357

The Kinnikinic Quartzite of Central Idaho— Redefinition and Subdivision

By S. W. HOBBS, W. H. HAYS, *and* R. J. ROSS, JR.

CONTRIBUTIONS TO STRATIGRAPHY

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Restriction of Kinnikinic Quartzite to a distinctive unit of Middle Ordovician age and description of this and five older stratigraphic units included in the Kinnikinic as originally defined

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CONTENTS

ILLUSTRATIONS

CONTRIBUTIONS TO STRATIGRAPHY

THE KINNIKINIC QUARTZITE OF CENTRAL IDAHO— REDEFINITION AND SUBDIVISION

By S. W. HOBBS, W. H. HAYS, and R. J. ROSS, JR.

ABSTRACT

Detailed study of the Kinnikinic Quartzite as defined by C. P. Ross in the Bayhorse region, Idaho, has resulted in subdivision of Ross' formation into six formations. Two similar but demonstrably distinctive sequences of quartzite-carbonate-quartzite units have been measured and described. The name Kinnikinic is retained for the uppermost pure well-sorted quartzite of one of the sequences. The Kinnikinic, as thus restricted, is the Kinnikinic of most other workers in central Idaho. It is about 700 feet thick, is overlain by the Saturday Mountain Formation, and is definitely dated as Middle Ordovician. The massive, commonly sandy, dolomite that underlies the redefined Kinnikinic is 700 feet thick and contains an early Middle Ordovician fauna. This unit is named the Ella Dolomite. More than 2,000 feet of poorly sorted impure feldspathic quartzite and some fissile shale and siltstone lies conformably below the Ella Dolomite and is named the Clayton Mine Quartzite. The age of this lower quartzite is unknown, but the unit appears to be older than Middle Ordovician.

The other quartzite-carbonate-quartzite sequence is overlain by shales containing unequivocally Middle Cambrian fossils and is thus Middle Cambrian or older. The upper quartzite of this sequence, named the Cash Creek Quartzite, is about 1,200 feet thick and has distinctive lithology. Nearly 600 feet of dolomite, thin-bedded color-banded shaly limestone, and some thin flagstone beds underlie the Cash Creek Quartzite. A thick-bedded fairly pure quartzite forms the basal unit of this sequence. Only about 400 feet of the basal unit is exposed above a thrust fault that bottoms the sequence.

INTRODUCTION

The Kinnikinic Quartzite was named by C. P. Ross (1934) from extensive exposures of quartzitic rocks along the lower reaches of Kinnikinic Creek in the Bayhorse region, Custer County, Idaho. He considered the formation to be of Ordovician age and limited definite application of the name to strata extending from the vicinity of Kinnikinic Creek northeastward 20 miles to the vicinity of Round Valley, near Challis. In subsequent work, Ross (1947, 1961, 1962) extended the name to other areas, and other workers including Anderson and Wagner (1944), Sloss and Moritz (1951), Scholten (1957), Shockey (1957), Anderson (1961), and Mapel, Reed, and Smith (1965) applied the name to quartzites elsewhere in Idaho that correspond generally in both lithology and age to those described by Ross at the type locality.

Our detailed work in the Bayhorse region from 1963 to 1966 showed that the quartzites mapped by Ross as a single unit and named the Kinnikinic by him are several map units of different composition and age. Only one of these units fulfills the basic criteria upon which the Kinnikinic was established as a formational unit. The basic changes that these new concepts make in the description of the type Kinnikinic Quartzite are to reduce its thickness from more than 3,500 feet to less than 1,000 feet and to eliminate the calcareous units that were previously mapped as lenses in the quartzite. Such revisions of central Idaho stratigraphy as are proposed here were realistically anticipated by Ross (1934) when he first described in detail the lower Paleozoic formations in the Bayhorse region. He stated (p. 940):

In considering the Paleozoic stratigraphy of south-central Idaho it should be borne in mind that the structure of the region is complex. In general, the rocks are steeply tilted; in many places they are contorted and locally overturned. Normal faults are plentiful, and many have dipslacements of several thousand feet. In some places, notably in the Wood River region, there are closely spaced reverse faults. Paleozoic strata are extensively intruded by igneous rocks of at least two ages. Metamorphism resulting from these intrusions has locally changed the rocks almost beyond recognition. Large areas are covered by Tertiary lava, making it impossible to trace directly the connection between different masses of the older rocks.

Regarding the Cambrian(?) System, he stated (p. 940–941):

No Cambrian fossils are known, and some of the beds now supposed to belong to other systems may conceivably be Cambrian, so that some revision is to be expected in the future.

Figure 1 is an index may showing the location of the mapped area, and figure 2 is a generalized geologic map of a part of the Bayhorse region, based on the work by Ross (1937), that emphasizes the distribution of the quartzites and the intercalated carbonates, identifies the bounding formations where these are known, and outlines the blanket of Challis Volcanics that greatly hinders correlation between outcrops of older rock. The positions of the measured sections and of the sections that are described in more general terms are also shown in figure 2. The stratigraphic and structural complications of the area, some of which are the subject of this paper, are extensive and when worked out will lead to a reinterpretation of the structure and a refinement of the areal geology. Figure 3 illustrates the stratigraphic suc-

