small collection of conodonts from about the middle of the section on Cash Creek has been determined by R.J. Ross, Jr., L.A. Wilson, and J.W. Huddle (written commun., 1967) of the U.S. Geological Survey to be definitely of Ordovician age. Although only the eastern outcrop is dated from fossil evidence to be of Ordovician age, the western exposed dolomite is considered to be correlative on the basis of stratigraphic similarities and structural position. The following pertinent paleontological information on the Cash Creek locality is given:

USGS Collection D1799 CO. Dolomite, float near outcrop at approximate altitude 6,720 ft on low ridge on north side of little creek, 1,275 ft N. 44 ½ °E. from summit of hill 7246.

Tiny brachiopod fragments. These are articulates. One pedicle valve could be a very immature *Hesperorthis*. The other fragments are not even worth a guess. My bets here are post-Cambrian, pre-Devonian, probably Ordovician.

USGS Collection D1800 CO. Dolomite, north side of Cash Creek, 2.1 to 2.2 mi upstream from mouth of creek, Bayhorse Lake quadrangle.

Conodonts, probably include *Drepanodous* according to L.A. Wilson. Age probably Ordovician.

Huddle (written commun., 1968) reports the following:

Cordylodus sp.	1
Drepanodus suberectus Branson and Mehl	1
bar conodont	1

These conodonts indicate an Ordovician age for the dolomite as was indicated by L.A. Wilson. The specimens have been replaced by drusy quartz probably in internal molds. I have never seen conodonts with this type of preservation before.

Although the generalized Ordovician age of this carbonate unit suggests possible correlation with the Ella Dolomite, its stratigraphic position in depositional contact upon Middle Cambrian shale and Cash Creek Quartzite makes this correlation less tenable.

Black Carbonaceous Graptolite-Bearing Shale and Siltstone

Black to dark-gray carbonaceous shale and local, thinly laminated, medium-gray to tan siltstone crop out as narrow exposures along the lower reaches of Big Lake Creek and along Pine Creek near the junctions of these streams with the East Fork Salmon River at the south boundary of the Bayhorse area (pl. 1). At both places the shales occur in windows eroded in a nearly flat-lying thrust plate of the Salmon River assemblage (Hall, 1985).

These outcrops consist dominantly of shale with lesser amounts of siltstone that are jet black on fresh surfaces but weather to a medium dark gray or silvery gray. Silty layers show light- and dark-gray laminae with intermixed light-brown or tan laminae. In many places, especially close to the overlying thrust plate, the shale is highly crinkled and distorted and cleavage surfaces are coated with carbon slicks. Where the rock is less distorted, laminae and faint bedding planes can be identified, and at several of these localities graptolites are preserved. Collections of these fossils from one locality on Big Lake Creek were described by R.J. Ross, Jr., as follows:

USGS Collection D1962 CO. Phi Kappa Formation, SW corner sec. 30, T. 10 N., R. 18 E. Idaho coordinates, central zone: Potaman Peak 7½-minute quadrangle, Idaho.

Climacograptus 2spp

Glyptograptus sp

Age: Middle or Late Ordovician. Sheared nature of sediments hinders identification, but I believe these graptolites are probably correlative with those from the Saturday Mountain Formation on Bruno Creek.

The general character and age of these shales is very similar to that of Phi Kappa Formation in the Pioneer Mountains about 20 mi to the south- southeast. The probable correlation of the black shales in Big Lake Creek and Pine Creek with a part of the Phi Kappa Formation is discussed by Dover and others (1980, p. 5–14). As redefined and restricted by Dover and others (1980), the Phi Kappa comprises approximately 800 ft (240 m) of black shales that range in age from Early Ordovician at the base to Middle Silurian at the top. The black shales in the Bayhorse area are but a small part of a very thick section of Ordovician rocks that include the Ella Dolomite, Kinnikinic Quartzite, and Saturday Mountain Formation and that total more than 4,700 ft in thickness. These two very disparate Ordovician sections, that are now nearly adjacent, represent two facies of Ordovician strata that were deposited in different environments and juxtaposed by thrust faulting that has moved one over or near the other.

ORDOVICIAN OR OLDER QUARTZITE SEQUENCES

Quartzites of several distinctive types, originally mapped by C.P. Ross (1937) as belonging to the Kinnikinic Quartzite, crop out over more than 30 mi^2 (80 km^2) of the Bayhorse area. The redefined Kinnikinic is greatly restricted and consists of a total outcrop area of only about 0.75 mi^2 (2 km^2). The remaining part of the original Kinnikinic Quartzite exposures, as described by Ross (1937), comprises at least eight separate groups of strata whose ages and correlatives are unknown or questionable. Six groups, those combined here and on plate 1 as the Ordovician or older quartzite sequences, are suspected to be Lower Ordovician or Upper Cambrian. The other two groups of strata, the Cash Creek Quartzite and the basal quartzite of Boundary Creek, are known to be older than Middle Cambrian. These are discussed later under Middle Cambrian and older rocks of Squaw Creek.

The most widespread of the probable Ordovician-Cambrian part of the quartzite section was named the Clayton Mine Quartzite by Hobbs and others (1968), and the general description of the unit was based on a type section measured on the north wall of the canyon of the Salmon River west of the town of Clayton. Widely distributed exposures of quartzite to the east and north of the type section have been mapped as Clayton Mine Quartzite on the basis of similar lithology and geologic relations. Most of these correlations are well substantiated even though specific dating or physical continuity is lacking. In places, however, quartzite bodies that in most respects appear to be a part of the Clayton Mine package are sufficiently different lithologically, structurally, or in their stratigraphic relation to other rock units as to make their direct correlation with the Clayton Mine Quartzite suspect. In the following discussion these suspect groups of quartzites (Osq, Och, Osp, O€rr, and O€q on pl. 1) are described separately because of doubts regarding direct correlation and to emphasize the significance they may have in an understanding of the very complex structural history of the area.

Clayton Mine Quartzite

Most of the rocks included as Clayton Mine Quartzite (Hobbs and others, 1968) are part of a sequence of strata that differ from one outcrop to another. This sequence, however, is considered to have been a single, once continuous depositional unit that includes both vertical and lateral facies changes. Salient parts of the description of the Clayton Mine Quartzite as exposed across the area are paraphrased here from Hobbs and others (1968), and representative columnar sections are given in figures 5–8.

At its type section, the Clayton Mine Quartzite (fig. 5) is overlain by the Ella Dolomite along an apparently conformable contact that may, however, be a very low angle unconformity or regional disconformity. The strata that make up the Clayton Mine Quartzite below this contact are heterogeneous in composition, grain size, degree of sorting, and bedding, and total more than 2,000 ft (610 m) thick. The basal contact is not exposed. These strata contrast sharply with the very fine grained, clean, light-colored Kinnikinic Quartzite that overlies the Ella Dolomite and with which they were included by early workers (See Hobbs and others, 1968).

Distribution

The Clayton Mine Quartzite is the most widely distributed of the quartzites in the general Bayhorse area. The massive cliffs below the Ella Dolomite on both sides of the Salmon River canyon, west of the town of Clayton, are all formed by this unit; these same resistant rocks can be traced for several miles to the northwest of the river where they make up the high ridges between Squaw Creek and Kinnikinic Creek (pl. 1). They also extend for several miles south into the Potaman Peak and Ziegler Basin quadrangles, where they form the high rugged terrane along the south side of the Salmon River. Other extensive exposures of quartzite crop out in discrete, widely separated areas along the Salmon River north-northeastward from the junction of the East Fork of the Salmon River to within about 5 mi (8 km) of Challis, for several miles along the east side of the East Fork, on Poverty Flat, and for over 4 mi (6.5 km) northward from the Bayhorse Lakes in the north-central part of the Clayton 15-minute quadrangle.

In the Pioneer Mountains, about 40 mi (65 km) south of the type section of the Clayton Mine Quartzite, and in the Loon Creek area about 30 mi (48 km) to the northwest, high-grade metamorphic rocks contain conglomeratic quartzite that is probably equivalent to the Clayton Mine Quartzite. In both places these quartzites are overlain by metadolomite that in the Pioneer Mountains contains sparse fossil remains that suggest an Ordovician age (Dover, 1981, p. 30). A fine-grained very pure quartzite that lies above the dolomite is very probably correlative with the Kinnikinic Quartzite in the Bayhorse area. The Clayton Mine Quartzite has not been identified at any other locality outside the Bayhorse area.

Character

The following description of the Clayton Mine Quartzite is based primarily on two measured sections and two generalized composite sections that are widely spaced, represent the general lithology, and illustrate the variations that are inherent in strata that were deposited in a predominantly high-energy environment.

Feldspathic quartzite, that makes up the major part of the type section, is mostly medium to coarse grained. It ranges from light gray to very light gray and much of it has a very light yellow to orange cast; locally, it is pinkish or purplish gray. Most of the quartzite is less clean and vitreous than the Kinnikinic Quartzite. Weathered surfaces are commonly grayish orange, moderate brown, grayish red, and yellowish gray.

Bedding ranges widely from thick bedded or massive to thin bedded. Thin zones of flagstone occur locally. Crossbedding occurs at intervals throughout the measured section but seems to be more prevalent in the lower half. Some beds as much as 10 ft (3 m) thick comprise only one set of through-going cross laminae; more commonly, the cross-laminated layers are much thinner.

The great bulk of the strata is composed of moderately well rounded quartz grains that are characteristically poorly sorted. Thin conglomerate lenses, pebbly quartzite, and scattered pebbles occur in the upper two-thirds of the section. The upper 250 ft (76 m) is predominantly pebble-bearing quartzite containing rounded quartz pebbles that are mainly about ¼ in. (6.4 mm) in diameter but are locally larger than 1 in. (25.4 mm). The pebbles are predominantly colorless to dark-gray vitreous quartz and quartzite, but a few are chert, feldspar, and siltite. Dark, deep-blue-gray, very distinctive quartz pebbles are locally abundant. Feldspar, usually more angular than the quartz, is distributed throughout the section, except for the interval between 225 and 475 ft (68 and 145 m) from the top, which is virtually feldspar free. Even this interval contains microscopic structures that suggest complete

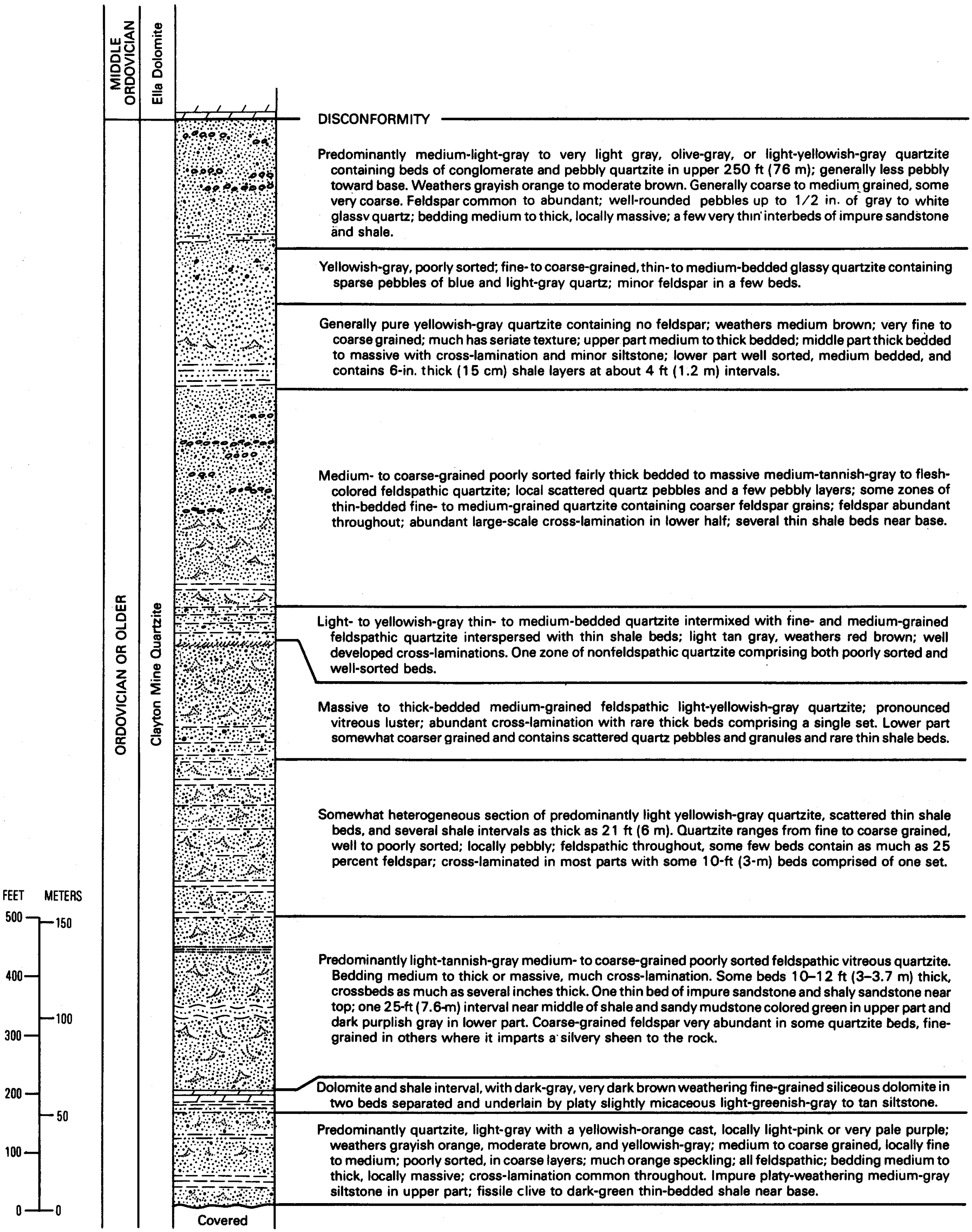


Figure 5. Measured columnar section of the Clayton Mine Quartzite at its type locality, SE¼ sec. 23, T. 11 N., R. 17 E., near the southern border of the Clayton 15-minute quadrangle, Bayhorse area, Custer County, Idaho. See page 7 for explanation of lithologic symbols used in this figure.

replacement of original feldspar grains by quartz and sericite. The feldspar ranges in size from small specks to fragments nearly ½ in. (12.7 mm) long, and, in places, feldspar forms possibly as much as 20 percent of the rock. Some is fairly fresh, but most is altered and is dull yellowish gray to white.

