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The Kinnikinic Quartzite (Middle Ordovician) in the Type Area, Central Idaho, and a New Reference Section near Arco, Idaho

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ABSTRACT.—Through most of its extent in east central Idaho, the Kinnikinic Quartzite of Middle Ordovician age is a fine- to medium-grained, silica-cemented quartz arenite. Gradual subsidence during deposition on a shallow, open-marine shelf resulted in accumulations of almost 100 m in the southeast, near Arco, and more than 450 m near and west of Gilmore.

In the type area, near Clayton, the Kinnikinic is noticeably darker and finer grained than elsewhere and contains interbedded shales that are sparsely fossiliferous. The fossils are the first found in the Kinnikinic. They include specimens of bryozoans and crinoidlike forms and the brachiopods *Lordorthis*, *Sowerbyella* or *Thaerodonta*, and a ?rhyntonellid. This assemblage is essentially the same as that in the lower shaly unit of the overlying Saturday Mountain Formation. Probably the Kinnikinic in the type area represents the transition from shelf deposits, typical farther east, and slope deposits of the Phi Kappa Formation, farther south. Two shale-rich units within the Kinnikinic in the type area may be tongues of the Saturday Mountain Formation.

The shales, the fine grain size of the quartzites, and the common dark colors of the Kinnikinic in the type area contrast with typical characteristics of the main body of the Kinnikinic farther east. Furthermore, in the type area, the Kinnikinic is complexly folded and faulted, and only an incomplete, composite section at least 124 m thick is present. For these reasons we propose a more accessible, and more typical, new reference section near Arco, Idaho, at the southeast end of the Lost River Range.

INTRODUCTION

James and Oaks (1977) documented the wide extent and open-shelf marine origin of the Kinnikinic Quartzite (Middle Ordovician) in the region east of the type area (Clayton, Idaho; fig. 1). In this eastern region the Kinnikinic consists of unfossiliferous, fine- to medium-grained, silica-cemented, super-mature quartz arenite, characterized by pale colors. Shale interbeds are unknown, and shale partings are extremely rare. Trace fossils are present locally within distinct zones and consist chiefly of *Skolithos*, a high-energy form we did not find in the type area.

Differential subsidence during deposition gave rise to depositional pinchout of the Kinnikinic to the northeast against the Lemhi Arch and thinning toward the Arco Arch in the southeast, from more than 450 m near and west of Gilmore to slightly less than 100 m near Arco (James and Oaks 1977, fig. 5). To the west and southwest, shales and finer-grained quartzites in the type area and the Phi Kappa Formation, respectively, suggest an offshore transition from shelf to slope deposits.

Oaks and others (1977) noted that the Kinnikinic Quartzite is consanguineous and approximately coeval, hence correlative, with the upper (Eureka) member of the Swan Peak Formation in north central Utah and southeastern Idaho, and with the Eureka Quartzite of northwestern Utah. Figure 2 shows extents of these units and other correlative units. Of special interest are the slope deposits of the Valmy Formation and of the Vinini Formation (Stanley and Chamberlain 1974),

probable southward depositional equivalents of the Phi Kappa Formation.

Hydrocarbons have been produced from the correlative Black Island Sandstone of the Winnipeg Group (Foster 1972) in the Williston Basin (North Dakota), from sandstones of the Simpson Group in Oklahoma, and from the St. Peter Sandstone through much of the Midcontinent region (fig. 2). Unfortunately, pervasive cementation by silica, predating the Lara-