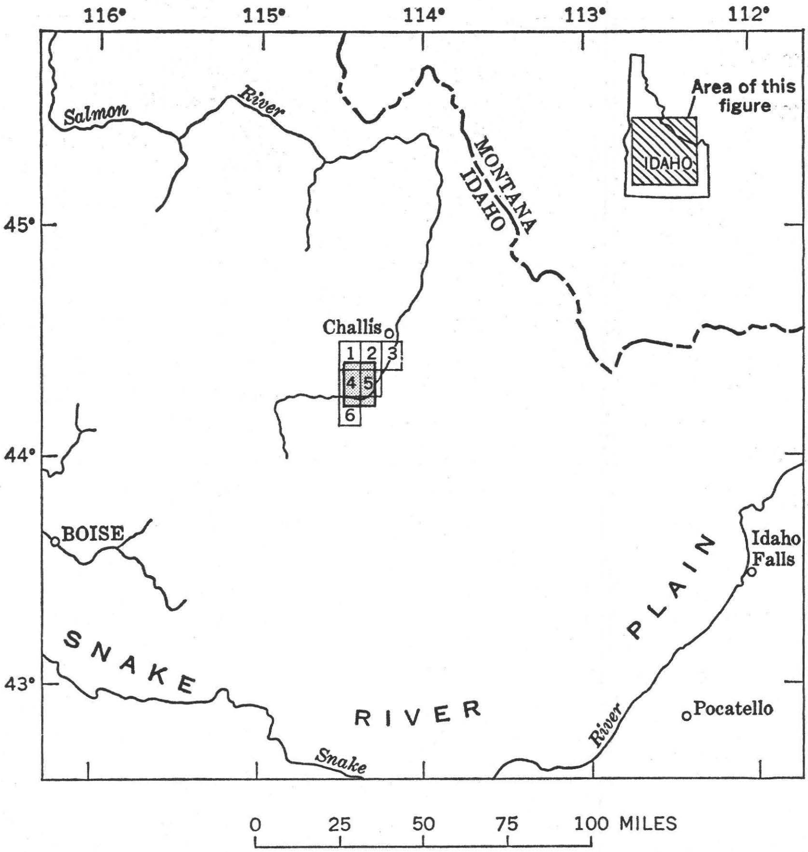

FIGURE 1.—Index map of central Idaho showing location of area illustrated in figure 2 (strippled). Numbered rectangles show location of the following 7 ½-minute quadrangles: 1, Bayhorse Lake; 2, Bayhorse; 3, Bradbury Flat; 4, Clayton; 5, Bald Mountain; 6, Potaman Peak.

cession at three places in the Clayton quadrangle where the quartzites and some of the associated formations are well exposed and apparently structurally undisturbed.

KINNIKINIC QUARTZITE AS USED BY ROSS

All the quartzites shown in figures 2 and 3 and the dolomitic and argillaceous rocks intercalated in the quartzites were included in the Kinnikinic as defined by Ross (1934). Ross described the Kinnikinic in more detail in his bulletin on the Bayhorse region (1937), and salient parts of this description (p. 17–18) are quoted here:

Character.—Most of the Kinnikinic quartzite is well bedded and nearly pure, but shaly partings and subordinate amounts of somewhat shaly beds

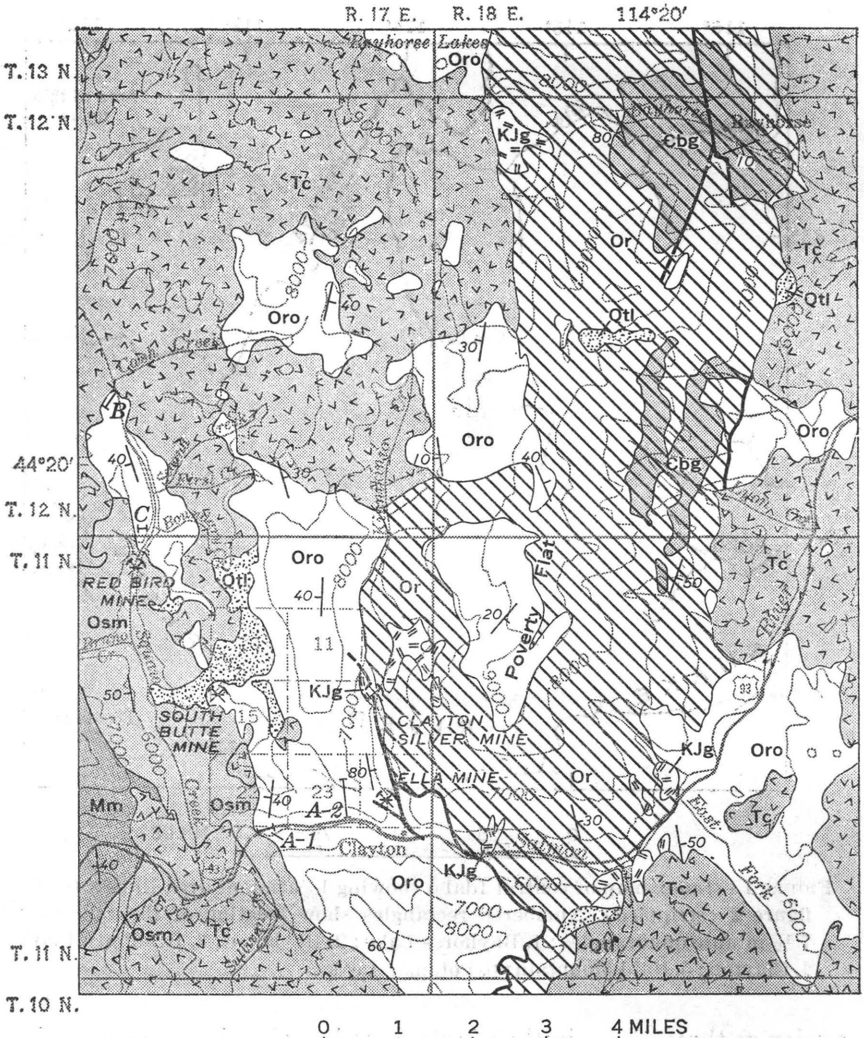

FIGURE 2.—Part of the Bayhorse region, Idaho, showing geology and location of measured stratigraphic sections. Base and geology generalized and slightly modified after C. P. Ross (1937, pl. 1).

EXPLANATION

Qtl

Quaternary talus glaciers and landslides

Tc

Tertiary Challis Volcanics

KJg

Cretaceous or Jurassic gabbro and granodiorite

Mm

Mississippian Milligen Formation

Osm

Middle Ordovician and younger Saturday Mountain Formation

Oro

Middle Ordovician and older rocks*

Includes Kinnikinic Quartzite, Ella Dolomite, Clayton Mine Quartzite, Cash Creek Quartzite, and unnamed formations. May include rocks as old as Precambrian

Or

Ordovician(?) Ramshorn Slate

Ꞓbg

Cambrian(?) Bayhorse Dolomite and Garden Creek Phyllite

Contact

Fault

Dashed where approximately located

20

General strike and dip of beds

Mine   Inactive mine

A

Line of measured section

*Kinnikinic Quartzite as used by Ross (1934).