Very thin shale partings occur throughout the formation, and the lower half contains several shale intervals as much as 40 ft (12 m) thick and one interval 200–300 ft (60–90 m) thick of interlayered quartzite, shaly quartzite, and thin beds of shale and siltstone. The shale is well bedded, generally fissile, and variably micaceous, and commonly includes sandy layers. The shale is mainly pale yellowish green or greenish gray; a little is grayish green and dark purplish gray. The siltstone is grayish yellow and greenish gray.

Two layers of dolomite separated by about 3 ft (1 m) of shale are enclosed in quartzite at 1,730 ft (527 m) below the top of the type section; the upper layer is 15 ft (45 m) thick, and the lower is 2 ft (0.6 m) thick. The dolomite is fine grained, medium to dark gray, and contains small amounts of sand and silt. It weathers to deep chocolate brown. Silty laminations weather out as fine ribbing on the surface.

The Clayton Mine Quartzite on the north side of the Salmon River west of Clayton (pl. 1; fig. 5) measures 1,980 ft (604 m) from the base of the overlying Ella Dolomite to the lowest exposure at the top of talus that covers the lower slopes. The rocks here are little deformed and represent a minimum thickness for the formation. An unknown thickness lies below the lowest outcrop. Along State Highway 75 (formerly U.S. 93) east of the type section, (5 on pl. 1), a few exposures of silty quartzite and shale on the east limb of the anticline are perhaps stratigraphically lower than the base of the type section. These beds, however, are separated from the measured section by a steeply dipping shear zone of unknown displacement, and therefore they cannot be projected into the measured section.

The upper several hundred feet of conglomeratic quartzite with its contact with the overlying Ella Dolomite, as exposed in the type section, is one part of the Clayton Mine Quartzite that is easily recognized, widespread, and because of abundant pebbles reasonably distinctive. Recognition of this zone has permitted most of the larger and more widely spaced quartzite units to be tied together with reasonable confidence in spite of significant differences in other respects. However, a number of other widely spaced, discontinuous, and isolated blocks of quartzite are in many places sufficiently different in composition, color, grain size and general aspect that direct correlation with the type section of the Clayton Mine Quartzite is uncertain. The stratigraphic base of the Clayton Mine Quartzite has not been unequivocally established, and some of the quartzite blocks that are in question may belong to a lower part of the formation that is nowhere fully exposed.

The extensive scattered outcrops along the Salmon River from the vicinity of the junction of the East Fork north-northeasterly to Mud Spring Gulch, a distance of 12 mi (18 km), differ in several significant aspects from the type section. Many of the quartzite beds, and especially the siltstones, are more colorful in shades of pink, light red, purple, and locally dark maroon. Shale and siltstone intervals are more abundant and in a few places exceed 200 ft (60 m) in thickness. Feldspar, so abundant in the upper part of the type section, is much less abundant in the upper part of the section near Alkali Springs, (fig. 7); the measured section of the quartzite in Rattlesnake Creek (fig. 6) is nearly 1,000 ft (305 m) thicker than the exposed part of the type section. A more significant difference affects the upper part of the section as exposed in the extensive outcrops in the Germer Peak–Bishop Springs area on both sides of the Salmon River north from the mouth of Bayhorse Creek. In a syncline on Germer Peak several hundred feet of medium- to thick-bedded, light-gray to pinkish-tan, fine- to medium-grained relatively pure quartzite constitutes the uppermost unit of the Clayton Mine Quartzite. This fine-grained quartzite lies conformably on the upper conglomeratic quartzite of the Clayton Mine type section and is overlain by the Ella Dolomite on a contact that may be either a disconformity or low-angle unconformity. Thick quartzite sequences in the upper reaches of Bayhorse and Garden Creeks, that are considered part of the Clayton Mine sequence, are also richly colored, conglomeratic near the top, and moderately feldspathic (fig. 8). We have little doubt that these beds are part of the Clayton Mine Quartzite.

Of the other isolated blocks of quartzite that were mentioned previously, those on Poverty Flat, in Happy Hollow, and east of the upper reaches of Kinnikinic Creek are, on the basis of lithology, acceptable as equivalent to some part of the Clayton Mine Quartzite sequence. Others are less certain.

Age

The age of the Clayton Mine Quartzite is not known; no fossils have been found in any part of the sequence and stratigraphic relations of its upper and lower contacts are uncertain. The formation lies with apparent conformity below the basal fossil-bearing zone of the Middle Ordovician Ella Dolomite suggesting that it is Middle Ordovician or older. However, the

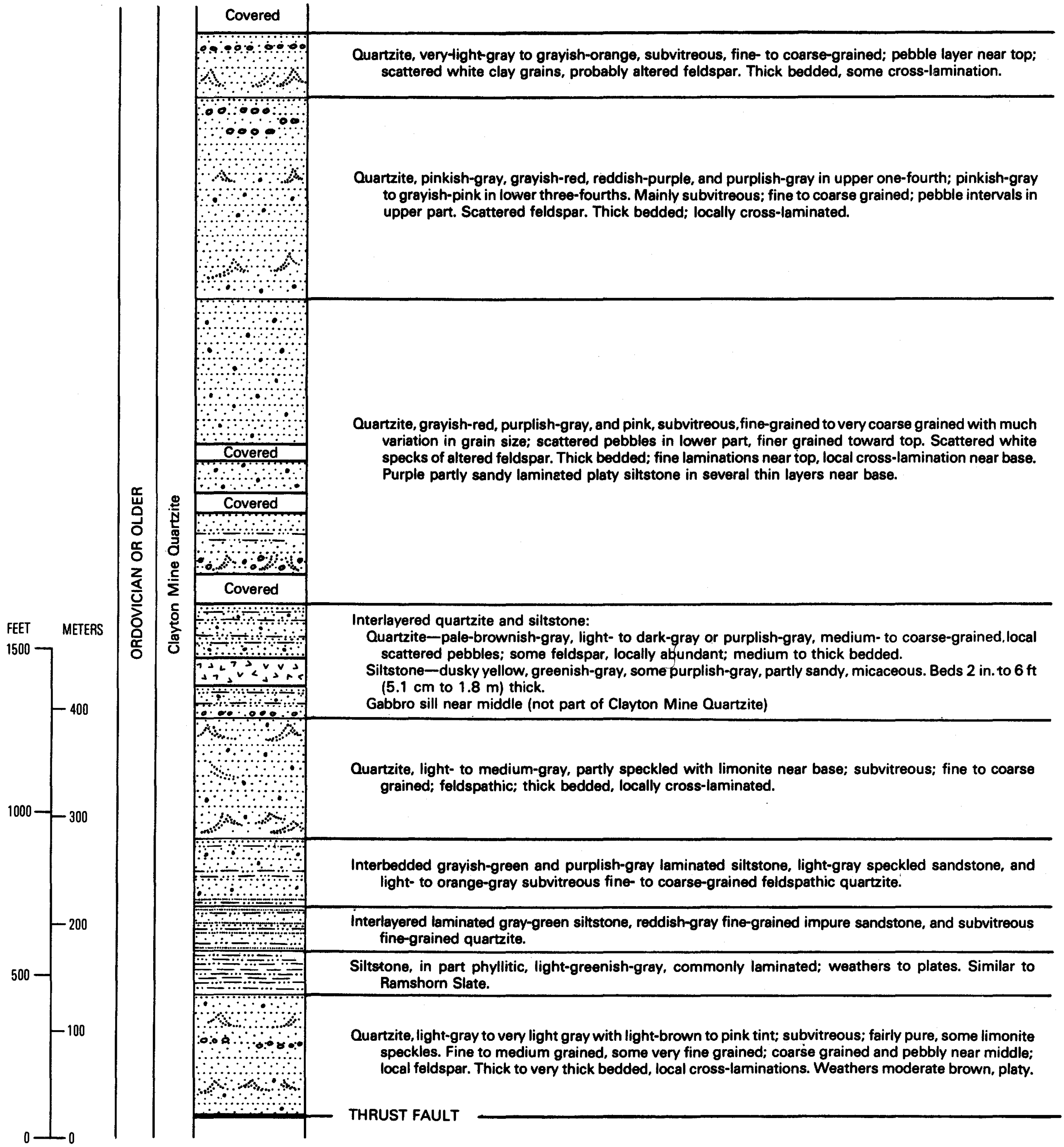


Figure 6. Measured columnar section of the Clayton Mine Quartzite on Rattlesnake Creek, secs. 25 and 26, T. 12 N., R. 18 E., in the east-central part of the Clayton 15-minute quadrangle. See page 7 for explanation of lithologic symbols used in this figure.

contact may be a disconformity representing a hiatus of indefinite duration, and all the quartzite may be older than Ordovician.

C.P. Ross (1937) described the Kinnikinic, as he defined it, as resting in stratigraphic continuity above the Ramshorn Slate, which he considered to be of earliest Ordovician age. This age assignment is now in doubt (Hobbs and others, 1968), and thus the Ramshorn Slate is no longer useful in limiting the age of the Clayton Mine Quartzite, which is now known to lie in thrust contact above the Ramshorn and was erroneously included in the original Kinnikinic Quartzite.

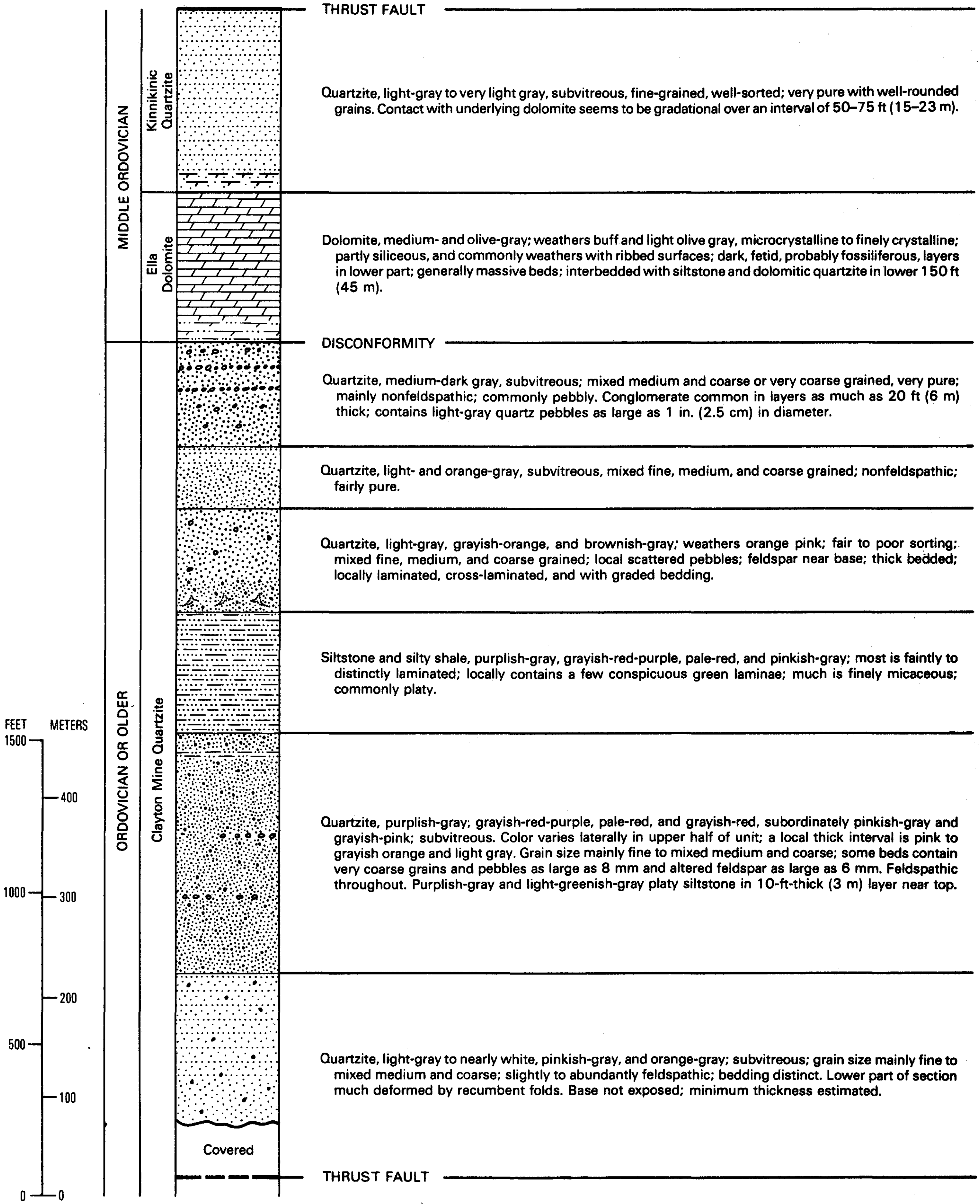


Figure 7. Generalized composite columnar section of the Clayton Mine Quartzite, Ella Dolomite, and Kinnikinic Quartzite in thrust plate exposed south of Alkali Spring (secs. 13, 14, and 24, T. 11 N., R. 18 E.), Clayton 15-minute quadrangle, Custer County, Idaho. Thicknesses computed from map measurements. See page 7 for explanation of lithologic symbols used in this figure.