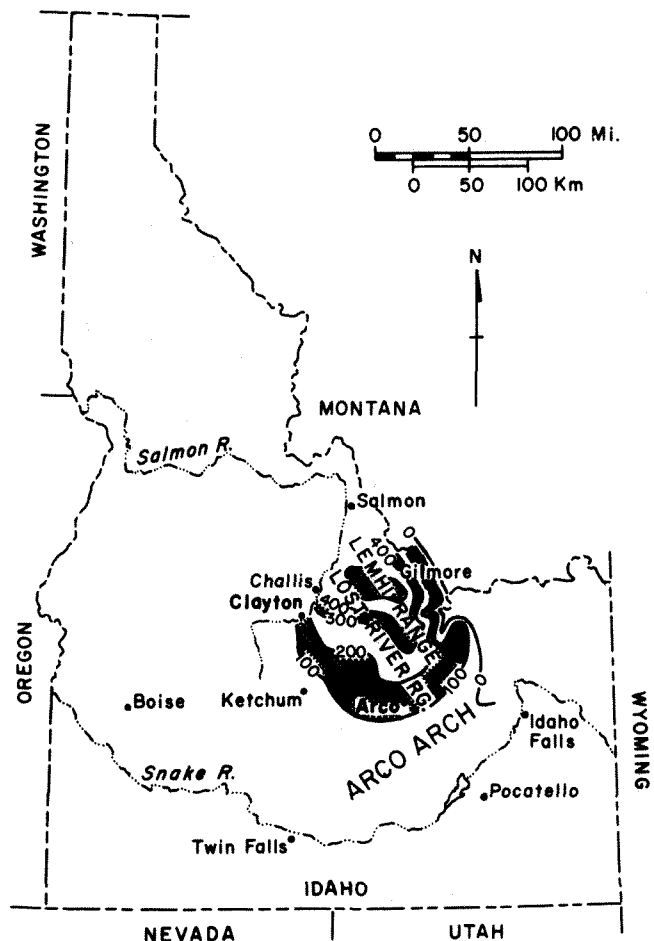


FIGURE 1.—Locality map of Idaho showing type area (Clayton) and new reference section (Arco). Thickness of Kinnikinic shown with contour interval of 100 meters.

mid orogeny, occluded porosity in the Kinnikinic Quartzite and its correlatives in Utah, Idaho, and Nevada.

PREVIOUS WORK

C. P. Ross (1934, p. 947-52; 1937, p. 11, 17-18) originally named the Kinnikinic "Formation" for about 1,065 m (3,517

ft) of quartzite containing local lenses of dolomite, dolomitic shale, and minor conglomerate. These rocks are exposed in the type area along Kinnikinic Creek, near Clayton, Idaho (fig. 1), and westward along the Salmon River between Kinnikinic Creek and Squaw Creek. In 1937, Ross changed the name of this unit to Kinnikinic Quartzite.