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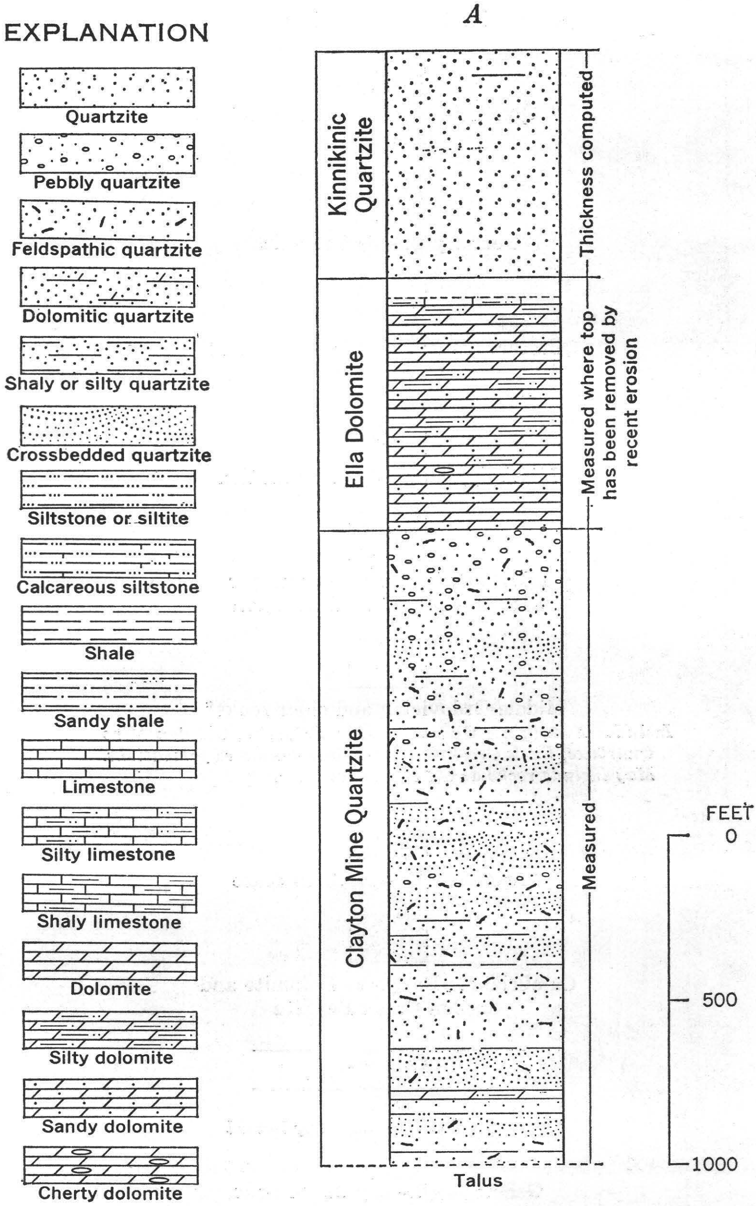
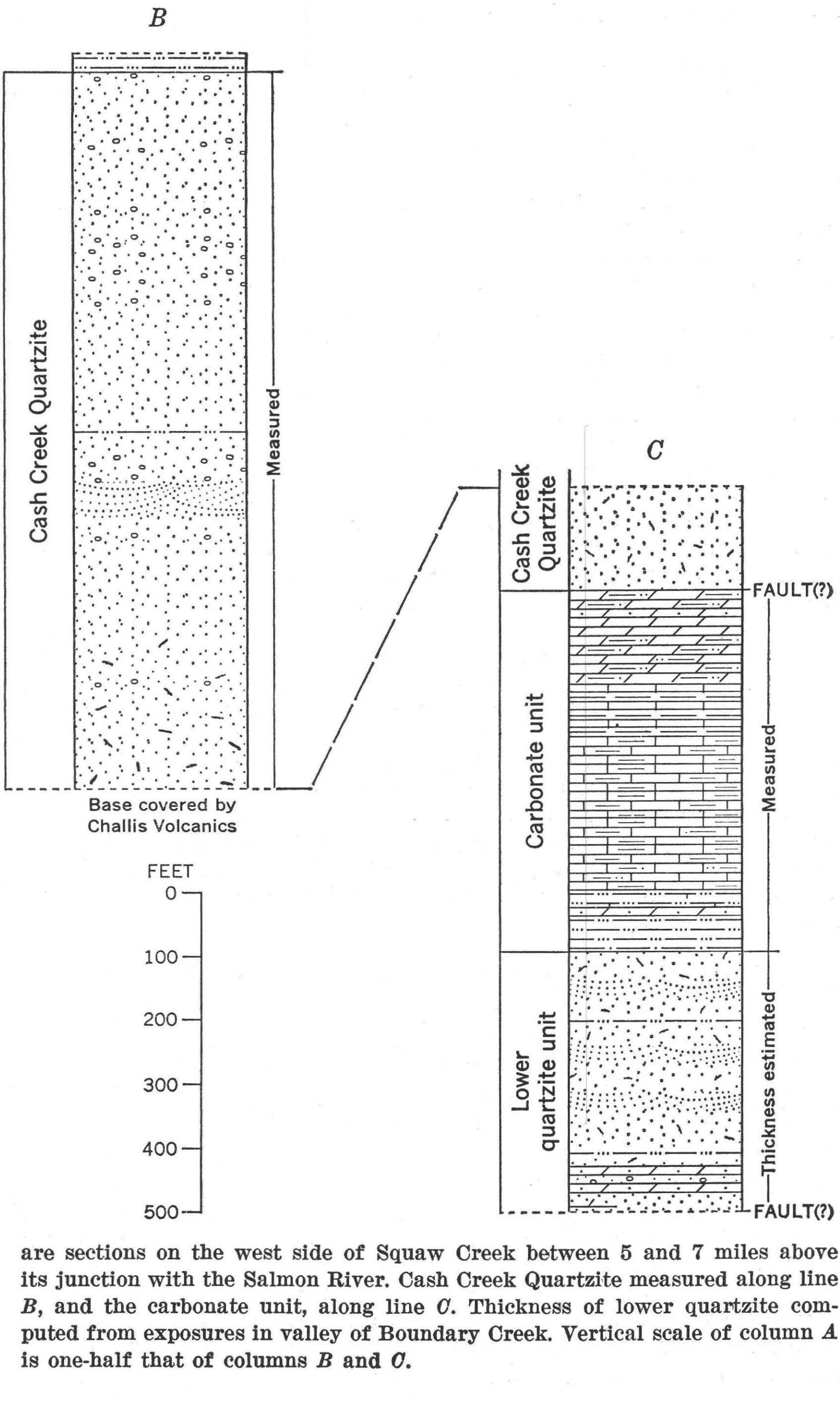