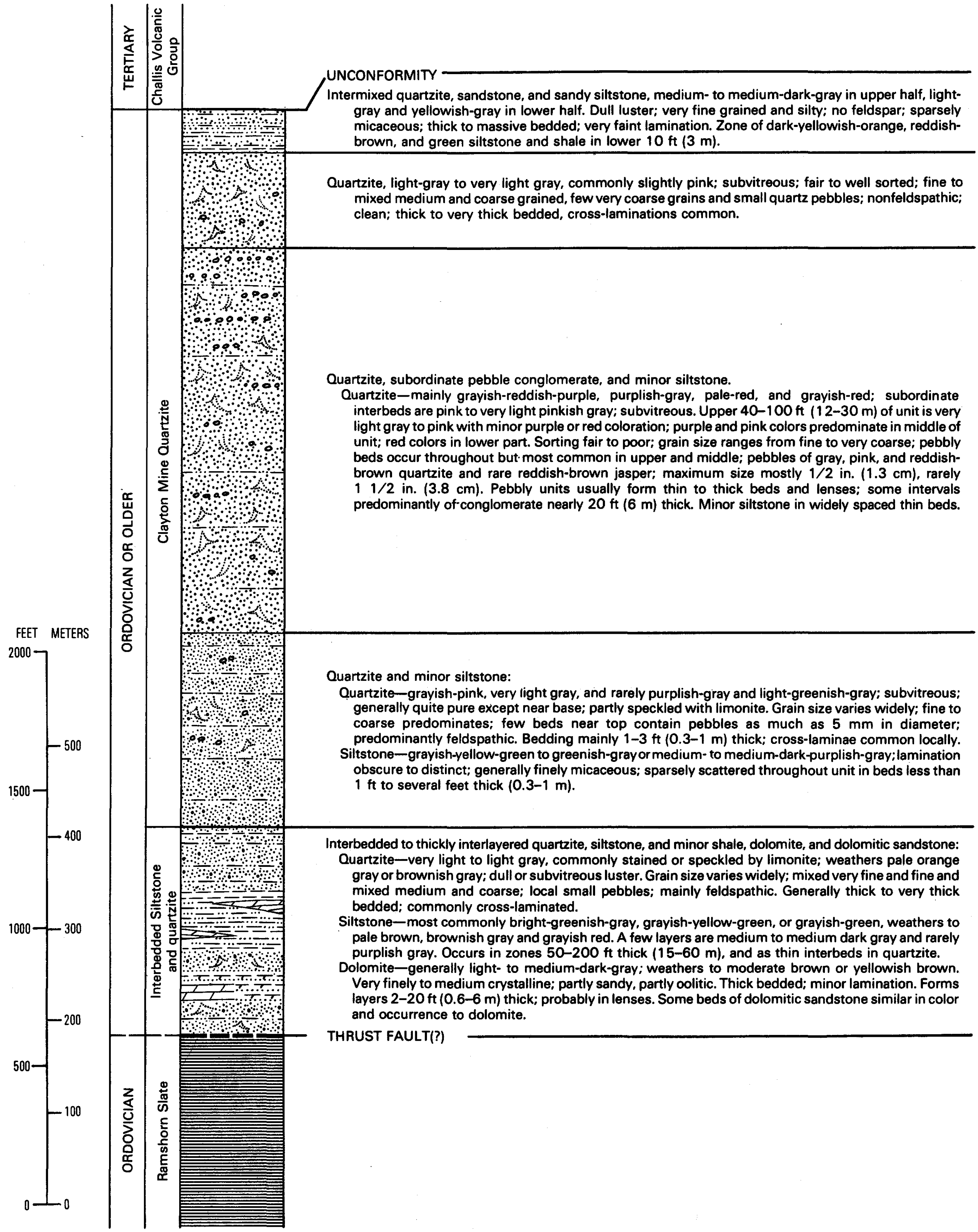


Figure 8. Generalized columnar section of the Clayton Mine Quartzite, interbedded siltstone and quartzite sequence, and upper part of the Ramshorn Slate as exposed along upper Garden Creek in the north-central part of the Clayton 15-minute quadrangle, Custer County, Idaho. Thickness based on field estimates and map measurements. See page 7 for explanation of lithologic symbols used in this figure.

Interbedded Siltstone and Quartzite

The Clayton Mine Quartzite grades downward into an interval that includes shale partings and individual beds of shale and siltstone as much as 20 ft (6 m) thick within the quartzite and, in several places, beds of nearly pure dolomite as much as 15 ft (4.5 m) thick. Although the composition and character of the quartzite and siltstone in this interval resemble parts of the Clayton Mine Quartzite and the Ramshorn Slate, they form a sufficiently distinctive assemblage to be mapped as a separate unit and have been given the informal name of interbedded siltstone and quartzite unit. This zone of mixed lithologies has been a zone of weakness along which a major thrust fault has carried the Clayton Mine Quartzite and all overlying formations over the subjacent Ramshorn Slate. Variations in the thickness of the interbedded siltstone and quartzite unit and its local absence is interpreted to result from movement on the thrust; as a consequence, the full thickness of the combined Clayton Mine Quartzite and the underlying interbedded siltstone and quartzite may never be unequivocally determined.

At the type section of the Clayton Mine Quartzite (fig. 5) the lowest exposed beds include shale and two dolomite layers that may be a part of the interbedded siltstone and quartzite unit, but extensive talus at the base of the cliff conceals the remainder of the section and the basal thrust fault. Birch Creek, a small stream that enters the Salmon River opposite the mouth of the East Fork approximately 4.5 mi downstream from the town of Clayton, cuts through the lower part of the Clayton Mine Quartzite and into the interbedded siltstone and quartzite unit. These strata include massive, cross-laminated, coarse-grained feldspathic quartzite, interbedded quartzite and thin siltstone, one silty shale zone as much as 250 ft (76 m) thick, and one thin dolomite bed. The sequence terminates at its western base against Ramshorn Slate along a major shear zone that closely parallels the bedding of the interbedded siltstone and quartzite unit. This shear zone is intruded by a complex of gabbro dikes and sills that extends for several miles along or close to the faulted contact with the Ramshorn Slate. About 4.5 mi (7.2 km) north of Birch Creek in the vicinity of Rattlesnake Creek where more than 3,000 ft (915 m) of Clayton Mine Quartzite has been measured (fig. 6), the interbedded siltstone and quartzite unit has been entirely cut out by the fault, and the Clayton Mine Quartzite rests on the Ramshorn Slate. The major outcrops of the Clayton Mine Quartzite that extend for about 5 mi (8 km) northward from Bayhorse Lake in the north-central part of the Clayton 15-minute quadrangle grade downward into the interbedded siltstone and quartzite unit that has been mapped for the same distance. Also, at one exposure along this contact the mixed lithologies of this unit seems to rest directly on the Ramshorn Slate with no obvious thrust fault. However, scattered gabbro intrusive bodies closely follow the contact as they do at numerous other places where a fault has been well documented. The fault may cut upward across the quartzite to the west, or dip deeper into the interbedded siltstone and quartzite unit where its contact with the Ramshorn Slate could be easily obscured by the juxtaposition of similar lithologies or concealed by the massive talus and numerous landslides that cover much of the bedrock.

Bits and pieces of the interbedded siltstone and quartzite unit with minor lenses of dolomite are folded and sheared into the major fault zone exposed along State Highway 75 for several miles north of the mouth of Bayhorse Creek.

Character

The interbedded siltstone and quartzite unit consists of various proportions of several rock types that are found in the Clayton Mine Quartzite above and the Ramshorn Slate below. In addition, widely spaced beds and lenses of dolomite are a minor component of these strata.

Quartzite ranges in color from very light gray to light grayish orange or brownish gray and locally is speckled with limonite. Some is faintly purplish pink. In places the rock weathers a light tan or brown, but most surface exposures are similar to the color of the fresh rocks. Grain size is predominantly very fine to fine, but locally some beds or laminae are medium to coarse grained with a few pebble zones. Much of the fine-grained quartzite is apparently nonfeldspathic although some coarser beds contain much coarse feldspar. The quartzite occurs as individual thin to thick beds and as groups of beds totaling 80 ft (25 m) or more in thickness interspersed in siltstone or interbedded with the minor beds of dolomite. Many thick beds are faintly laminated or cross-laminated and in many places are separated from each other by thin greenish-gray sericitic shale partings. Most of the quartzite beds or groups of beds are in sharp contact with the bounding siltstone or carbonate layers, although some beds of dolomitic quartzite or quartzitic dolomite suggest possible gradations between two rock types.

Light-brownish-gray, grayish-orange, light-greenish-gray, and locally pale-red, brown, or grayish-red silty shale or sandy siltstone make up the other major component of the interbedded siltstone and quartzite unit. In places it shows Liesegang rings and variegated colors. Most probably this rock was originally greenish gray. Bedding ranges from massive thick-bedded layers to thin alternating siltstone and fine-grained sandy siltstone beds that weather as thin plates and chips. Much of the siltstone is faintly laminated and locally micaceous. Cleavage in the siltstone is predominantly parallel to the bedding, but locally is at a pronounced angle to the bedding. In places, where more argillaceous and more intensely deformed, the rock has become a phyllite.

The dolomite in this unit forms beds with sharp contacts that make up a relatively small part of the section. In undeformed or slightly deformed parts of the sequence the dolomite is discontinuous or changes thickness along strike, and probably occurs as lenses. In several of the highly disturbed areas the erratic distribution is related to tectonic disruption. The least disturbed and perhaps the most complete section of the mixed lithology unit occurs north of the Bruno Cabin Ruins on upper Garden Creek and contains at least three distinct dolomite beds within a zone several hundred feet thick near the center of the section. These dolomite beds range from 2–10 ft (0.6–3 m) thick, and one of the layers thins from 10 ft (3 m) to about 3 ft (0.9 m) within a distance of about 1,500 ft (460 m) along strike. Two dolomite beds, one 15 ft (4.6 m) thick and the other 1 ft thick, separated by a shale layer, occur near the base of the measured section of the Clayton Mine Quartzite west of the town of Clayton and probably belong within the upper part of the interbedded siltstone and quartzite unit. One 3-ft-thick (0.9 m) bed of dolomite was measured in what is probably the upper part of the interbedded siltstone and quartzite unit on Birch Creek in the southeast corner of sec. 15, T. 11 N., R. 18 E. (see Hobbs and others, 1990). Several large, disjointed segments of dolomite beds occur in the intensely folded and jumbled mass of rock comprised of the Clayton Mine Quartzite, interbedded siltstone and quartzite unit, and Ramshorn Slate in the major thrust zone along State Highway 75 between 1–2 mi (1.6–3.2 km) north of the mouth of Bayhorse Creek.

Most of the dolomite layers in these mixed lithologies are medium to medium light gray on fresh fracture and weather tan or brown, are fine grained, and range from nearly pure dolomite to sandy or silty dolomitic sandstone. In a few places several layers may contain pisolitic structures, but this feature is not abundant.

The upper contact of the mixed lithology unit is best exposed in the stratigraphic sequence that extends north and south of upper Garden Creek in the vicinity of Bruno Cabin Ruins. In this area the interbedded siltstone and quartzite lithologies are distinguished from the overlying Clayton Mine Quartzite by a greater abundance of siltstone and shale and by the interbedded quartzite which is very light gray to grayish orange, commonly speckled quartzite with very fine to fine or medium sized grains. This contrasts with medium- to coarse-grained, generally poorly sorted and generally very colorful rock of the Clayton Mine Quartzite. As at Birch Creek a few of the beds are coarse grained with a few pebble layers, and some are quite feldspathic.

The basal contact with the Ramshorn Slate at this locality has been placed where light- or pale-olive, yellowish-gray siltite interbedded with light- or pale-orange-gray quartzite is underlain by darker gray siltstone with few if any quartzite interbeds that is characteristic of the Ramshorn Slate. The exact nature of the lower contact zone is indeterminate, but it could mark a change in depositional regime in a nearly continuous depositional sequence, or it could be a bedding-plane fault of considerable magnitude that could easily be masked by the extensive talus and colluvium that mantles much of the area.

Stratigraphic Relations and Age

Exposures at Clayton Canyon, Birch Creek, and on upper Garden Creek show that the overlying Clayton Mine Quartzite grades downward into the mixed lithologies of the interbedded siltstone and quartzite unit. The lower contact of these mixed lithologies west of Clayton is covered, but on Birch Creek the lower contact is exposed as a major sheared zone that we interpret to be a thrust fault. At Rattlesnake Creek, the interbedded siltstone and quartzite unit is entirely cut out and the Clayton Mine Quartzite rests on Ramshorn Slate above a major thrust fault. Similar relations occur along the thrust near Alkali Spring where units as high as the Kinnikinic Quartzite rest on the Ramshorn Slate. Other quartzite and mixed lithology exposures that may in part be correlative with the Clayton Mine Quartzite and the interbedded siltstone and quartzite unit occur on Poverty Flat, between Poverty Flat and Kinnikinic Creek, and in the north-central part of the Clayton quadrangle. In most of these areas, the contact relations are equivocal for one or the other boundaries. In the structurally complex exposures along State Highway 75 north of Bayhorse Creek, the rocks are so disrupted as to completely obliterate both the upper and lower contacts of the interbedded siltstone and quartzite unit. Although no information is available by which to date these mixed lithologies specifically, their close affinities to the Clayton Mine Quartzite with which they seem to be gradational, strongly suggest that they are of similar or slightly older age.

Quartzite of Happy Hollow

Quartzitic strata, which are most probably related to the Clayton Mine Quartzite, crop out over an area of approximately 3 mi^2 (7.8 km^2) in the vicinity of Happy Hollow, a small drainage area on the east side of Kinnikinic Creek about 5 mi from its mouth. The triangular area of outcrop extends from Kinnikinic Creek on the west nearly to the edge of Poverty Flat on the east and is overlapped on the southwest and the northwest by volcanics of the Challis Group. On the east side these quartzites are separated from quartzites of the Poverty Flat area by near-vertical north-trending faults.

The quartzite of Happy Hollow is predominantly very light gray to light gray, fine to medium grained, locally coarse grained and fairly pure. In a few places it contains granule conglomerates. Some beds are speckled with limonite and others are stained slightly red or pink, but variations from shades of light gray are rare. Much of the strata appears to be slightly feldspathic, and locally the coarser grained part may contain considerable amounts of easily recognizable altered feldspar grains. For the most part the quartzite is medium to thick bedded with local faint lamination and cross-lamination. Thin beds or partings of grayish-red siltstone or shale are scattered through the section, and in the lower part at least one and possibly more sequences of pale-yellowish-green, platy, finely laminated siltstone at least 40 ft (12 m), and possibly 140 ft (43 m) thick occur. No carbonate has been found.

The thickness of this quartzite has not been determined. The upper contact is covered by the Challis Volcanic Group and the lower contact is probably a thrust fault. The quartzite is bounded by steep normal faults that separate it from the Ramshorn Slate that underlies most of the Poverty Flat area to the east. For the most part, this block of quartzite appears to be relatively undisturbed, and an estimate of the exposed thickness based on map measurement is approximately 1,800 ft (550 m). Undetected structural complications could modify this figure either way.

Tentative correlation of this unit with the Clayton Mine Quartzite is based on similarity in general characteristics, thickness, structural setting, and proximity to major blocks of undoubted Clayton Mine Quartzite. The differences in color, bedding thickness, and feldspar content may result from the juxtaposition of facies within the unit by complex thrust faulting.