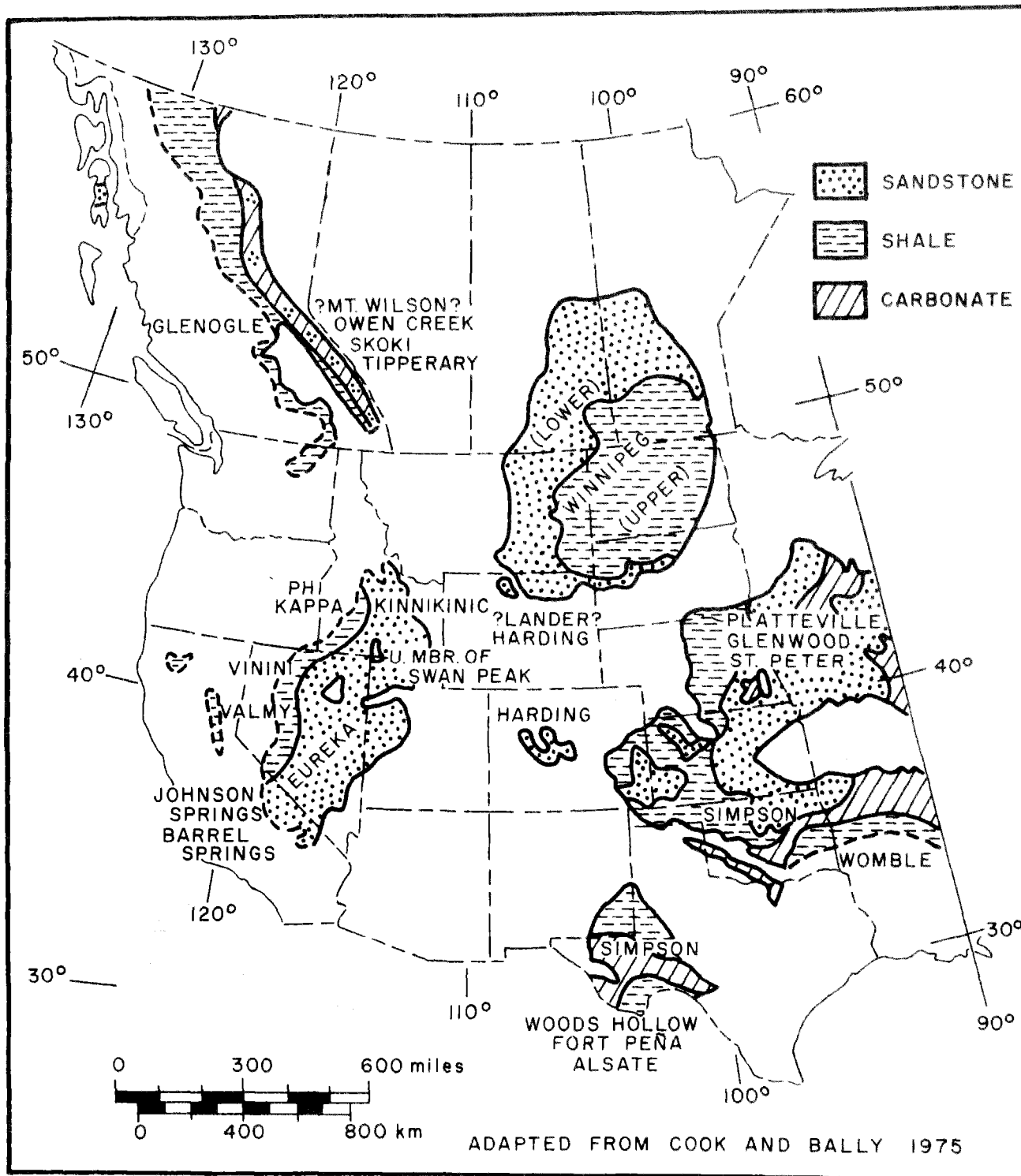


FIGURE 2.—Locality map, western North America, showing extents and local names of Middle Ordovician stratigraphic units.

Ross (1934, 1937) believed that this entire sequence was Early or Middle Ordovician in age, on the basis of the Late Ordovician age of the overlying Saturday Mountain Formation and the earliest Ordovician age of the apparently conformably underlying Ramshorn Slate. Sparse, unspecified fossils, presumably from the Kinnikinic, were found in the central Lemhi Range near Gilmore, Idaho (fig. 1), and subsequently assigned an early Late Ordovician age by G. A. Cooper (Ross 1947, p. 1,104). Recent work in the Gilmore area, by R. J. Ross, Jr., and E. T. Ruppel has established that these fossils probably came from an faulted block of the overlying Fish Haven (Saturday Mountain) Formation (E. T. Ruppel oral communication 1976). Otherwise, we know of no other fossils previously reported from the Kinnikinic.

In the type area, Patton (1948, p. 7-15) proposed subdivision of the Kinnikinic of Ross into four lithologically distinct members, from oldest to youngest as follows: (1) Lower Member, at least 670 m (2,200 ft; composite section) of interbedded quartzites, dolomitic quartzites, and shales, incompletely exposed along the axis of the north-trending Clayton anticline; (2) Clayton Quartzite Member, about 480 m (1,580 ft) of pebbly, feldspathic quartzite, conglomeratic near the top, shaly near the base, exposed on both flanks of the Clayton anticline; (3) Ella Dolomite Member, about 105 m (340 ft) of quartz-bearing dolostone exposed on both flanks of the Clayton anticline; and (4) South Butte Quartzite Member, 255 m (840 ft) of quartzite, dolomitic near the base, locally shaly, with "fucoids" near the top, completely exposed only along the west flank of the Clayton anticline (p. 14), but nearly absent along the east flank, near Kinnikinic Creek, because of faulting. Patton (1948, p. 7, 9) accepted the age assignment of Early Ordovician for the Ramshorn Slate and believed its contact with the Kinnikinic to be conformable.