FIGURE 3.—Columnar sections of two predominantly quartzitic sequences in the Bayhorse region, Idaho. Column *A* constructed from sections on the north side of the Salmon River, 1–2 miles west of Clayton, Idaho. Kinnikinic Quartzite part of the section computed along line *A–1*, and Ella Dolomite and Clayton Mine Quartzite parts of section measured along line *A–2*. Columns *B* and *C*



are sections on the west side of Squaw Creek between 5 and 7 miles above its junction with the Salmon River. Cash Creek Quartzite measured along line *B*, and the carbonate unit, along line *C*. Thickness of lower quartzite computed from exposures in valley of Boundary Creek. Vertical scale of column *A* is one-half that of columns *B* and *C*.

are common. The prevalent color of the fresh quartzite is nearly white, but in most exposures some or all of the beds have a distinctive lavender cast, which is useful in recognizing isolated outcrops of the formation. Many exposures are stained brick red, largely through the oxidation of flakes of specularite of hydrothermal origin, which are commonly disseminated sparsely through the quartzite and quartz veinlets. The rock is composed essentially of a mosaic of detrital quartz grains 0.1 to 0.5 millimeter in diameter and slightly enlarged by deposition of secondary silica. These grains are set in a siliceous cement containing sericite.

The more argillaceous beds are generally also calcareous. They are on the average finer-grained than the quartzite and contain dolomite, sericite, graphite, chlorite, and epidote in varying proportions. In several places, mainly in the vicinity of Clayton, the formation contains irregularly lenticular aggregates of impure magnesian limestone and argillaceous beds that are large enough to be mapped separately * * *. Conglomerate was noted in the Kinnikinic quartzite only in the vicinity of Little Bayhorse Lake, near the head of Bayhorse Creek.

The Kinnikinic quartzite is everywhere contorted. In many exposures the effects of crenulation are surprisingly intricate for a rock of this character. On the slope flanking the Salmon River on the east below the mouth of Bayhorse Creek contorted beds with an average dip of fully 20° are exposed through a vertical range of 2,400 feet. The river cuts almost directly across an anticline in this formation west of Clayton. The west side of the fold is almost vertical near the river and has a width of 4,000 feet at the base of the exposure in the canyon. These data indicate that the Kinnikinic quartzite is about 3,500 feet thick or possibly somewhat more, a thickness that accords well with those indicated by the structure sections representing other parts of the region * * *.

Age.—Bedding surfaces in the quartzite show fucoid markings in many places. Such markings are especially plentiful in the hills east of Round Valley. The limestone intercalated in the formation near the mouth of Kinnikinic Creek contains small calcareous algae. These organic remains, the only fossils known in the formations, are not accurately identifiable. As the formation lies below the Saturday Mountain formation (Upper Ordovician) and above the Ramshorn slate (lowest Ordovician) with approximate concordance in attitude, it is doubtless of Lower or Middle Ordovician age.

NECESSITY OF STRATIGRAPHIC REVISION

In several places in the Bayhorse region, the areal distribution of quartzite units and the juxtaposition of quartzitic sequences of different characteristics and age are the results of a complex history that is as yet little understood. New fossil localities, the stratigraphic sequence in local sections unbroken by faults, the recognition of several distinctive varieties of quartzite, and new mapping indicate clearly, however, that the Kinnikinic Quartzite of Ross consists of several thick mappable units of different ages and that the name Kinnikinic Quartzite should be redefined and restricted.

The complexity of the stratigraphy is shown by the columnar sections in figure 3, which represent units included in Ross' Kinnikinic. Examination of fossils reveals that the rocks shown in columns *B* and *C* of figure 3 are of Cambrian or older age and, hence, older than the upper quartzite of column *A* (the authors' restricted Kinnikinic) and the dolomite unit below it, both of which are of Ordovician age. The lower quartzite of column *A*, the lithologically different upper quartzite of column *C*, and the carbonate-siltstone unit of column *C* are almost certainly separate units. The lower quartzite of column *C*, whose basal stratigraphic relations are not yet known, is probably another distinct unit. In all, two carbonate-bearing units and four quartzite units are discussed in the present report, starting with the restricted Kinnikinic and working generally downward in the section to units less well dated and less fully understood. Three new formation names are proposed. So little is yet known about the age and regional characteristics of most of the units that correlations are avoided for all but the Kinnikinic as restricted.

STRATIGRAPHIC SEQUENCE NEAR CLAYTON, IDAHO

KINNIKINIC QUARTZITE REDEFINED

As a consequence of the subdivision of the original Kinnikinic Quartzite of Ross, it is proposed here that the name Kinnikinic be restricted to the uppermost quartzite unit exposed in the Clayton quadrangle, Idaho—the upper unit of column *A*, figure 3. The original type locality of the Kinnikinic Quartzite was in the lower reaches of Kinnikinic Creek near Clayton, Idaho, and the name was derived from that of the creek. However, the quartzites that crop out so prominently along the course of Kinnikinic Creek are now excluded from the Kinnikinic as redefined, and therefore the name is not strictly applicable. Nevertheless, because of long usage that is generally consistent with the restricted definition of the Kinnikinic and the fact that rocks of this unit do occur within 2 miles of Kinnikinic Creek, the name is retained.