Upper Sawmill Creek–Poverty Flat Sequence

Several square miles of a heterogeneous sequence of quartzite, siltstone, and dolomite underlie the south end of Poverty Flat at an altitude of about 9,200 ft (2,800 m) and extend down both the east and west sides of the Flat to about the 8,000-ft contour. The generally horizontal configuration of the basal contact of this block of strata, and the discordance between the beds of quartzite and siltstone of the block and those of the underlying Ramshorn Slate make almost mandatory the interpretation that a thrust fault of considerable magnitude exists at the base of the unit. At places along the west edge of Poverty Flat, the quartzite of Happy Hollow appears to have been thrust over the Sawmill Gulch units.

From the west edge of Poverty Flat at an altitude of 9,400 ft (2,865 m) down to the forks of Sawmill Creek an estimated 2,300 ft (700 m) of strata belong to a continuous section of intermixed siltstone, quartzite, and dolomite. Siltstone, roughly 30 percent of the section, occurs mostly in the upper half and is mainly grayish yellow green or light greenish gray and weathers to a yellowish brown and reddish brown, and forms float of small chips and slabs. Most of the siltstone is very finely laminated, and some has micaceous bedding surfaces. In places, the siltstone contains thin interbeds of highly speckled, nonfeldspathic quartzite and a little sandy dolomite.

Quartzite makes up more than 40 percent of the section and is most abundant in the lower two-thirds below the thick siltstone unit. It is fairly well sorted, generally very light gray to yellowish-gray or light-grayish-orange quartzite that is commonly speckled with limonite and composed of fine to medium grains with local coarse grains and sparse quartzite pebbles. Feldspar is present in many beds and is locally abundant. The quartzite is mostly subvitreous and fairly clean except for some thin argillaceous layers or thin laminae containing specks of iron oxide. A few of the widely spaced siltstone layers may be 2–3 ft (0.6–0.9 m) thick. Much of the bedding is thick with some conspicuous cross lamination. Dolomite beds from a few inches (1–5 cm) to 2 or more feet (1–2 m) thick occur at widely spaced intervals. In some places, the quartzite contains small amounts of carbonate cement, but the rock is generally carbonate free.

Dolomitic sandstone is prevalent in the lower part of the section and constitutes nearly 20 percent of the total thickness. These beds tend to be various shades of brown, are medium grained, and are similar in many respects to the purer quartzite previously described, except for a greater amount of carbonate cement that makes the rock softer and subject to disintegration. In many places there are thin interbeds of more resistant light-yellowish-gray to nearly white quartzite that is speckled with limonite. Some thin siltstone layers and well defined dolomite beds are dispersed throughout this part of the section. The lowermost 200 ft (60 m) of the section is a mixed sequence of thin quartzite layers with interbedded siltstone, some carbonate-bearing sandstone, and several dolomite beds as much as 10 ft (3 m) thick.

The distinct layers of dolomite that are scattered through the section are commonly only a few feet thick, somewhat sandy, and medium gray on fresh fracture; they are medium brown and usually ribbed on weathered surfaces. These layers are estimated to be about 5 percent of the section.

In many respects, the characteristics of this unit are very similar to those of the interbedded siltstone and quartzite unit previously described. Although the general rock types are analogous, significant differences in relative amounts of the major components, distribution of carbonate, and thickness of bedding raise questions as to the validity of direct correlation with the interbedded siltstone and quartzite unit exposed in the Birch Creek area 1.5 mi (2.4 km) to the east. The thrust fault that seems to floor the two rock sequences—one on Poverty Flat and one on Birch Creek—cuts across the interbedded siltstone and quartzite unit.

Rob Roy Sequence

The informally named Rob Roy sequence consists of siltstone and quartzite and lesser amounts of dolomite that occurs as both distinct beds of nearly pure carbonate and as a subsidiary component of either quartzite or siltstone. The sequence is exposed for about 3 mi (4.8 km) along the west side of Kinnikinic Creek from the Clayton Silver Mine northward to Coal Creek. At Coal Creek the section is overlapped by volcanics of the Challis Group and is not known to be exposed at any other locality.

More than 3,000 ft (900 m) of strata compose the Rob Roy sequence, named for a nearby mining property. Figure 9, generalized from a section measured across the exposed width of the Rob Roy sequence, illustrates the general character of this stack of strata. At least one fold and several steep faults cross the line of section, and these structures together with the faults that bound this block of strata on the west and east sides introduce considerable uncertainty into the estimates of total thickness and of the relative proportions of the various component lithologies. There are no duplications in the measured section though there may be some gaps. This conclusion is supported by the lack of matching segments of stratigraphy across documented faults, or on the opposite limb of an anticlinal structure that has been disturbed by an axial plane fault of unknown displacement.

The lower 1,200 ft (370 m) of the Rob Roy sequence is predominantly quartzite with subordinate and erratically distributed thin interbeds of dolomite, sandy siltstone, and silty sandstone. Most of the quartzite is medium to coarse grained and moderately well sorted, but with local zones of seriate texture and a few pebble layers. Colors range from light gray to light or medium grayish orange pink, with some shades of very pale orange or yellowish gray. Sparse to prominent medium-orange-brown limonite speckling characterizes most of the quartzite beds in this part of the section. These specks result from the weathering of iron-bearing dolomite grains as identified in thin sections. The sequence includes a few layers of dolomitic quartzite. Sparse feldspar, both orthoclase and plagioclase, occurs in most layers but is not obvious in hand specimen. Bedding ranges from a few thin platy layers to thick, cross-laminated, well-defined beds, but most is of medium thickness.

Partings and thin beds of medium-pale-reddish-gray and brownish-gray shale and phyllite occur commonly between quartzite layers and in a few places thicken to as much as 50 ft (15 m) thick. Pale-reddish-brown, interlaminated fine-grained sandstone and siltstone occur near the top of this part of the section and are precursors to the predominance of similar lithology in the overlying part. At least eight beds of nearly pure dolomite that range in thickness from 1–8 ft are scattered in this predominantly quartzitic part of the section. The dolomite ranges from light gray to a light tannish gray on fresh fracture and weathers to a rich medium brown. Some dolomite beds are silty or sandy and tend to be fine grained; others are reasonably pure and coarsely crystalline with a vitreous luster.

The lower quartzite sequence terminates upward abruptly at the top of a 6-ft-thick (2 m) pure crystalline dolomite bed. The dolomite bed is overlain by more than 1,000 ft (300 m) of a very distinctive, strikingly laminated argillite and sandy siltstone sequence. Although these rocks above the dolomite show variations in color, degree of lamination, and proportions of components from one part of the section to another, all are characterized by a lithology that is not duplicated in other parts of this stratigraphic group. These strata are predominately a rich dark brown to purplish brown and comprise laminae or thin beds of dark-brown or purplish-brown sandy siltstone interbedded with medium-gray-green phyllitic shale. In some beds very finely laminated layers of reddish-brown siltstone and green waxy shale only ¼ in. (6 mm) thick are interbedded with ¼–1 in. (6–25 mm) thick beds of essentially unlaminated dark-brown, very fine grained sandy siltstone. Other parts of the unit are composed of the same lithology but on a much coarser scale in which the individual beds may be from ½–1 in. (12–25 mm) thick. The more coarsely layered rocks contain current bedding, soft-sediment deformation, and other features analogous to those found in other formations in the Bayhorse area. The upper 300 ft (90 m) of the laminated siltstone-shale strata are a somewhat more massive but thoroughly laminated rock composed

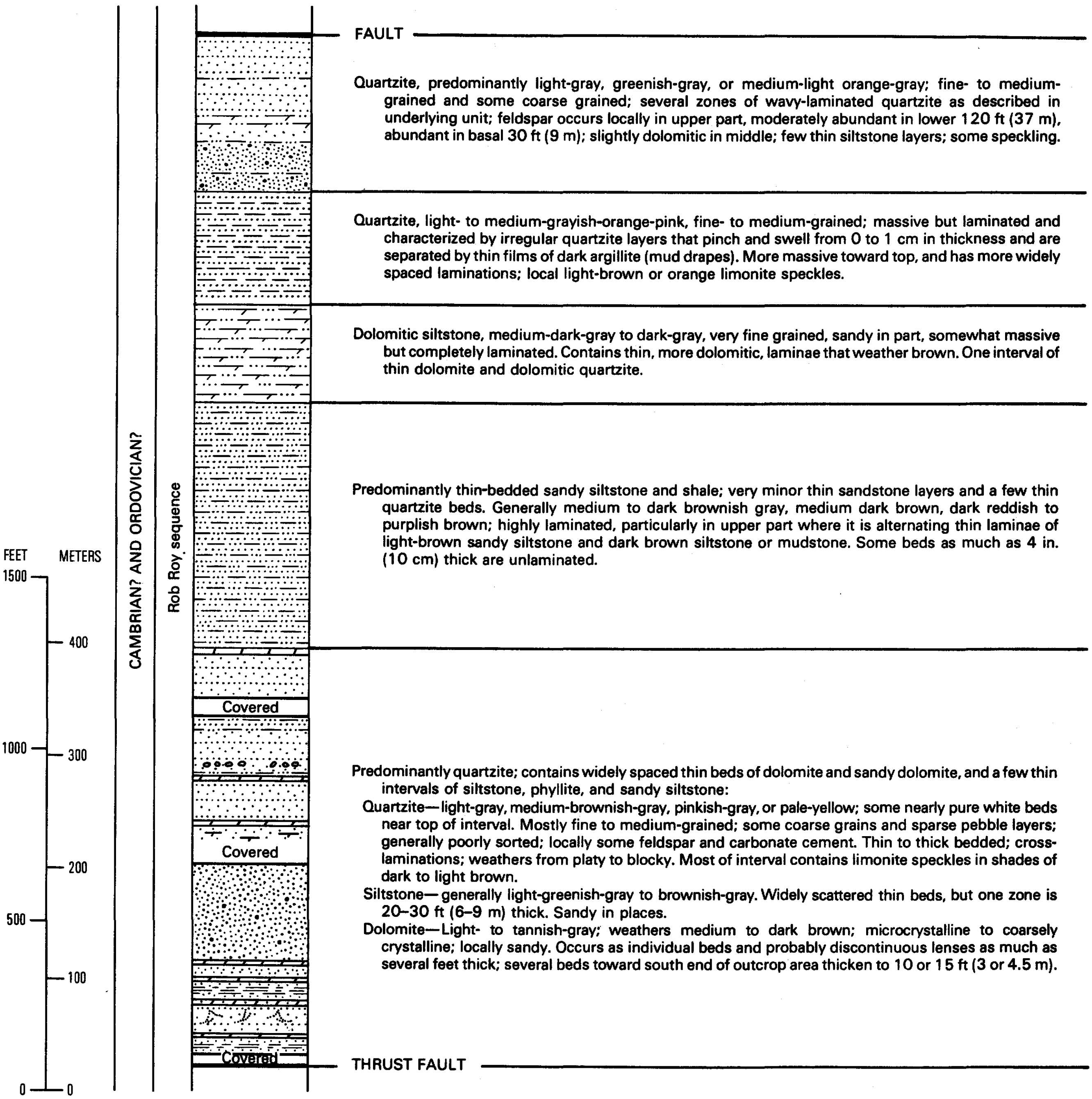


Figure 9. Measured columnar section of the Rob Roy sequence, E½ sec. 11 and W½ sec. 12, T. 11 N., R. 17 E., Custer County, Idaho. See page 7 for explanation of lithologic symbols used in this figure.

of medium-dark-grayish-red to purple sandy siltstone interlaminated with moderate-brown, slightly limonitic silty sandstone. Locally, some beds are slightly dolomitic.

The finely laminated siltstones are overlain by about 300 ft (90 m) of fine- to medium-grained moderately well-sorted, generally thick-bedded, light- to medium-grayish-orange-pink quartzite that is marked by pervasive, closely spaced wavy partings of dark-gray silty argillite. The argillaceous partings are generally paper thin and account for only a few percent of the bulk content, but because the rock breaks along these partings, the dark argillite imparts a disproportionate sombre hue to the float. Above this, in the uppermost 300 ft (90 m) of the exposed section, as measured in the Rob Roy area, the strata are mostly nonlaminated, medium-gray or tannish-gray, medium- to fine-grained, fairly well sorted quartzite. Some lamination occurs at intervals but is not dominant. Most notable is the appearance of feldspar as a constituent of the quartzite immediately above the well-laminated sequence, where the feldspar constitutes as much as 10–15 percent of the rock for some tens of feet. Feldspar continues as a sparse constituent nearly to the top of the section.

The Rob Roy sequence, with an exposed area of over 2 mi^2 (5 km^2), occupies a graben bounded on both east and west by major steeply dipping normal faults, and at the base by a thrust fault that truncates the underlying Ella Dolomite. The block includes many of the rock types and general features that characterize the upper Sawmill Creek-Poverty Flat sequence and to some extent those of the interbedded siltstone and quartzite unit. Although it is tempting to correlate the Rob Roy area strata with all or parts of the similar units to the east, the details are sufficiently varied and the character, distribution, and proportions of the various lithologies are sufficiently different as to preclude any definitive correlation.

Quartzite and Siltstone of Upper Cash Creek

About 2 mi^2 (5 km^2) of strata are exposed in a window eroded through the cover of volcanics of the Challis Group in the west-central part of the Clayton quadrangle on both sides of the north-trending stretch of upper Cash Creek. Except for the southwestern corner of this exposure, where rocks of Cambrian and Ordovician age have been identified, these strata are composed dominantly of quartzite and siltstone of uncertain age that in many respects resemble parts of the Clayton Mine Quartzite. In general, the strata west of this segment of Cash Creek are medium-bedded, medium- to coarse-grained feldspathic quartzite that contain local but minor interbeds of reddish-brown to greenish-brown siltstone. Eastward from this quartzite for nearly ½ mi (0.8 km) is a fairly thick sequence of phyllitic shale and siltstone that includes some locally laminated beds, some massive siltstone, and a small component of sandy siltstone or silty sandstone. Light-gray to medium-gray, fine- to medium-grained quartzite is interbedded at intervals in the siltstone and becomes dominant on the upper slopes of the high ridge east of Cash Creek and extends eastward from the ridge crest for nearly half a mile. The position of this quartzite-siltstone sequence due north from the type section of the Clayton Mine Quartzite and essentially on the main structural trend with both the Clayton Mine and Rob Roy sequences adds support to the correlation with one of these two groups of strata. A probable fault along the northerly course of Cash Creek may separate the dominantly quartzite part of this sequence on the west from the more heterogeneous quartzite-siltstone sequence to the east. This fault could be analogous to the steep fault several miles to the south that separates the Clayton Mine Quartzite from the Rob Roy sequence.