Ketner (1964, p. 90) recognized that only the upper part of the Kinnikinic as originally defined in the type area conforms with usage farther east and northeast and that the more metamorphosed, underlying strata resemble Cambrian and Precambrian quartzites in Utah. Restriction and redefinition were proposed formally by Hobbs, Hays, and R. J. Ross, Jr. (1968), who had clear fossil evidence (brachiopods, conodonts) that the Ella Dolomite is early Middle Ordovician in age, that the lowest part of the Saturday Mountain Formation is late Middle Ordovician in age (cf. Churkin 1963, Ross and Berry 1963), and that the Clayton Quartzite Member, renamed the Clayton Mine Quartzite, probably is stratigraphically above trilobites and brachiopods of early Middle or late Early Cambrian age. Hobbs, Hays, and Ross (1968, p. 17) challenged the correlation by C. P. Ross (1934) of fossiliferous strata 9.5 km (6 mi) south with the Ramshorn Slate in the type area of the Kinnikinic. They therefore proposed that the name Kinnikinic be restricted to the unit between the Ella and the Saturday Mountain. As redefined, the Kinnikinic in the type area is consistent with established usage elsewhere (cf. James and Oaks 1977).

Hobbs, Hays, and Ross (1968, p. 9) designated a reference section about 3 km (2 mi) west of Clayton at exposures near road level along the north side of U.S. 93 from the river bridge eastward for about 245 m (800 ft). They noted (p. 9-10) that faulting has repeated part of the formation, so that their computed thickness of about 215 m (700 ft) probably is too great. They described the redefined Kinnikinic as a predominantly light gray to white quartzite composed almost entirely of medium-grained (0.1-0.5 mm), rounded quartz grains cemented with secondary silica overgrowths. They also noted (1968, p. 10) that the reference section contains an unusually large

amount of dark quartzite, that thin beds of shale and mudstone are present locally in the upper part, and that minor shaly partings locally separate quartzite beds elsewhere in this section.

ACKNOWLEDGMENTS

John E. Bircher assisted in part of the fieldwork. Peter T. Kolesar made and interpreted X-ray diffractograms of five samples. Reuben J. Ross, Jr., identified the fossils from the Middle Member. S. Warren Hobbs, Michael Churkin, Jr., and Edward T. Ruppel reviewed the manuscript and offered helpful suggestions and criticisms.

STRUCTURE OF TYPE AREA

General Statement

Because it is a long distance from other complete sections of Kinnikinic in east central Idaho and because it is the type area, we hoped to locate and measure a complete type section in the Clayton area. Because of the structural complexity of the region, we mapped an area of about 1.3 km² (0.5 sq. mi) north of the Salmon River, and measured six partial sections. The measured sections are designated U through Z, from north to south (fig. 3). Measured section U is in section 15, T. 11 N, R. 17 E, about 0.1 km north of section 22. Measured section V is about 0.15 km south of section 15, whereas measured section Z is on the north margin of section 27. On account of faulting and cover, we were able to compile only a partial, composite section.

Figure 3 is our reconnaissance geologic map, traced over U.S. Forest Service air photo EQX-15-172 (3 September 1966). Hobbs, Hays, and McIntyre (1975) released a detailed, open-file geologic map of more than 500 km² (200 sq. mi) that showed a different structural interpretation for the small area in question. Therefore, we revisited the type area but concluded that our map required only minor changes.

Structural Features

Several features are of importance in our structural synthesis. The first is a tightly folded, north-trending syncline along the axis of the main ridge (Squaw syncline, here named for the Squaw B.M., Clayton 15-minute quadrangle). Fossiliferous silt-shale, with slaty cleavage and fossils characteristic of the Saturday Mountain Formation, is present along the syncline axis (figs. 3, 4). This syncline is flanked to the west by a tightly folded and overturned, north-trending anticline in the Kinnikinic Quartzite (Ridge Line anticline). The Ridge Line anticline appears to be a disharmonic fold that dies out downward in shales of the Middle Member of the Kinnikinic (fig. 4).

East of the Squaw syncline are two west-dipping, high-angle reverse faults that repeat portions of the west-dipping Kinnikinic Quartzite. These two reverse faults are present between the Salmon River and the line of section in figure 3. They merge northward near the top of the high, eastward-facing cliffs we call the Palisades (fig. 4), and meet between measured sections X and Y (fig. 3). North from where they merge, two faults of small displacement, possibly also high-angle reverse, slope upward to the west and to the east (figs. 3, 4). Rocks above the two major, west-dipping reverse faults have overrun the west flank of the Clayton anticline. Finally, several normal faults cut the Squaw syncline and Ridge Line anticline. These are nearly vertical and probably of small offset (fig. 3).