Distribution

The Kinnikinic as redefined is best exposed and most accessible on the west limb of a large anticline that is cut across by the Salmon River along the south edge of secs. 22, 23, and 24, T. 11 N., R. 17 E., Clayton quadrangle, Idaho. The top of the Kinnikinic is at the level of the river near the east end of the bridge that carries U.S. Highway 93 across the Salmon River about 2 miles west of the town of Clayton, and the formation is exposed in roadcuts for about 800 feet eastward from the bridge. This exposure along Highway 93 is designated the reference section. Although this is one of the least disturbed exposures of the quartzite known in the Bayhorse region, faulting has caused some duplication of the formation, and the computed thickness of approximately 700 feet in this area is probably too great. Other exposures of the Kinnikinic occur north of the reference section and east of the valley of Squaw Creek, but these are structurally isolated remnants of partial exposures surrounded by Challis Volcanics and a mantle of rock debris. To the northeast in the Bradbury Flat quadrangle (fig. 1, No. 3), Kinnikinic Quartzite is exposed along U.S. Highway 93 in the first outcrops south of the mouth of Mud Springs Gulch. Rather extensive exposures also occur in the eastern part of the Germer Basin in the southwestern part of the same quadrangle.

The original description of the Kinnikinic by C. P. Ross emphasizes many characteristics that apply closely to the proposed restricted formation, and Ross' description has been used by him and others, but not by us, for correlation beyond the Bayhorse area. As a fortunate result, where the name Kinnikinic has been used in other areas of central and southeastern Idaho, it has been applied in most places to quartzites whose lithology and age are similar to those of the unit as here restricted.

Character

The Kinnikinic Quartzite as redefined is generally medium to thick bedded and exceptionally pure. The major part of the formation is composed of medium-grained well-sorted vitreous quartz grains cemented into a mosaic by secondary overgrowths of silica. Most grains are 0.1–0.5 mm in diameter, but a few scattered grains are larger. In many specimens, despite the tight cementation, the rounded shape of the original grains is visible with the hand lens. On fresh surfaces the rock has a subvitreous to vitreous luster and usually shows a conchoidal fracture. Most of the rock is light gray to white, but locally some is darker gray and includes a few very dark layers. The reference section, west of Clayton, contains a disproportionate amount of dark quartzite. Generally, the weathered surface is similar to the fresh surface in color, and only locally where fracturing or brecciation has allowed the introduction of some hydrothermal iron-bearing minerals or has allowed the alteration of very small amounts of included hematite are weathered surfaces stained brown, tan, or red.

In general, argillaceous material is limited to a few shale and shaly sandstone partings separating pure quartzite beds. Locally the upper part of the formation includes beds of dark-gray shale and mudstone, generally thin but exceptionally several feet thick.

Age

C. P. Ross (1934, 1937) believed that the Kinnikinic Quartzite is essentially conformable with the overlying Saturday Mountain Formation. This interpretation is probably correct, but evidence of shearing in the poorly exposed basal dark shale of the Saturday Mountain Formation west of Clayton and erratic lateral variation in the apparent thickness of the shale from zero to a few hundred feet suggest that faulting of at least local extent is common near and subparallel to the base of the formation. The Saturday Mountain Formation was dated as Late Ordovician at the time it was defined and described by C. P. Ross (1934). Subsequent studies by Churkin (1963) and R. J. Ross, Jr., and W. B. N. Berry (1963) established that at least part of the Saturday Mountain Formation is upper Middle Ordovician. The dolomite that underlies the redefined Kinnikinic in apparent conformity was mapped by C. P. Ross as a lens within the Kinnikinic, but the lenslike distribution can now be demonstrated to result, at least in part, from faulting. Fossils from near the base of this dolomite in the Clayton section were determined by R. J. Ross, Jr., and John Huddle of the U.S. Geological Survey to be probably early Middle Ordovician. The Kinnikinic as redefined thus falls between the lower part of the Middle Ordovician and upper part of the Middle Ordovician. Fossil collections from the basal part of the overlying Saturday Mountain Formation were described by R. J. Ross, Jr., as follows:

USGS Colln. D1410 CO. Saturday Mountain Formation, basal black shales. Altitude 5,600 ft. NW¼NE¼NE¼ sec. 27, T. 11 N., R. 17 E. Idaho coord., central zone: E. 385,650 ft., N. 945,450 ft. Clayton 7½-minute quadrangle, Idaho.

Lordorthis variabilis Ross
Rafinesquina? sp.
Strophomena sp.
Isotelus sp.
Dolichoharpes? sp.
Remopleurides sp.
Amphilichas? sp.

This assemblage is equivalent to fossils in the basal beds of the so-called Saturday Mountain Formation in the Lemhi Range. Its age is probably late Middle Ordovician.

USGS Colln. D1464 CO. Saturday Mountain Formation, lower few hundred feet, south of Salmon River, SW¼NE¼NE¼ sec. 27, T. 11 N., R. 17 E. Idaho coord., central zone: E. 385,700 ft. N. 944,840 ft. Clayton 7½-minute quadrangle, Idaho.

Orthograptus quadrimucronatus var. *whitfieldi* Hall
Climacograptus raricaudatus Ross and Berry
Numerous indeterminate, badly sheared specimens of graptolites

Age of this collection is probably equal to that of the zone of *Orthograptus truncatus* var. *etheridgei*, or Middle Caradoc; correlative with Trenton or late Middle Ordovician.

USGS Colln. D1463 CO and D1465 CO. Saturday Mountain Formation, just above top of Kinnikinic Quartzite, at south end of anticlinal nose in SW¼ sec.

15, T. 11 N., R. 17 E. Idaho coord., central zone: E. 382,600 ft. N. 951,850 ft. Clayton 7½-minute quadrangle, Idaho.

D1463 CO:

Orthograptus? 2 spp.

Leptograptus sp.

Dicellograptus or *Dicranograptus* sp.

D1465 CO:

Climacograptus sp. (a variety with a pair of tiny basal spines, and rhabdosome a little too narrow for *C. bicornis* s.s.)

Climacograptus cf. *C. bicornis* (no proximal ends preserved)

Orthograptus cf. *O. calcaratus* var. *acutus* Elles and Wood

Orthograptus sp.

Amplexograptus? sp.

Age of these two collections is probably the same as that of zone of *C. bicornis* and zone of *O. truncatus etheridgei*—Middle Caradoc, Trenton, or late Middle Ordovician. Preservation of graptolites is poor: more conservative paleontologists would probably be reluctant to carry identifications below the rank of genus to species and variety. Despite this fact the dating is considered reasonable.