The quartzite and siltstone of this block are probably part of the thrust plate that has overridden the Cambrian-Ordovician strata that crop out along the central reaches of Cash Creek and both sides of Squaw Creek south from the mouth of Cash Creek. The strata in the overriding allochthon are in places folded and broken by both steep faults and subsidiary thrusts with a resulting complex pattern that is difficult to decipher.

ORDOVICIAN AND CAMBRIAN(?) ARGILLACEOUS AND DOLOMITIC SEQUENCE

One of the most extensively exposed and well-defined stratigraphic sequences of pre-Challis strata in the Bayhorse area forms the core of the large north-trending Bayhorse anticline that occupies most of the east-central part of the Clayton quadrangle. These strata, more than 5,000 ft (1,500 m) thick, comprise four distinctive units—a massive dolomite at the base overlain in succession by the Garden Creek Phyllite, Bayhorse Dolomite, and Ramshorn Slate. The last three units were first described and named by Ross (1934a). The basal massive dolomite, which is exposed for only a very short distance in the bottom of Bayhorse Creek, was recognized much later by D.P. Wheeler, Jr. (oral commun., 1966), who was conducting a mineral exploration program in the Bayhorse Mining District.

These four stratigraphic units form a coherent package that extends for over 20 mi (32 km) from Mill Creek in the north to about 1 mi (1.6 km) beyond the Salmon River in the south. Beyond these limits this stratigraphic section is buried beneath the extensive Challis Volcanic Group. Other more remote outcrops of possibly related strata are so far removed or sufficiently different as to preclude definitive correlation. The problem of this section is further complicated by a paucity of diagnostic paleontologic evidence and a complex structural history. As a result, the position of this package of strata in the stratigraphic column is uncertain. The details of this problem are discussed in the following descriptions.

Ramshorn Slate

The Ramshorn Slate, named by Ross (1934a) for the Ramshorn Mine on Bayhorse Creek, has been described by Ross (1934a, 1937, 1962b) in several publications, and by Anderson (1954) who essentially paraphrased Ross. Our more recent and more detailed work has largely confirmed the essential character of the unit as presented by Ross, but with several significant modifications that relate specifically to its distribution and age.

This slate, covering an area more than 2 mi (3 km) wide by 20 mi (32 km) long is the most extensively exposed stratigraphic unit in the core of the Bayhorse anticline. It is bounded on the west by a major north-trending fault that terminates the west limb of the Bayhorse anticline. This fault, which is well identified along the course of Kinnikinic Creek, undoubtedly extends far to the north beneath volcanics of the Challis Group and accounts for the remarkably straight-line contact between the older rocks of the Bayhorse anticline and the Tertiary volcanics. We believe that the volcanics were deposited against a fault-line scarp.

The east boundary of the major area of Ramshorn Slate is less well defined, but extends northward from near the mouth of the East Fork of the Salmon River almost to the north edge of the Clayton 15-minute quadrangle. The easternmost extent is identified by several small outcrops southwest and southeast of Alkali Spring and by bits and pieces of the slate exposed in tight folds and badly sheared rocks in the zone of thrust faulting that is exposed for several miles along State Highway 75 northward from the mouth of Bayhorse Creek. The north and south limits are determined by the overlapping Challis Volcanic Group. No Ramshorn Slate has been recognized west of the fault in Kinnikinic Creek, nor east of the Salmon River lineament. The only similar lithologies outside of the Bayhorse area occur in a very small structurally complex area in Sawmill Gulch at the west foot of the Lost River Range approximately 25 mi (40 km) to the southeast and as part of highly metamorphosed roof pendant material in the Idaho batholith to the west.

Ross (1937) gave the most complete description of the Ramshorn Slate in his bulletin on the Bayhorse area and much of the following description includes the results of his work together with our new information.

Character

The main mass of the formation is composed of thinly banded argillite and siltstone with prominent slaty cleavage cutting the banding at high angles. For a distance of nearly 4 mi (6.5 km) in the northern part of the Clayton 15-minute quadrangle a thick conglomerate and sandstone lense occurs at the base of the formation, and a few beds elsewhere in the unit include fine to medium sand, a few pebbles, and locally minor carbonate.

The essential characteristics of the Ramshorn Slate, as emphasized by Ross (1937), are the generally fine-grained argillaceous or silty composition, the conspicuous thin banding, the dark color on fresh fracture—generally in shades of gray, green, or purplish gray—and a pervasive slaty cleavage that may be inconspicuous or absent where the formation is slightly coarser grained. Locally, the Ramshorn is lightened by the inclusion of fine sand or darkened by carbonaceous matter. Cleavage intensity seems to phase out gradually toward the north end of the exposed area. Where the cleavage is well formed, the rock weathers to thin chips, plates, or slabs that mantle the surface and produce extensive talus slopes. The sheen of secondary sericite on the cleavage planes under a bright sun gives the striking illusion of wet surfaces on such talus when viewed from a distance.

The slate consists largely of quartz, in grains rarely more than a few hundredths of a millimeter in diameter, and fine aggregates of chlorite, serpentine, biotite, and other micaceous minerals. In several places igneous metamorphism has produced chiastolite, a variety of andalusite. On both sides of Juliette Creek and locally near the Ramshorn Mine the slate has been metamorphosed by the Juliette stock and numerous small satellite igneous intrusions into a coarse-grained gray to black rock that on weathered surfaces is studded with projecting andalusite crystals.

The "basal conglomerate" in Daugherty Gulch and Garden Creek, which Ross (1934a) described, flanks both sides of the Bayhorse anticline for a distance of nearly 4 mi (6.5 km) and is more than 500 ft thick (150 m). To the north and south, the conglomerate interfingers with fine sandstone and siltstone that are part of the lower main Ramshorn lithology. The conglomerate is probably a channel filling of one of the major streams that helped cut the erosion surface on which the Ramshorn Slate was deposited. It is thickest along an axis that trends approximately west-northwest, and this direction is presumed to be the general trend of the channel at this location.

The conglomerate is composed almost exclusively of moderately well rounded clasts of vein quartz and quartzite that range in size from small pebbles to cobbles, rarely in excess of 3 in. (7.6 cm) in diameter, in a siliceous matrix. Interbedded with it locally are pebble-free shaly quartzite and scattered lenses of slate. Some of the beds of conglomerate and quartzite are reticulated with quartz veins. The pebbles of the conglomerate are so well worn and so dominantly composed of quartz as to suggest that the land mass from which they came was rich in silica and had long been exposed to denudation. Possible source terrane and distance of travel are unknown. Several small occurrences of pebble conglomerate in the upper reaches of Rattlesnake Creek and near the east edge of Poverty Flat may be near the base of the Ramshorn, but they are probably not connected to the main channel conglomerate farther to the north. The conglomerate that Ross (1937, p. 14) mentioned as near the head of Corral Creek in the southern part of the area is not part of the Ramshorn Slate.

The Ramshorn Slate is everywhere drag folded and contorted, although rarely as intensely crenulated as the Garden Creek Phyllite. The folding makes it difficult to determine the thickness of the Ramshorn; however, it is certain that the average thickness is more than 2,000 ft (610 m) (Hobbs and others, 1990).

Problems of Correlation and Age

The black, carbonaceous, graptolite-bearing shale and argillite together with the overlying allochthon of the Mississippian, Devonian, and Cambrian Salmon River assemblage along Pine Creek and Big Lake Creek (Hobbs and others, 1990) are strata that Ross (1937, pl. 1 and p. 15) considered to be part of the Ramshorn Slate, but which he described as being somewhat different from the larger mass of Ramshorn north of the Salmon River. The shales beneath the allochthonous Salmon River assemblage contain fossils by which Ross assigned the Ramshorn to the Lower Ordovician. These fossils, all from the unit shown on plate 1 as black carbonaceous graptolite-bearing shale and siltstone, have been given a Middle and Late Ordovician age in recent more detailed study (this report, p. 14; Dover and others, 1980). These shales and siltstone are now considered correlative with the siltstone-black argillite interval of the Middle and Upper Ordovician Saturday Mountain Formation in the Clayton quadrangle, and probably with the Phi Kappa Formation in the Pioneer Mountains of central Idaho whose age spans most of the Ordovician (Dover and others, 1980).

The lithologic differences recognized by C.P. Ross between the strata in the Big Lake Creek–Pine Creek exposures and the typical Ramshorn Slate are now known to distinguish different units. The correlation of the black, carbonaceous, graptolite-bearing shale and argillite to well known Upper Ordovician rocks in adjacent areas, together with the lack of cleavage, so characteristic of the Ramshorn Slate, makes any relation of the Big Lake Creek-Pine Creek shales to the Ramshorn Slate improbable. No new direct evidence on which to date the Ramshorn Slate has been discovered, and its position in the stratigraphic column is related to the ages tentatively assigned to the other units of the package as discussed on pages 29–33.

Bayhorse Dolomite

Distribution and General Features

The Bayhorse Dolomite, as defined by Ross (1934a, 1937), underlies the Ramshorn Slate beneath an erosional disconformity and overlies the Garden Creek Phyllite with a gradational contact. It is exposed at three major localities along the crest of the Bayhorse anticline: (1) Near the north end the Bayhorse Dolomite forms an elongated oval band about 3.5 mi (5.5 km) long and 1 mi (1.6 km) across and is well exposed where cut into by the valleys of Garden Creek and Daugherty Gulch; (2) A second exposure occurs in the valley of Bayhorse Creek nearly 4 mi (6.5 km) to the south where the dolomite forms a crudely circular pattern that has been downfaulted on the east side; (3) The third locality is at a nearly equal distance farther south of Bayhorse Creek where the valleys of Rattlesnake and Lyon Creeks expose the crest of the folded dolomite in several irregular, elongate segments that parallel the axis of the fold and that have been offset by several steeply dipping north-trending normal faults. Several other small exposures of the dolomite are along the east limb of the main anticline where the overlying Ramshorn Slate has been stripped away. No other exposures of the Bayhorse Dolomite are known. The blanket of the Challis Volcanic Group, which extends for long distances on all sides beyond the mapped area, and the massive Idaho batholith, which destroyed the formation to the west, effectively prevent any direct tracing or projection of the Bayhorse Dolomite beyond the Bayhorse area. Correlation with more remote carbonate sequences is hindered by the paucity of fauna in the Bayhorse Dolomite, by lack of any information on the age of the bounding units, by an unknown amount of erosion, before deposition of the Ramshorn Slate, and by any firm information on possible facies variations or depositional environments.

Early descriptions of the Bayhorse Dolomite emphasized a predominant dolomitic composition of the unit (Ross, 1934a, 1937; Anderson, 1954). More recent work by Chambers (1966), who made a very detailed study of the geology and ore deposits of the central part of the Bayhorse mining district, refined the description and emphasized that the unit is somewhat heterogeneous and includes appreciable amounts of limestone and shale. Further mapping of all known exposures of the Bayhorse Dolomite during the preparation of the regional map of the Bayhorse area (Hobbs and others, 1990) provided more insight into the diverse character of the unit.

Most of the early studies in the area recognized that the Bayhorse Dolomite graded from the underlying Garden Creek Phyllite but that its upper contact with the overlying Ramshorn Slate was an erosional disconformity or low-angle unconformity; an unknown amount of the dolomite was removed during the development of this unconformity. As a consequence, the thickness of the dolomite varies substantially. A section measured on the north side of Bayhorse Creek in the west limb of the major anticline totaled approximately 1,700 ft (518 m) (fig. 10). Chambers (1966, p. 25) measured 1,560 ft

(475 m) ½ mi farther west and reported thicknesses of 1,000 ft (300 m) and 1,150 ft (350 m) on Keystone Mountain about 3 mi (4.8 km) to the north, and 1,100 ft (335 m) on the north side of Garden Creek. Less than 500 ft (150 m) has been reported north of Garden Creek. In the light of such evidence of erosion it is likely that the failure to identify the formation in other localities may be at least in part due to the total destruction of the formation beyond the Bayhorse area.

Character

Although predominantly a carbonate sequence comprised of both limestone and dolomite, the Bayhorse Dolomite contains various amounts of both silt and sand as impurities in the form of dispersed grains and as concentrations in fine laminae or shale beds. A measured columnar section is shown in figure 10. Also, at least four intervals of nearly pure siltstone or argillite that range from 10–50 ft (3–15 m) in thickness each are dispersed within the central 400–500 ft (120–150 m) of the exposed section. One argillite-siltstone interval approximately 900 ft (275 m) above the base of the formation ranges in color from medium dark to dark greenish gray on both fresh and weathered surfaces, but where slightly carbonate-bearing it weathers brownish gray to medium tan. Parts of the argillite are finely banded or laminated with as many as 40 laminations per inch of thickness. This is a distinctive rock type, and the unit serves locally as a key bed, especially in the mineralized area along Bayhorse Creek; in other places where the formation has been deeply eroded this member has been destroyed.

In general, the lower 300–400 ft (90–120 m) of the Bayhorse Dolomite is predominantly thin- to medium-bedded and laminated, dark-gray, impure, fine-grained limestone. Various amounts of silt and fine sand are dispersed through the carbonate or localized in thin laminae. In places recrystallization of the carbonate results in coarser grain size and the generation of small calcite veinlets that cut across the bedding. This part grades from the Garden Creek Phyllite through a zone of increasingly abundant thin limestone interbeds in the slate across a thickness of 50 ft or more (15 m). The lower zone of predominantly limy strata is overlain by a somewhat heterogeneous mixture of thin- to medium-bedded silty and fine sandy limestone, dolomitic limestone, limy shale and several nearly pure argillite or slate intervals. The upper part of this zone includes the distinctively laminated key bed previously described.

Distinctive oolite beds occur below the laminated argillite interval, and, like the argillite interval, has served as a key bed for stratigraphic correlation. Most of the strata in the upper 500 ft (150 m) of the section, where measured on the north side of Bayhorse Creek, are thick-bedded, almost massive, medium-dark to medium-light-gray, fine-grained dolomite that weathers various shades of light brownish gray to orange gray. Several beds in the upper part of the section higher than 750 ft (230 m) above the base are crowded with nearly black ovoid bodies that are presumed to be oolites or pisolites and that are as much as 0.2 in. (5 mm) in largest dimension.