Hobbs, Hays, and Ross (1968, p. 10-11) presented evidence suggesting that faulting has occurred "near and subparallel to

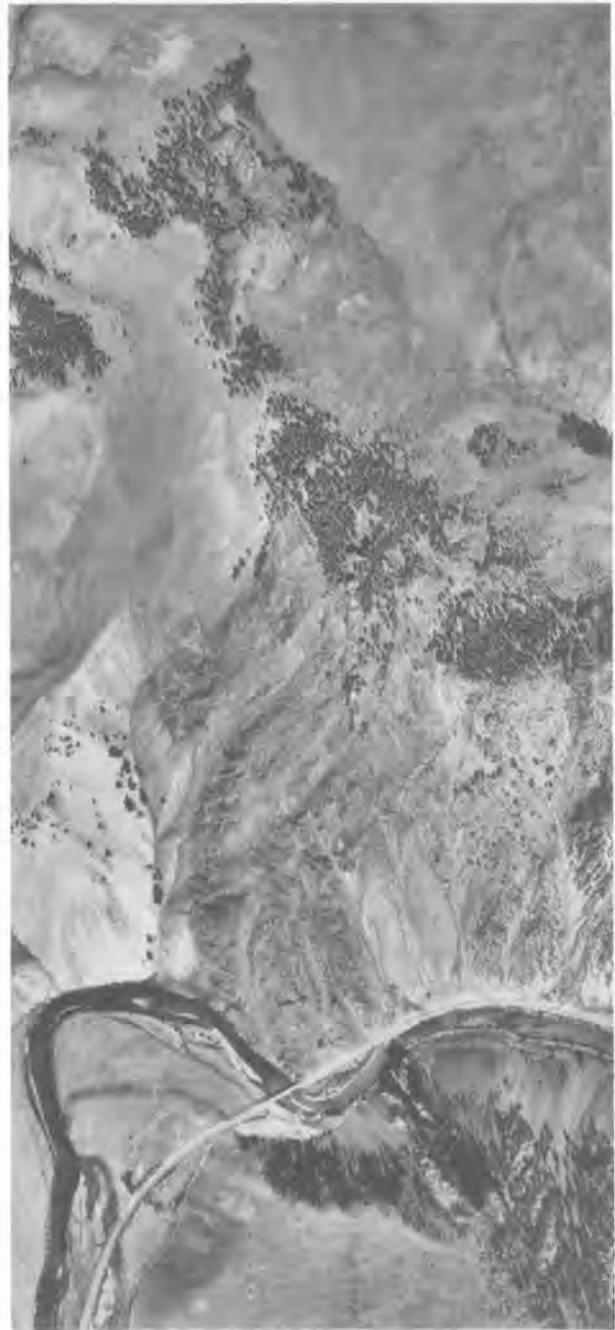


FIGURE 3.—Reconnaissance geologic map and section of Kinnikinic type area, north of Salmon River and west of Clayton, Idaho, and corresponding aerial photograph. Explanation: 1 = Lower Quartzite Member; 2 = Middle Member; 3 = Upper Quartzite Member; S = Slump block; Dots = Margin of colluvium; Sawtooth = Reverse fault. Heavy lines show locations of measured sections U to Z, respectively, from north to south.