These collections from the lowest part of the Saturday Mountain Formation are of late Middle Ordovician age, indicating not only that the Saturday Mountain is partly Middle Ordovician in age, but also that the Kinnikinic can be no younger than late Middle Ordovician.

ELLA DOLOMITE

At least 700 feet of massive dolomite and sandy dolomite lies below the Kinnikinic Quartzite in the anticlinal structure along the Salmon River canyon west of the town of Clayton. The dolomite 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 about 1½ miles upstream. These steeply dipping beds are the host rocks for the ore deposits of the old Ella mine near Clayton, and it is proposed here that the name Ella Dolomite, first used by Patton (1948), be used for this unit.

Distribution

Although this dolomite is exposed along U.S. Highway 93 beneath the reference section of Kinnikinic and along Kinnikinic Creek near the Ella mine, the best 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 between the reference section of Kinnikinic Quartzite and the town of Clayton. This section, designated the type section and shown in column *A* of figure 3, is accessible by a jeep trail that connects the Squaw Creek road to the South Butte mine and extends southeastward to the dolomite outcrops on the cliff face. The dolomite is also exposed on the south wall of the Salmon River canyon in the west limb of the anticline, and it extends as a discontinuous band of outcrops southward for several miles on the east side of the valley of Sullivan Creek to a point where it is lost under a cover of Challis Volcanics.

Small detached outcrops of dolomitic rocks that are thought to be correlative with the Ella Dolomite occur for several miles to the north-northwest of the type section in a gently rolling area in secs. 10 and 15, T. 11 N., R. 17 E. This area is mantled in large part by Challis Volcanics, extensive talus, rock glaciers, and landslides through which only isolated and largely indeterminate patches of the pre-Challis bedrock project. A thin fault slice of Ella Dolomite is exposed at an altitude of 9,000 feet on the ridge crest near the center of sec. 11. Dolomite at the same stratigraphic position in a quartzite sequence as the type Ella Dolomite crops out at intervals for several miles along a north-trending line east of the Salmon River and the East Fork in the southeast corner of the area shown in figure 2. Although no fossils have been identified from this dolomite, it is correlated with the type Ella.

Character

The Ella Dolomite is a sequence of predominantly medium- to thick-bedded dolomite, most of which contains some silt and fine sand, usually in thin laminae that on weathered surfaces show as fine ribbing or a hackly texture. This lamination is not obvious on fresh fractures. The dolomite is predominantly fine grained, but some portions as much as 25 feet thick are medium to coarsely crystalline. The 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 and dark-gray color and weather to deep brown. This basal zone is distinctive and has proved useful as a marker bed.

Locally, as at the horizon of the small prospect at the end of the jeep trail northwest of Clayton and about 230 feet above the base of the Ella, a 20- to 30-foot zone of beds is more siliceous. Some layers in this zone consist of fine-grained quartzite, some of sandy dolomite, and some of chert that appears to have replaced other material. One highly silicified zone has an oolitic appearance that seems to have resulted from the replacement of subspherical algal structures by silica. Microlayered siliceous laminae are also believed to result from the replacement of algal structures.

Age

Brachiopods and conodonts from a zone near the base of the Ella Dolomite and conodonts from the dolomite about 450 feet above the base were determined by R. J. Ross, Jr., and J. W. Huddle of the U.S.

Geological Survey to be probably of early Middle Ordovician age, and the Ella Dolomite is thus assigned to the Middle Ordovician. The narrow sliver of Ella that crops out northwest of the Clayton silver mine on the high ridge in sec. 11, T. 11 N., R. 17 E., 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.

The following lists of the fossils from the vicinity of the type section were given by R. J. Ross, Jr., and J. W. Huddle (written commun., 1966):

USGS Colln. D1594 CO. Ella Dolomite, from lower 30 ft near base. Altitude 7,000 ft. NW cor. NE¼SE¼ sec. 23, T. 11 N., R. 17 E. Idaho coord., central zone: E. 390,660 ft., N. 948,400 ft., Clayton 7½-minute quadrangle, Idaho,

Brachiopods: (*Anomalorthis* zone, Whiterock Stage)

Anomalorthis sp.
Orthambonites? sp.
Desmorthis? sp.

Conodonts:

Acodus auritus Harris and Harris
Acodus sp.
Drepanodus sp.
Eoneoprioniodus cryptodens Mound
Falodus brevis (Harris)
Leptochirognathus gracilis? Branson and Mehl
Leptochirognathus prima Branson and Mehl
Multioistodus tridens (Cullison)
Multioistodus 2 spp.
Neomultioistodus compressus Harris and Harris
Oistodus cf. *O. contractus* Lindström
Paltodus sp.
Panderodus sp.
Pteracontiodus aquilatus Harris and Harris
Scandodus? sp.
Tricladiodus clypeus Mound

Huddle stated: "Probably this collection is early Middle Ordovician in age (Whiterock to Marmor). *Multioistodus* and *Leptochirognathus* are rarely found, and *Eoneoprioniodus*, *Neomultioistodus*, and *Pteracontiodus* were described recently. Their ranges are not firmly established, but in the Arbuckle Mountain area they were described from the West Springs Formation in the top or the Arbuckle Group, the Joins and McLish Limestones of the Simpson Group, and the Dutchman Limestone of Missouri. Several of these genera occur together and may have belonged in the same animal. They are not always present in early Middle Ordovician formations but seem to be a good index of that age when they are found. *Multioistodus* occurs near the middle of the Antelope Valley Limestone Member of the Pogonip Formation in the Groom Range in Nevada."

USGS Colln. D1848 CO. Ella Dolomite, approximately 450 ft above base. Altitude 7,280 ft. On southwest side of ridge crest. NE¼ sec. 23, T. 11 N., R. 17 E. Idaho coord., central zone: E. 391,000 ft, N. 949,200 ft. Clayton 7½-minute quadrangle, Idaho.

Cyrtoniodus flexuosus (Branson and Mehl) type element
prinoniodina element (probably belongs here, cordylodus element with compressed base
Cyrtoniodus? n. sp. or *Phragmodus*?
ligonodina element probably belongs to this species, *Dichognathus typica* element may belong to this species
Keislognathus n. sp.
4 nondenticulated bar elements
Erismodus? *horridus* Harris
Erismodus? sp.
Hibbardella sp.
Drepanodus sp.
Paltodus sp.
Prioniodina sp.