Over most of the area where the upper contact of the Bayhorse Dolomite is exposed, the carbonate strata in its upper part have been affected by processes that produced an extensive karst terrane. Post-burial alteration, solution, and deposition have been caused by water that circulated through the highly permeable uppermost part of the carbonate sequence beneath the overlying relatively impervious argillaceous beds of the Ramshorn Slate. At the Pacific Mine on the axis of the anticline north of the town of Bayhorse the dolomite below the Ramshorn Slate is recrystallized, brecciated, and locally silicified for nearly 200 ft below the contact. In places within the mine workings that explore the dolomite are zones of massive breccia that resemble the collapse breccias in a karst region. Near Daugherty Gulch on the northeastern end of the Bayhorse anticline, a highly silicified breccia beneath the contact is estimated to be 200 ft (60 m) thick (Chambers, 1966, p. 30); whereas, the breccia on the west limb of the anticline on upper Bayhorse Creek is very narrow or absent. The localization of many base metal sulfide and fluorspar deposits along, within, or parallel to this disturbed zone attest to its importance as a control for circulating ore-bearing solutions (Snyder, 1978; Hobbs, 1985b).

The amount and distribution of calcium-magnesium carbonate in the Bayhorse Dolomite raises questions as to its origin. Most of the massive, thick-bedded upper part of the unit is dolomite, and in most places the dolomite constitutes less than one third of the exposed section. Elsewhere, especially in the general vicinity of the mineralized area, the thickness of dolomite or dolomitic limestone is greatly extended to include all but a few hundred feet of limestone at the base. At least part of the dolomite may have resulted from the introduction of magnesium by mineralizing solutions. Most if not all of the upper contact zone, especially where disturbed, brecciated, or weathered on the paleo-land surface, is dolomite, much of which seems to be recrystallized into coarse-grained sandy dolomite. The dolomitization of predominantly limestone strata must be considered probable for these beds, and may be in part related to karst formation.

Age

Ross (1937, p. 11, 14) dated the Bayhorse Dolomite as probably Late Cambrian because of its position below the Ramshorn Slate (which was then considered to be Lower Ordovician) and because of the presence of dubious algal remains. His statement follows:

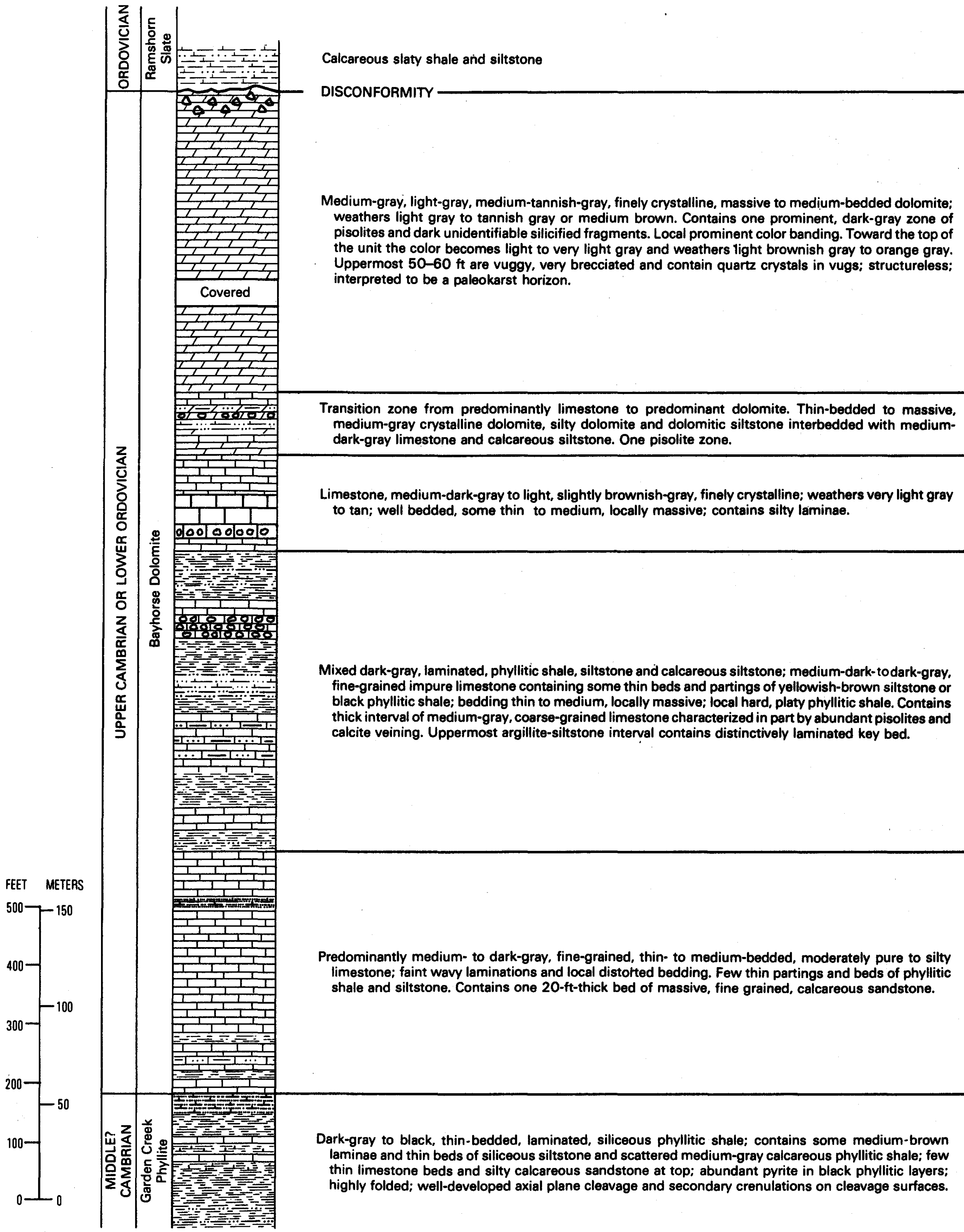


Figure 10. Measured columnar section of the Bayhorse Dolomite on Bayhorse Creek in the NE¼ of unsurveyed sec. 4, T. 12 N., R. 18 E., in the southwest part of the Bayhorse 7½-minute quadrangle. See page 7 for explanation of lithologic symbols used in this figure.

No diagnostic fossils have been found in the Bayhorse dolomite, although some of the larger concretionary masses so common in it have forms suggestive of algae or kindred organisms. The fucoid markings on quartzite beds resemble those locally abundant in the Kinnikinic quartzite. The formation is unconformable below slate of Lower Ordovician age and is lithologically quite unlike any known member of the Belt series. For these reasons the dolomite is tentatively regarded as of Cambrian age.

Chambers (1966) did not address the age of the unit directly, but he implied that it is most likely Late Cambrian on the basis of arguments used by Ross for the age of the bounding formations and the similarities to well-known sections in southeastern Idaho.

A definitive age for the Bayhorse Dolomite is critical to an understanding of the geologic evolution of east-central Idaho. In view of the fact that an Ordovician age of the overlying Ramshorn Slate must now be suspect (p. 28), we did very extensive sampling of both the dolomite and limestone facies of the Bayhorse Dolomite but with only ambiguous results. Each of two localities near the base of the formation near the town of Bayhorse yielded one tiny fragment of a ribbed brachiopod shell as reported in our paleontological reports here. A third locality near the same stratigraphic position produced two pelmatozoan columnals of probable Ordovician age. The collections are described as follows:

Reuben J. Ross, Jr. (witten commun., 1968) reported:

USGS Colln. D1961 CO. Bayhorse Dolomite, low thin bedded limestone. On south side of creek below road just east of bridge below town of Bayhorse.
Idaho coord., cent. zone: E 419,200 ft; N 994,825 ft.
A small fragment of ribbed brachiopod, otherwise indeterminate
The age of this formation must be Paleozoic; it is probably post-Cambrian, though possibly Late Cambrian.

USGS Colln D1960 CO. Bayhorse Dolomite, near base of formation, Idaho coord., cent. zone: E 417,900 ft; N 997,650 ft, Bayhorse quad., Idaho.
Brachiopod, a tiny fragment of a ribbed shell. None of the critical cardinalia or hinge structures are preserved.
Age: Certainly post-Precambrian. Probably lower Paleozoic.

Jean M. Berdan (written commun., 1969) stated:

This report concerns a slide from collection 69-RJ-115, from the Bayhorse Dolomite, on west side of top of hill 8362. Alt. 8,360 ft., E. 410,825'; N. 1,020,900', Bayhorse Quad.

The specimens sent in as ostracodes? are still doubtful. They could be ostracodes, but I have seen similar objects which were silicified crusts over oolites. In any case, the presence of ostracodes would not necessarily indicate a Middle Odovician age, as there are a number of Lower Ordovician ostracodes and even rare leperditiids in the Cambrian. However, Mike Taylor and I have both examined the pelmatozoan columnals and as nearly as we can determine, it is unlikely that they are older than Ordovician. Both specimens have crenulae with pentameral symmetry, and an investigation of Moore, Jeffords, and Miller (1968) suggests that this type of columnal does not appear before the Ordovician. Cystoid eocrinoid plates in the Cambrian would have crenulae, but would be curved in cross-section and without a lumen, and Cambrian columnals, would not have crenulae with pentameral symmetry. It seems most probable that the age of the collection is Ordovician or younger.

James Sprinkle (written commun., 1971) stated:

I've looked over the collection from the Bayhorse Dolomite, and the fragments are definitely echinoderm columnals and not calyx plates. This makes the age post-latest Middle Cambrian, and very probably *Early Ordovician or later*. I have seen nothing at all resembling these specimens in the Cambrian collections, but I did illustrate several columnals from the lower part of the Antelope Valley Limestone (Nevada), (collection D 719f CO) in fig. 1, items 26–27, of my annual review paper (Sprinkle, 1971), which are quite close (but not identical) to those Bayhorse specimens. Both the Antelope Valley and Bayhorse columnals could well belong to the Ordovician crinoid *Iocrinus* (see Moore, Jeffords, and Miller, 1968).

The possibility of contamination has been carefully considered in the light of failure to duplicate the results by repeated collections from the same localities. However, the three discoveries in the same general part of the section from rather widely separated localities cannot be ignored. In spite of the equivocal results so far obtained we are compelled to recognize the Bayhorse Dolomite as probably either Late Cambrian or Early Ordovician in age or of both ages and the overlying Ramshorn Slate as almost certainly Ordovician.

Garden Creek Phyllite

Distribution

The Garden Creek Phyllite, named by Ross (1934a, p. 941), underlies the Bayhorse Dolomite and is exposed along the canyon walls in the core of the Bayhorse anticline where the structure has been breached by Bayhorse Creek, and in a similar occurrence to the north where the formation is exposed in the valleys of Garden Creek and Daugherty Gulch. These exposures, which total about 2¼ mi^2 (6 km^2), are the only recognized occurrences of this unit. Ross (1937) described the formation as follows:

The formation is composed exclusively of a dark-gray or nearly black phyllite with abundant silvery sericite on cleavage surfaces. Some of the phyllite is slightly calcareous. Bedding is represented by thin crenulated bands visible only on close inspection. The rock is soft and weathers so readily that satisfactory exposures are rare except locally, as in the inner gorge of Garden Creek. It breaks into small smooth flakes and slivers that form masses of mobile talus.

The phyllite is much contorted and commonly steeply inclined. As the base of the formation is nowhere exposed its thickness is indeterminate, but plate 1 shows that the beds aggregate at least several hundred feet. The local crumpling and poor exposures characteristic of the phyllite make its relations to the overlying Bayhorse dolomite difficult to determine. In general, as the map indicates, there is little discordance in attitude between the two formations along the contact.

More recent work in the area during exploration by mining companies led to the discovery of a massive dolomite that barely crops out in the floor of Bayhorse Creek and the top of which marks the base of the Garden Creek Phyllite. As a consequence, Ross' conclusion on the indeterminate thickness of the phyllite as quoted can be modified although his comment regarding the crumpling, contortion, and generally poor exposures of the strata is valid and these features could easily explain the local thickening of the section, duplication of beds, and other distortions that would lead to inaccurate results from any attempt at direct measurement. An estimated 1,200 to 1,400 ft (365 to 425 m) of phyllite is included between the base and the top of the unit where these contacts are exposed on the north side of Bayhorse Creek 2,000 ft (600 m) west of the Bayhorse townsite; slightly more is exposed on the south side. The nearly horizontal top and bottom contacts, together with the gradational transition from the phyllite into the overlying carbonate (as described in the section on the Bayhorse Dolomite, p. 29), suggest that our thickness estimates (1,200 to 1,400 ft) may be close to the true thickness, but local thickening by flowage is probable. A stratigraphic interval of nearly 1,800 ft (550 m) of exposures on the ridge between Garden Creek and Daugherty Gulch is most certainly the result of thickening of the phyllite in the axis of the more tightly folded part of the anticline.

Even though the basal contact of the phyllite could nowhere be closely examined, the general concordance of the phyllite with the underlying dolomite suggests stratigraphic continuity. Several carbonate beds occur in the lowest exposed part of the section along Garden Creek, even though no underlying massive dolomite is exposed, suggesting that the contact is gradational.

Details of the complex internal structures of the Garden Creek Phyllite can be observed only in old mine workings most of which are now inaccessible. Axes of small drag folds plunge at various angles to both the north and south, and the steeply dipping cleavage strikes consistently within a few degrees west of north and generally parallel to the axis of the Bayhorse anticline. Most of the structures resulted from adjustment by flowage of an incompetent, thick, argillaceous unit tightly folded between massive and more competent strata.

Most of the beds in the phyllite are between 0.05–0.5 in. (1–15 mm) thick, and the grain size ranges from that of clay to silt. Interbeds of fine sand up to several feet thick have been found in a few places. Unaltered argillite from mine workings is reported by Chambers (1966) to be "* * * dead black and to stain the fingers with impalpable soot." Marcasite is a common constitutent of the black shales and a faint odor of hydrogen sulfide pervades old mine workings. The fine grain, dark carbonaceous constituents and iron sulfide content are hallmarks of deposition in an anaerobic, black shale environment that is generally inhospitable to living organisms and could be the major factor for their absence as fossil remains in the rock.

Age

No direct fossil evidence was found by which to date the Garden Creek Phyllite. Any borings, trails, or tests that existed would, in all probability, have been destroyed by the well-developed cleavage and low-grade metamorphism. On stratigraphic evidence, Ross' correlation (1937, p. 11) with Middle Cambrian formations in southeastern Idaho is reasonable, and the Garden Creek Phyllite is considered to be of Middle(?) Cambrian age.