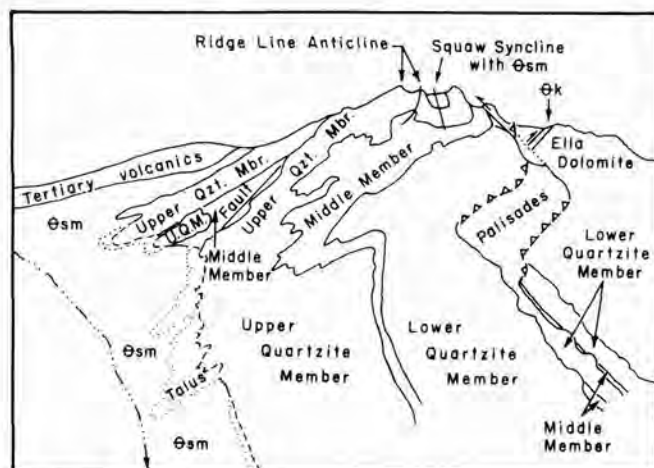
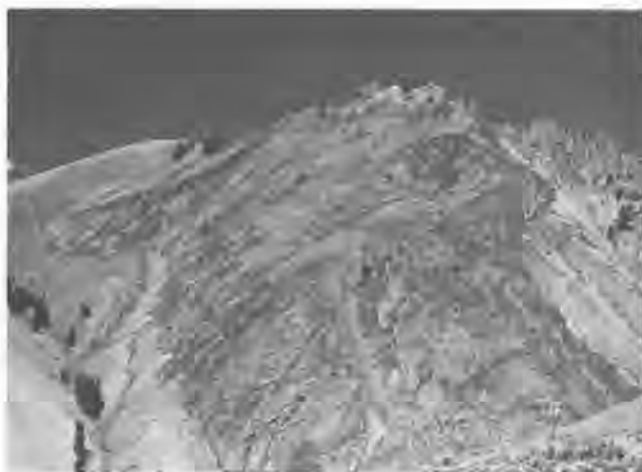


FIGURE 4.—Type area of Kinnikinic Quartzite with structural interpretations. View NNE from entrance of Sullivan Hot Springs, at U.S. 95. Θk = Kinnikinic Quartzite; Θsm = Saturday Mountain Formation.

the base" of the Saturday Mountain Formation in this area, at least locally. Hobbs, Hays, and McIntyre (1975) showed a northwest-trending fault of small displacement across the base of the Palisades, with which we concur (not shown in fig. 3).

STRATIGRAPHY OF KINNIKINIC QUARTZITE

Overview

The structural synthesis outlined above was facilitated by a laterally persistent shaly sequence within the Kinnikinic. Interbeds of shale within the Kinnikinic previously were noted by Patton (1948) and by Hobbs, Hays, and Ross (1968). However, the distinctiveness and the importance of this unit were not previously determined. Furthermore, this shaly sequence contains the first definite body fossils found *within* the Kinnikinic. Correspondingly, we propose to subdivide the composite type section of the Kinnikinic into the following units: (1) Lower Quartzite Member, at least 75 m thick, composed of a basal quartzite, a shaly quartzite, and a top quartzite; (2) Middle Member, about 25 m thick, composed of a lower shaly marker, a quartzite marker, and an upper shaly marker; and (3) Upper Quartzite Member, about 27 m thick. In the field, the contact between the Lower and Middle Members is sharp and appears conformable. Contacts within the Lower Quartzite Member, within the Middle Member, and at the base of the Upper Quartzite Member, are all gradational. Stratigraphic relations and thicknesses are shown in figure 5, and the members are described in sequence below.

Lower Quartzite Member

The basal quartzite of the Lower Quartzite Member conformably overlies the Ella Dolomite in section X. There it is at least 17 m thick below a fault and consists of fine- to medium-grained quartz arenite in parallel to gently wedging beds 9 to 55 cm thick. Laminae are indistinct and bedding generally is also. No burrows were observed. Fresh colors range from white (N9) to light olive gray (5 Y 6/1), medium gray (N5), and brownish gray (5 YR 4/1). In section W, the basal quartzite is at least 16 m thick, above a covered and faulted interval (fig. 5). Here the upper part is locally fine to coarse grained, but otherwise it is similar to the basal quartzite in section X.

The shaly quartzite within the Lower Quartzite Member consists dominantly of quartzites containing dark gray partings of silt-shale (cf. Blatt, Middleton, and Murray 1972, p. 375) and thin beds of noncalcareous silt-shales up to 1 or 2 cm thick. The quartzites associated with these silt-shales tend to be thinner, medium to dark gray, very fine- to fine-grained quartz arenites, or quartz siltites with more than half the quartz in the coarse-silt grade. Quartzites without silt-shales form a minor part of the shaly quartzite unit. "Packets" of quartzites without silt-shales are interbedded with the other quartzites but tend to be thicker, white or light gray, and fine to medium grained or even coarse grained. Bedding in quartzites is parallel and wavy parallel to gently wedging and 1.5 to 91 cm thick. Simple and branched, horizontal, sinuous burrows about 5 mm in diameter are rare, chiefly in quartzites associated with the shales. This shaly unit of the Lower Quartzite Member is partially exposed in sections U and Y and entirely exposed in section W (fig. 5). Its thickness is about 29 m.