Huddle (written commun., 1967) stated: "This is an undescribed fauna, and its age is uncertain. *Erismodus? horridus* was described from the Joins Formation of Oklahoma, and this suggests an early Middle Ordovician age for the collection.

The first three species listed are probably biologic species, but this can only be determined by additional collections. The other species listed are probably Form species."

CLAYTON MINE QUARTZITE

In the core of the anticline west of Clayton, the Ella Dolomite rests in apparent conformity on a series of quartzitic rocks that are significantly different from the Kinnikinic Quartzite that overlies the Ella. In contrast to the Kinnikinic, these quartzites are heterogeneous in composition, degree of sorting, and bedding characteristics, and are at least 2,000 feet thick. The base is not exposed. The name Clayton Mine Quartzite is applied here to these rocks from exposures in the high cliffs and high ridge west of the Clayton mine on Kinnikinic Creek. The name Clayton Quartzite was given to this unit by Patton (1948), but as the name Clayton alone is preempted, the change to Clayton Mine has been made.

Distribution

The rocks of this unit are perhaps the most widely distributed of the quartzites in the general Bayhorse region. The massive cliffs below the Ella Dolomite on both sides of the Salmon River canyon west of Clayton are all of this unit, and these same resistant rocks can be traced for several miles north of the river, where they make up the high ridges between Squaw Creek and Kinnikinic Creek. They also extend south into the Potaman Peak quadrangle, where they form many of the highest ridges. Other extensive exposures of quartzite are (1) along the Salmon River downstream from Clayton from near the junction with the East Fork of the Salmon River to 5 miles south of Challis, (2) for several miles up the East Fork, (3) on Poverty Flat, and (4) north of the Bayhorse Lakes.

Character

The description of the Clayton Mine Quartzite that follows is based on the section measured in the Salmon River canyon west of Clayton, which is designated the type section and is illustrated in column *A* of figure 3. The general features of the quartzite here appear to be characteristic of the formation over wide areas, although variations probably occur from place to place because of local facies changes that generally exist in rocks of this kind.

Bedding ranges widely from thick bedded or massive to thin bedded. Thin zones of flagstone occur locally. Cross-lamination occurs at intervals throughout the measured section but seems to be more common in the lower half. Some beds as much as 10 feet thick form but one set of through-going cross laminae; more commonly the cross-laminated layers are much thinner.

The section consists predominantly of coarse- to medium-grained feldspathic quartzite, but very thin shale partings occur throughout, and the lower half contains several zones of shale as much as 40 feet thick and one zone 200–300 feet thick of interlayered quartzite, shaly quartzite, and thin beds of shale and siltstone. The great bulk of the rock is composed of fairly 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 feet is predominantly pebble-bearing quartzite containing rounded quartz pebbles that are mainly about one-fourth inch in diameter but are locally larger than 1 inch. The pebbles are predominantly colorless to dark-gray vitreous quartz and quartzite, but a few are chert, feldspar, and siltite. Feldspar, usually more angular than the quartz, is distributed throughout the section, except for the interval between 225 and 475 feet from the top, which is virtually feldspar free. Even this interval contains microscopic structures that suggest complete replacement of original feldspar grains by quartz and sericite. The feldspar ranges in size from small specks to fragments nearly half an inch long and in places forms as much as 20(?) percent of the rock. Some is fairly fresh, but most is altered and is dull yellowish gray to white.

The quartzite ranges from medium light gray to very light gray. Much has a yellow to orange cast, and a little is pink or purplish gray. It generally appears less clean and vitreous than the Kinnikinic. Weathered surfaces are commonly grayish orange, moderate brown, grayish red, and yellowish gray.

The thicker intervals of shale and siltstone are similar lithologically to the thin partings that separate many quartzite beds. They are well bedded, generally fissile, and variably micaceous, and they commonly include 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 feet of shale are enclosed in quartzite at 1,730 feet below the top of the section; the upper layer is 15 feet thick, and the lower is 2 feet thick. The dolomite is fine grained, medium to dark gray, and slightly impure. 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 measures 1,980 feet from the base of the overlying Ella Dolomite to the lowest exposure at the top of talus that covers the lower slopes. The rocks of this type section are little deformed and represent a minimum thickness for the formation. An unknown thickness lies below the lowest outcrop. Along U.S. Highway 93 east of the type section, a few exposures of silty quartzites and shales on the east limb of the anticline are perhaps stratigraphically lower than the base of that section. These beds, however, are separated from the measured section by a shear zone along which the displacement is unknown, and therefore they cannot be projected into that section.

Age

The age of the Clayton Mine Quartzite is not known with certainty, as no fossils have been found in any part of the sequence and its basal stratigraphic relations are unknown. The fact that the formation lies with apparent conformity below the basal fossil-bearing zone of the Middle Ordovician Ella Dolomite suggests an Early Ordovician age for at least the upper part of the quartzite. However, the 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 on Ramshorn Slate, which he considered to be of earliest Ordovician age from fossil evidence discovered 6 miles south of the area shown in figure 2 in rock he correlated with the Ramshorn. This correlation is now in doubt, and thus the Ramshorn is no longer useful in limiting the age of the Clayton Mine Quartzite, which is above it and is included in the original Kinnikinic Quartzite.

STRATIGRAPHIC SEQUENCE ON UPPER SQUAW CREEK

Squaw Creek, a major stream along the west edge of the Clayton 7½-minute quadrangle, cut across a sequence of quartzites and carbonate rocks for about 2 miles between the mouth of Cash Creek and the Red Bird mine. This sequence, roughly analogous to the Kinnikinic

Quartzite, Ella Dolomite, and Clayton Mine Quartzite, was included by C. P. Ross in his original Kinnikinic unit. These rocks are now known to be separate and distinct and definitely older than the Kinnikinic, as here restricted, and the Ella. Columns *B* and *C* of figure 3 illustrate the sequence.