Basal Dolomite of Bayhorse Creek

The dolomite that lies beneath the Garden Creek Phyllite and forms the relatively inconspicuous outcrops in the stream bed west of the Bayhorse townsite may have been noted by various workers in the mining area over the years since Ross did the first mapping. This carbonate was given the informal name of "Garden Creek dolomite" by D.P. Wheeler, Jr. (personal commun., 1964), and was further mentioned by Chambers (1966), who implied it was no more than a carbonate lens in the Garden Creek Phyllite. However, it was not until an intensive mineral exploration program during the 1960's that the extent, thickness, and character of the unit was documented and its status as a probable new formation rather than local facies of the phyllite was determined. In this report, we have informally called this unit the basal dolomite of Bayhorse Creek.

Although the very limited outcrops of this dolomite are confined to a narrow gorge-like reach of Bayhorse Creek that is only about 1,500 ft (460 m) long and 30–35 ft (9–11 m) deep, nearly 60 ft (18 m) of dolomite crops out in the most westerly exposure. Exploration drill holes penetrated more than 600 ft (180 m) of dolomite before intersecting rhyolite porphyry that intrudes it. The porphyry was cut in other drill holes at somewhat higher levels and seems to transect bedding at a low angle, although it maintains the general configuration of a sill-like intrusive controlled for the most part by gently dipping strata.

Most of the dolomite exposed along the creek represents the upper 30 ft (9 m) of the unit. It is generally light gray on fresh surface, but ranges from medium light gray to very light gray, and weathers to various shades of yellowish brown. The dolomite is generally pure, aphanic to fine grained and locally silty in massive or thick beds that have local faint lamination. The lower 30 ft (9 m) of the exposed part of the section are composed of a yellowish-gray, fine-grained, thin- to medium-bedded nearly pure dolomite that weathers grayish orange to pale yellowish brown. The bedding planes are sharply defined, and the rock weathers into angular blocks and slabs rather than the rounded shapes that characterize the upper part.

No fossils were found in this dolomite with which to date it, and the only indication of its age is its stratigraphic position beneath the Garden Creek Phyllite, which is beneath the Bayhorse Dolomite of Late Cambrian and (or) Early Ordovician age. So far as is known, no other comparable sequence of rocks has been recognized in east-central Idaho.

MIDDLE CAMBRIAN AND OLDER ROCKS OF SQUAW CREEK

A sequence of rocks comprising four distinctive formations that are of Middle Cambrian age or older are exposed in two relatively small areas along and near the middle reaches of Squaw Creek about 7 mi above its junction with the Salmon River. One of these areas is cut by Squaw Creek between the Red Bird Mine on the south and the mouth of Cash Creek on the north. The other is on Cash Creek about 2.5 mi to the northeast of the Squaw Creek exposures. Both areas of outcrop total less than 2 mi^2 (5 km^2).

This package of strata has an unnamed shale unit at the top underlain by a thick, fairly pure, medium-bedded quartzite—the Cash Creek Quartzite, a heterogeneous impure carbonate unit, and a massive to thick-bedded quartzite at the base. The quartzite-carbonate-quartzite part of the sequence was originally considered by Ross (1937) to be correlative with the Kinnikinic Quartzite of Ordovician age. The subsequent more detailed work of our study discovered fossil evidence that shows this assemblage of four units to include Middle Cambrian, and possibly older strata, and that this assemblage is not correlative with the originally defined Kinnikinic Quartzite. This problem together with a description of the various types of strata as presented by Hobbs and others (1968) in their report on the redefinition of the Kinnikinic Quartzite, is paraphrased and, in part, refined in the following paragraphs. Detailed columnar sections of the stratigraphic sections are given in figures 11 and 12.

Shale

The shale at the top of the sequence is exposed both along the top of the cliffs on the west side of Squaw Creek and in the somewhat broken and faulted counterpart of this package of strata exposed east of Squaw Creek on the north side of Cash Creek. At the north end of the outcrops on the west side of Squaw Creek, the shale, with the overlying carbonate of Cash Creek area, rests directly on the Cash Creek Quartzite. To the south across a small fault of pre-Ordovician age the shale is missing and the carbonate rests directly on the Cash Creek Quartzite. No more than 200 ft (60 m) of the shale exists on the west side of Squaw Creek. On the north side of Cash Creek, about 2 mi (3.2 km) from its junction with Squaw Creek, an estimated 200 ft (60 m) of the shale rests on the Cash Creek Quartzite and is overlain in apparent conformity by the carbonate of Cash Creek. At this place both contacts appear to be conformable and relatively undisturbed even though the upper contact is probably a disconformity as suggested by the Squaw Creek locality. On the basis of this evidence and the very limited exposures, we can conclude that about 200 ft (60 m) of shale of an unknown original thickness forms the uppermost unit of the sequence of Middle Cambrian and older rocks of Squaw Creek.

The upper shale unit is mostly a fissile to slabby-weathering siltstone or shale that is slightly micaceous on bedding planes and slightly phyllitic in the more argillaceous layers. Color ranges from light to medium greenish gray, yellowish gray, olive drab, to dark gray on fresh surfaces. Weathered surfaces are predominantly light olive gray to slightly brownish olive drab that has a local maroon or purplish overcast. Some beds weather red or pale reddish brown to a deep brick red or grayish red. In most exposures the bedding is evidenced by the platy character of the weathered outcrop or the talus debris rather than by compositional or textural layering. Faint laminae mark some beds and slight variation in grain size is evident in parts of the section. Local color banding in shades of red and orange red form concentric patterns or anastomosing patterns that are superposed across and independent of lamination or bedding. This color banding represents redistribution of oxidized iron as Liesegang rings.

An early Middle Cambrian age has been assigned to the shale unit on the basis of distinctive fossils collected from the basal part at or near the contact with the underlying Cash Creek Quartzite. The most complete assemblage came from the shale at the top of the cliffs west of Squaw Creek and 2,000 ft (620 m) south of the mouth of Cash Creek. Although most abundant in this locality, similar fossils as individual specimens or in small concentrations have been found in exposures at this same horizon along the strike of the unit to the south as well as in exposures on Cash Creek to the northeast. These collections were reported on by A.R. Palmer in the report by Hobbs and others (1968, p. J19), and are repeated here:

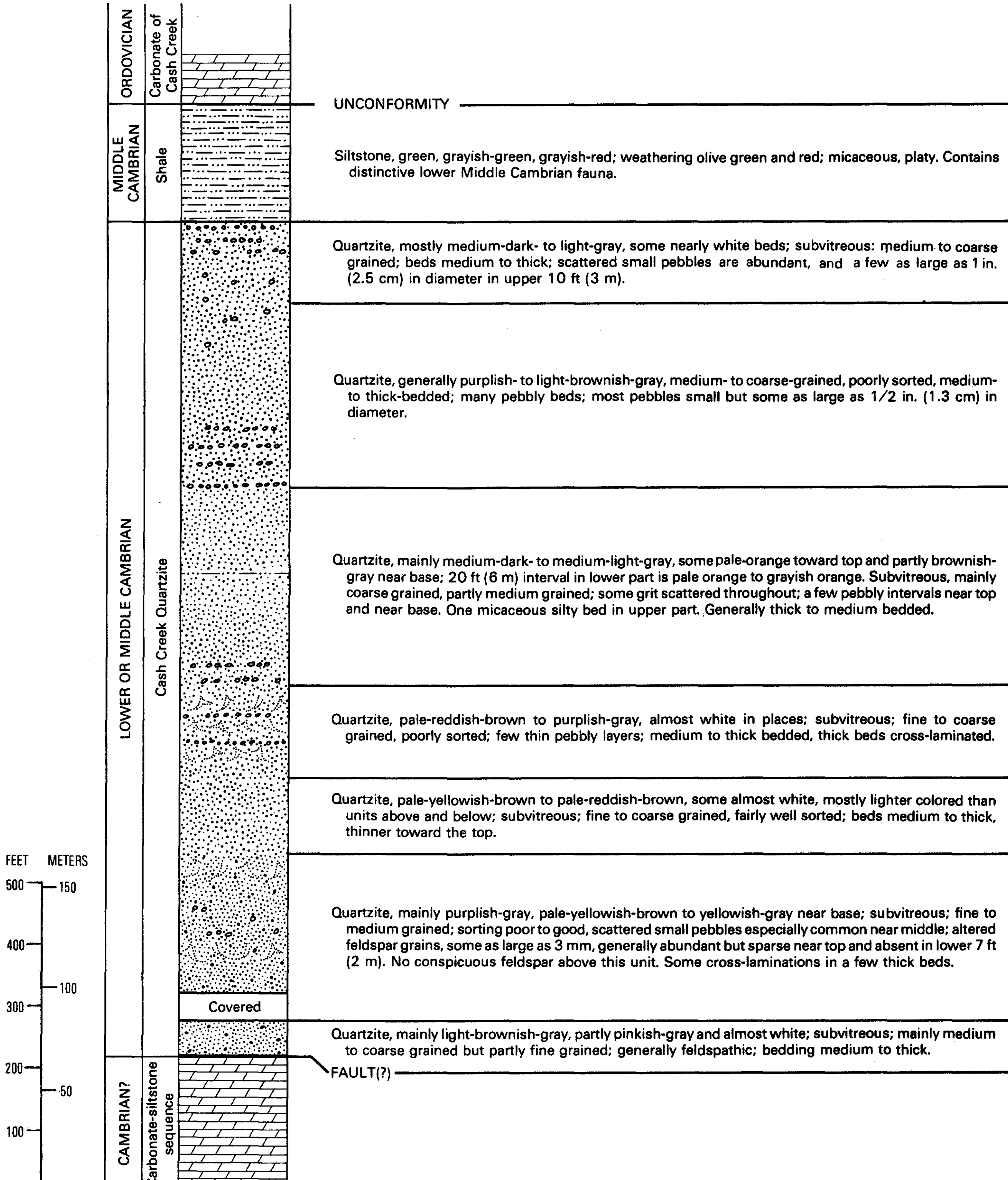


Figure 11. Columnar section of the Cash Creek Quartzite and overlying shale showing relations to the bounding formations along Squaw Creek in SW¼ of unsurveyed T. 12 N., R. 17 E. Cash Creek Quartzite was measured; thicknesses of other units estimated from map relations. See page 7 for explanation of lithologic symbols used in this figure.

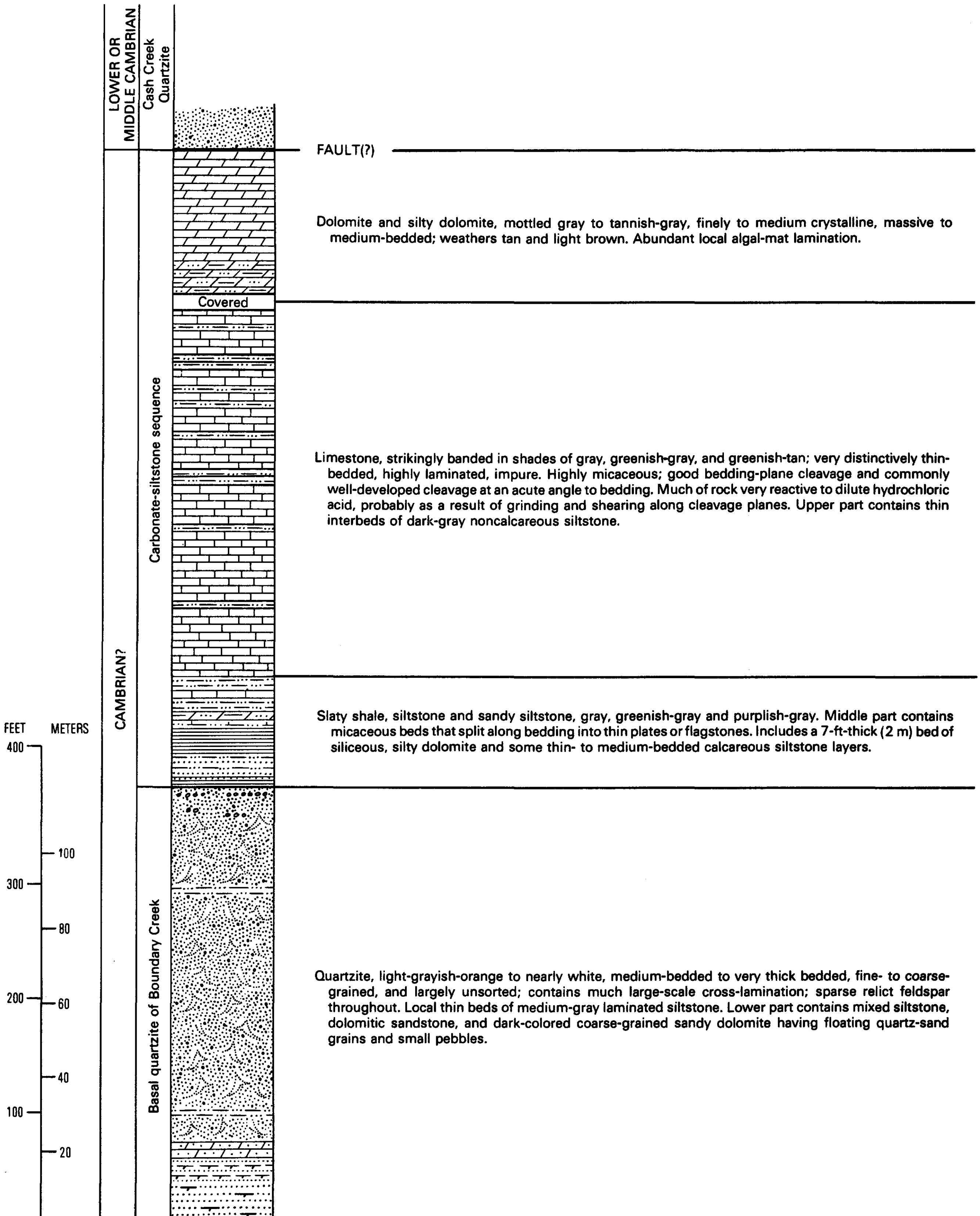


Figure 12. Columnar section of the carbonate-siltstone sequence below the Cash Creek Quartzite, and the underlying basal quartzite of Boundary Creek as exposed along Squaw Creek in SW¼ of unsurveyed T. 12 N., R. 17 E. The carbonate-siltstone sequence was measured; thickness of the quartzite of Boundary Creek was estimated from field and map relations. See page 7 for explanation of lithologic symbols used in this figure.

USGS Colln. 5461 CO and 5462 CO. Siltstone above Cash Creek Quartzite, on west side of top of hill 6897, west of Squaw Creek, 3.5 miles north of mouth of Bruno Creek. Idaho coord., central zone: E. 373,800 ft., N. 976,270 ft., Clayton 7 ½-minute quadrangle, Idaho.

Nisusia sp.
Pagetia sp.
cf. *Spencia* sp.
Ptychoparioid trilobites of early Middle Cambrian aspect
Undetermined corynexochoid trilobites, cranidia only
Acrothele? sp.
Gogia sp.

Palmer (written commun., 1965) stated:

The presence of the distinctive eodiscid trilobite *Pagetia* is a definitive element in this collection. It is known in western North America only from beds older than medial Middle Cambrian. *Nisusia* is a distinctive ribbed brachiopod found only in Middle Cambrian beds. *Gogia* is a distinctive echinoderm which is represented by a number of nearly complete specimens in this collection which show well the characteristic morphology of this Middle Cambrian genus. The ptychoparioid trilobites are not well enough preserved to be satisfactorily named, but their aspect is most characteristic of forms from the lower part of the Middle Cambrian. The presence of a corynexochoid trilobite is the most significant evidence for a Middle Cambrian age from the trilobite data. Corynexochoid trilobites are confined, except for a few unusual and distinct exceptions, to Middle Cambrian and older beds, and forms such as those in this collection, with long eyes, are medial Middle Cambrian or older.

Cash Creek Quartzite

Distribution and General Features

The Cash Creek Quartzite is best exposed and most easily examined in the cliffs along the west side of Squaw Creek south of the mouth of Cash Creek. Good, but less accessible, exposures are on Cash Creek about 2 mi from its mouth and these two localities are the only ones known anywhere in the Bayhorse area. This quartzite underlies the Middle Cambrian shale of the sequences and has been named and described by Hobbs and others (1968) in their report on the Kinnikinic Quartzite. Salient parts of this description are repeated here.

A section 1,105 ft (337 m) thick of the Cash Creek Quartzite, designated the type section, was measured on the steep cliffs about ¼ mi south of the mouth of Cash Creek and almost entirely on the west side of Squaw Creek (fig. 11). The basal part of the section is covered, a short distance east of Squaw Creek, by volcanics of the Challis Group, but the covered interval is exposed within a mile to the south along the strike of the formation. Map projections indicate that not more than 200 ft (60 m) of the basal part of the formation is concealed at the type section. The total thickness of this quartzite unit can thus be reasonably estimated at between 1,200 and 1,300 ft (365 and 396 m).

Character

The Cash Creek Quartzite along Squaw Creek is pure quartzite except for sparse thin layers of shale and silty quartzite. Beds are predominantly medium to thick, and some of them, particularly in the lower half, are cross-laminated. Although some intervals are nearly white or various shades of pure gray, more colorful quartzite, in shades of yellowish gray, brownish gray, light orange, and subtle pink and purple, is more characteristic of the formation.

Grain size ranges from fine to coarse. Pebble layers and lenses and isolated pebbles are scattered through the section but nowhere are sufficiently abundant for the rock to be called conglomerate. Sorting is good in some beds but is more commonly fair to poor. The upper two-thirds of the unit is nearly pure quartzite and pebbly quartzite; the lower third contains as much as 5 percent altered feldspar. Some feldspar grains are as much as 3 mm in diameter, but most are much smaller.

Age

At both localities the Cash Creek Quartzite is overlain in apparent conformity by the lower Middle Cambrian shale of the sequence. No fossils have been found in the quartzite nor in either of the two units that underlie it. Although it is tempting to suggest a possible correlation with the closely similar Wolsey Shale-Flathead Quartzite sequence of Middle Cambrian age in southwestern Montana, the assignment of the Cash Creek Quartzite to the Middle or Early Cambrian is unsupported by specific evidence.

Carbonate-Siltstone Sequence

The heterogeneous carbonate-siltstone sequence that lies below the Cash Creek Quartzite and above a lower series of massive quartzites comprises a group of very distinctive strata that includes impure dolomite, impure limestone, fissile siltstone, and flaggy siltstone. These rocks are known only along Squaw Creek and are most extensively exposed in the lower part of the cliffs that border the west side of that creek. The unit crosses Squaw Creek valley and is exposed in the creek bed and in roadcuts along the east side of the creek about ¼ mi (0.4 km) north of the mouth of First and Second Creeks—a tributary flowing into Squaw Creek from the east.

Character

A measured columnar section of this unit is shown as figure 12. The base rests conformably on massive, nearly pure, subvitreous, unsorted quartzites. Above this contact the lower 65 ft (20 m) includes thin-bedded, micaceous, gray, greenish-gray, and purplish-gray slate or siltstone and sandy siltstone and local layers of micaceous quartzite. The upper 25 ft (7.5 m) of siltstone splits along the bedding into smooth thin slabs and has been prospected for commercial flagstone. The flagstone interval is overlain by a 7-ft (2-m) massive bed of siliceous dolomite and, in turn, by a 30-ft (9-m) layer of thin- to medium-bedded limy siltstone. This siltstone grades upward into a sequence 250 ft (76 m) thick of very distinctive impure limestones that forms the middle part of the section. The limestone is very thin bedded, strikingly banded in shades of gray and greenish gray, and highly micaceous. It has prominent bedding-plane cleavage and commonly a conspicuous cleavage at an acute angle to the bedding. The thin bedding and color banding are the most distinctive characteristics of these beds. Many of the laminae are calcareous and effervesce violently in dilute hydrochloric acid. Above this central part is a zone about 80 ft thick (24 m) of thinly interbedded light-colored limestone and darker colored nonlimy siltstone, the limestone becoming dominant in the upper 10 ft (3 m). A covered interval of 15 ft (4.5 m) separates the limestone from a sequence of dolomite and silty dolomite that forms the upper 130 ft (40 m) of the measured section. The upper dolomite is massive to medium bedded and fine to medium crystalline and contains silty laminae that weather as prominent ridges; some of these probably are algal mats. Indistinct bedding lines are visible in the massive layers. The color is generally mottled gray to tannish gray; weathered surfaces are tan and light brown.

Evidence for a fault semiparallel to the bedding at the top of the massive dolomite in the measured section is conclusive. The dolomite and overlying Cash Creek Quartzite are brecciated and heavily iron stained and extensive gossan has developed in fractures and irregular open spaces adjacent to the contact. To the south the dolomite is gradually cut out along the fault which cuts down section. However, about 0.5 mi north of the measured-section locality along the strike of the unit the upper dolomite of the carbonate-siltstone sequence is not faulted against the Cash Creek Quartzite and the dolomite below the Cash Creek Quartzite compares in thickness to the section described in the measured section (fig. 12). The thickness of the dolomite is probably little more than that at the measured section, and the stratigraphic sequence for the carbonate-siltstone strata below the Cash Creek Quartzite seems to be unbroken.

Thickness and Age

The carbonate-siltstone sequence is at least 570 ft thick (174 m) and lies in apparent conformity below the Cash Creek Quartzite. Some of the upper massive dolomite includes layers that weather out as closely spaced, somewhat undulant thin ribs of more silty composition that are tentatively interpreted as algal mats. Careful search of these and other horizons for useable fossils proved fruitless, and the age of this unit remains uncertain. In this report the carbonate-siltstone unit is considered to be Cambrian? but could be Middle Cambrian or older.

Basal Quartzite of Boundary Creek

Below the carbonate-siltstone sequence on Squaw Creek are quartzitic rocks that are known only at this locality along Boundary Creek, but like the other quartzites in the Bayhorse area, they may be laterally equivalent to some of the numerous isolated quartzite masses of similar character and uncertain age that are scattered to the north and east.

Most of the basal quartzite of Boundary Creek is light grayish orange to nearly white. Weathered surfaces are grayish orange to light brownish gray. The beds are medium to very thick, and many exhibit large-scale cross laminae. The component grains are generally unsorted and range from fine to coarse but are dominantly fine to medium. Most of the grains are quartz, but many of the beds contain numerous particles of white or orange clayey material that most probably results from the alteration of feldspar. A few thin layers of medium-gray laminated siltstone, notably micaceous, are distributed through the section. Beneath the massive quartzite which forms the upper several hundred feet of the section is a sequence of mixed lithologies that contains some medium to thick beds of siltstone together with pebble-bearing quartzite, dolomitic sandstone, and coarse quartz-pebble-bearing dolomite. One layer of blue-black coarse-grained dolomite contains conspicuous rounded quartz grains and pebbles. Some of the quartzite in this mixed-lithology sequence contains carbonate granules that weather out and leave a pitted surface on many of the outcrops. The base of the sequence is not exposed, but the lowest outcrops show much brecciation of the quartzite and shearing in the siltstone and contain many quartz veins; all these features suggest major structural disturbance. The original thickness of the sequence of mixed lithology is uncertain because of the incomplete exposures and obvious structural disturbance, but the zone comprises several hundred feet of rocks in the lower half of the basal quartzite of Boundary Creek.

The basal quartzite of Boundary Creek was not measured, but from the distribution and attitude we estimated that at least 400 ft (122 m) is exposed in the valleys of Boundary Creek and First and Second Creeks. The base probably rests on a major thrust fault.

Relations of the Middle Cambrian and older rocks of Squaw Creek to other parts of the local stratigraphic picture and to the regional setting are largely conjectural.

Even in their present position, the Middle Cambrian and older strata represent one of the most westerly known occurrences of the so-called eastern facies of the lower Paleozoic in this part of Idaho. Should these strata be allochthonous, and in turn be capped by a higher thrust plate containing eastern facies Ordovician carbonate strata—all moved in from the west—important questions about their physical and temporal relations to the cratonic eastern facies indigenous to southwestern Montana must be carefully considered. The source area or correlative counterparts may never be found since most of the potential root zone has foundered in the Cretaceous Idaho batholith and Tertiary intrusives, or has been buried beneath the Eocene Challis Volcanic Group.

ORDOVICIAN(?) AND LATE PROTEROZOIC(?) ROCKS

A sequence of strata comprising predominant quartzite with subordinate interbeds of dolomite, siltstone, and argillite is well exposed in the south central part of the Challis quadrangle (McIntyre and Hobbs, 1987) that adjoins the Lone Pine Peak quadrangle on the north. Although only the southern end of these strata extend into the area of this report, these strata are an integral part of the regional geologic story and will be briefly considered in the context of the Bayhorse area. In the Challis quadrangle these rocks crop out extensively between Beardsley Hot Springs and the crest of the Pahsimeroi Mountains to the east, along and mostly north of Leaton Gulch, and in the headwaters of Pennal Gulch about a mile to the north of Beardsley Hot Springs. These strata also form a band extending eastward from Leaton Gulch and a very short distance north of the northern boundary of the Lone Pine Peak quadrangle. A southerly extension of the east end of these outcrops projects for about 2 mi (3.2 km) into the Bayhorse area (pl. 1).

In the Challis quadrangle the dominant lithology of this sequence is quartzite that ranges in color from deep red to dark purplish gray and medium gray. In places the quartzite is light pink, tannish gray, very light gray or nearly white. Bedding is mostly thin to medium with some well-laminated layers that weather into thin plates and slabs. Most of the quartzite is medium to fine grained, but locally it is coarse grained and pebbly with several horizons of very coarse conglomerate or intraformational breccia. Much of the thin-bedded, platy quartzite shows ripple marks, flute casts, and worm trails or borings. Some beds in the sequence are marked by abundant magnetite.

Dolomite is not abundant but occurs as distinct beds, usually massive, that range in thickness from a few feet to as much as 15 ft (4.5 m) and are dispersed in quartzite. Most of it is restricted to about the first 0.6 mi (1 km) of an exposed sequence that extends eastward from Beardsley Hot Springs. The dolomite is very fine grained to dense, relatively pure, and is medium tan on fresh surface. It weathers rich reddish tan or brown, and some layers show prominent ribbing on weathered surfaces.

Argillaceous parts of this rock sequence are minor in most places and occur mainly as thin laminae or thin beds. In Pennal Gulch, however, one argillaceous interval is as much as 325 ft (100 m) thick. The argillite or siltite is thin bedded, fissile, and usually dark gray or purplish gray, and in places is altered to a deep gray green. Many argillaceous layers are metamorphosed to phyllite where highly sheared as near major thrust faults.

The part of the sequence exposed in the Lone Pine Peak quadrangle is mainly a fairly pure quartzite that ranges in color from light to very light gray but with local areas of light pink, pale red, and light grayish red. Grains are generally well rounded and fine to medium. Small amounts of hematite pigment occur in the interstices. Impurities include minor amounts of sericite and in some places very small amounts of carbonate and limonite. Little if any feldspar is present. Bedding ranges from massive and thick through medium to thin platy beds with wavy, irregular bedding planes. As in the Challis quadrangle, certain parts of the section are characterized by worm trails and borings on the bedding planes, but no organic remains were found. The actual sequence of the various rock types is indeterminate because of the complex structure and the discontinuity of exposures.

The strata described in this section do not correlate in any satisfactory way, either by lithology or by relation to adjoining units, with any of the previously described units. They bear no resemblance to any of the well-dated Paleozoic formations in the Clayton and Lone Pine Peak quadrangles to the southwest and south, or in the Lost River Range to the east; nor are they compatible with such marginally dated units as the Clayton Mine Quartzite and related units, the Rob Roy sequence, the quartzite and siltstone of upper Cash Creek, the Cash Creek Quartzite, or the basal quartzite of Boundary Creek. Known Middle Proterozoic sequences within a few miles to the northeast, north, and northwest include the Lawson Creek Formation (Hobbs, 1980), the Swauger Quartzite (Ross, 1947), and the Gunsight Formation (Ruppel, 1975a). Of these nearby quartzites, the Swauger Quartzite most closely resembles some parts of the Leaton Gulch rocks, but the presence of dolomite, certain distinctive bedding characteristics, grain size, and various impurities discourages correlation. Many features of the Leaton Gulch–Penal Gulch rocks more closely resemble those described by Ruppel (1975b) as belonging to the Wilbert Formation and Summerhouse Formation of Late Proterozoic and Early Ordovician ages, respectively, and by McCandless (1982) who was concerned with these same units as well as one of Cambrian age.

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