CASH CREEK QUARTZITE

Distribution and thickness

The upper quartzite of this sequence has been identified only in the massive cliffs along the west side of Squaw Creek south of the mouth of Cash Creek and is here named the Cash Creek Quartzite. Some of the quartzitic beds that are exposed several miles to the east in the upper reaches of Cash Creek and beyond also may belong to this unit. A section 1,105 feet thick of the Cash Creek Quartzite, designated the type section, was measured in the steep cliffs about a quarter of a mile south of the mouth of Cash Creek and almost entirely on the west side of Squaw Creek. It is overlain by a unit of siliceous platy shale and siltstone at least 200 feet thick that contains a Middle Cambrian trilobite fauna. The type section is terminated at the base, a short distance east of Squaw Creek, by a cover of Challis Volcanics, 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 feet of the basal part of the formation is concealed at the type section. The total thickness of this quartzite unit can thus be quite reasonably estimated at between 1,200 and 1,300 feet.

Character

The Cash Creek Quartzite along Squaw Creek is all quartzite, except for rare 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 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

The Cash Creek Quartzite is overlain conformably by greenish-gray, yellowish-gray, and reddish siltstone and shale, much of which weathers to deep brick red. Several hundred feet of these beds is exposed in the saddle above the top of the type section, but the total thickness is not known because the Challis Volcanics overlie the shale to the west. These shales contain fossils that are especially abundant within 1–2 feet of the top of the quartzite and that have been determined to be of unequivocally Middle Cambrian age by A. R. Palmer of the U.S. Geological Survey. Palmer describes the fauna as follows:

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 7½-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.

(written commun., 1965) Palmer 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."

On the basis of these relations, the Cash Creek Quartzite is considered to be probably of Early or Middle Cambrian age and possibly equivalent to the Flathead Quartzite. Further work may clarify the relation of these rocks to the rest of the section.

CARBONATE-SILTSTONE SEQUENCE BELOW THE CASH CREEK QUARTZITE

Distribution

Between the Cash Creek Quartzite and a lower series of massive quartzites is a group of very distinctive strata that includes impure dolomite, impure limestone, fissile siltstone, and flaggy siltstone. These rocks are known only below the Cash Creek Quartzite on Squaw Creek and are most extensively exposed in the lower part of the cliffs that border the west side of the 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 one-fourth mile north of the mouth of First and Second Creeks—a tributary flowing into Squaw Creek from the east.

Character

The base rests conformably on massive clean subvitreous unsorted quartzites. The lower 65 feet is composed of thin-bedded micaceous gray, greenish-gray, and purplish-gray slate or siltstone and sandy siltstone and local layers of micaceous quartzite. The upper 25 feet of the siltstone splits along the bedding into smooth thin slabs and has been prospected for commercial flagstone. The flagstone interval is overlain by a 7-foot massive bed of siliceous dolomite and, in turn, by a 30-foot layer of thin- to medium-bedded limy siltstone. This siltstone grades upward into a sequence 250 feet thick of very distinctive impure limestones that forms the central part of the section. The limestone is thin bedded, strikingly banded in shades of gray and greenish gray, and highly micaceous. It has good bedding-plane cleavage and commonly a well-developed cleavage at a distinct angle to the bedding. The thin bedding and color banding are the most distinctive characteristics of these beds. Many of the laminae react violently to dilute hydrochloric acid. Above this central part is a zone about 80 feet thick of thinly interbedded light-colored limestone and darker colored nonlimy siltstone, the limestone becoming predominant in the upper 10 feet. A covered interval of 15 feet separates the limestone from a sequence of dolomite and silty dolomite that forms the upper 130 feet of the measured section. The upper dolomite is rather massive to medium bedded and fine to medium crystalline and contains silty laminae. 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. The top of the dolomite at the measured section is separated from the overlying Cash Creek Quartzite by a zone of brecciated dolomite and quartzite that is heavily iron stained. Gossan has been developed in some fractures and open spaces. Evidence for a fault semiparallel to the bedding is conclusive; the dolomite is gradually cut off along the fault south of here. However, a fault is not apparent at the contact about one-half mile along the strike to the north, and the dolomite in the unfaulted section is comparable in thickness to the section just described. The original thickness of the dolomite is probably little more than that at the measured section.

Thickness and age

This predominantly carbonate-bearing sequence of rocks is at least 570 feet thick. Its age is uncertain. The sequence lies in apparent conformity below the Cash Creek Quartzite, but no fossils have been found in it, nor have any been found in the quartzite that lies below.

LOWER QUARTZITE

Below the carbonate sequence on Squaw Creek are quartzitic rocks that are known only at this locality, but like the other quartzites in the Bayhorse region, they may be represented among the numerous isolated quartzite masses of uncertain age that are scattered to the north and east.

Most of this lower quartzite 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-lamination. The component grains are generally unsorted and range from fine to coarse but are predominantly in the fine to medium range. 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 zone of mixed lithologies that contains some medium to thick beds of siltstone together with pebble-bearing quartzite, dolomitic sandstone, and coarse clean 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-lithologies zone contains carbonate granules that weather out and leave a pitted surface on many of the outcrops. The base of the zone is not exposed, but the lowest outcrops show much brecciation of the quartzite and shearing in the siltstone and contain many quartz veins; all of these features suggest major structural disturbance. The exact position in the section and the thickness of the zone of mixed lithologies are uncertain because of the incomplete exposures and obvious structural disturbance, but the zone comprises several hundred feet of rocks below the massive quartzite.

The lower quartzite was not measured, but from the distribution and attitude it is estimated that at least 400 feet is exposed in the valleys of Boundary Creek and First and Second Creeks. The base probably rests on a major thrust fault.

CONCLUSION

Detailed studies in the Bayhorse region have revealed that the Kinnikinic Quartzite established by C. P. Ross (1934) and mapped by him in the vicinity of the type exposures (1937) includes two different carbonate-bearing units and three or four distinct quartzite units of widely different ages. The name Kinnikinic is here restricted to the youngest quartzite unit of the original formation, and three new formational names are introduced for older quartzite and dolomite units. The new subdivisions of Ross' original Kinnikinic occur in two stratigraphic sequences, represented by columns *A*, *B*, and *C* of figure 3. The stratigraphic and structural relations between these sequences and the further delineation and regional correlation of the new units are subjects of continuing investigation.

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