The top quartzite of the Lower Quartzite Member is exposed in all 6 sections measured. It is approximately 26 m thick (fig. 5). It contains rare silt-shale partings in section V but not elsewhere. This top quartzite consists of fine- to medium-grained and medium- to coarse-grained quartz arenite in parallel and wavy parallel to gently wedging beds 6 to 76 cm thick. Indistinct laminae are parallel. Rare, simple and branched, horizontal, sinuous burrows about 5 mm in diameter are present locally (fig. 5). Fresh colors typically range from white to medium gray and, rarely, dark gray. One dark gray bed in section V contains rounded chips of siltstone up to 8 mm in diameter. Overall, the top quartzite is coarser grained than quartzites in the shaly unit and in the basal quartzite. This coarseness is also reflected in the scarcity of quartz siltites and of dark colors in the top quartzite.

Middle Member

The lower shaly marker of the Middle Member is completely exposed in sections U, V, W, and Y (fig. 5). It averages 5 m thick. This unit consists of subequal amounts of interbedded quartzites and noncalcareous silt-shales. The quartzites are medium to dark gray quartz siltites and very fine- to fine-grained quartz arenites in parallel to wavy parallel beds 3 to 15

cm thick. The silt-shales are mostly dark gray, parallel to wavy parallel bedded, and 3 mm to 9 cm thick. Simple and branched, horizontal sinuous burrows about 5 mm in diameter are common in several quartzites and some minor light colored siltstones in sections U and Y. Scattered molds of broken fossil debris were found in medium-gray burrowed siltstones of the lower shaly marker in section W.

The quartzite marker of the Middle Member is completely exposed in sections U, V, W, and Y. It averages 5 m thick. This unit consists of quartzites with varying but subordinate amounts of interbedded silt-shales. The quartzites are white to dark gray quartz siltites and very fine- to medium-grained quartz arenites in parallel beds 3 to 37 cm thick. Where visible, laminae are parallel. The silt-shales are medium to dark gray, parallel to wavy parallel bedded, and 3 mm to 6 cm thick. In section U quartz siltites and some minor, light colored siltstones are burrow churned (bioturbation).

The upper shaly marker of the Middle Member is completely exposed in sections U, V, W, and Y. It averages 15 m thick and is essentially identical in character to the lower shaly marker. A fossiliferous horizon just above the base was traced continuously from section W to section Y, and similar molds of fossils were collected from the top of this unit at section V. The fossils include *Lordorthis*, *Sowerbyella* or *Thaerodonta*, and a rhynchonellid? (brachiopods) and specimens of bryozoans and crinoidlike forms, all identified tentatively by R. J. Ross, Jr. (written communication 1976). Ross noted that this assemblage is essentially the same as that in the lower shaly unit of the Saturday Mountain Formation.

Upper Quartzite Member

The Upper Quartzite Member is well exposed in all sections although probably thinned by a fault at the top of sections U and V and likely partly repeated by faulting in section X (figs. 3, 5). It averages about 27 m thick. This member contains minor shale partings and, locally, thin silt-shales up to 3 cm thick. The basal part in section V contains numerous thin silt-shales and minor quartz siltites and is gradational with the underlying Middle Member through an interval of about 10 m. Elsewhere, this contact is sharp or else gradational through an interval of 2 m or less. With the exceptions noted above, the Upper Quartzite Member consists of white to dark gray, fine- to medium-grained and medium- to coarse-grained quartz arenite in parallel and wavy parallel to gently wedging beds 3 to 46 cm thick. Slight overall upward coarsening was noted in sections U and V. Rare, simple, and branched horizontal burrows were found only in the transitional zone at the base of this unit in section V.

DISCUSSION

The Lower Quartzite Member of the Kinnikinic is thicker than the combined Middle and Upper Members. However, the shaly quartzite unit of the Lower Quartzite Member is about the same thickness as the Middle Member, and the top quartzite is about the same thickness as the Upper Quartzite Member (fig. 5). Thus, the possibility exists of repetition along a bedding-plane fault at the base of the Middle Member. Except for the sharp basal contact of the Middle Member and minor local

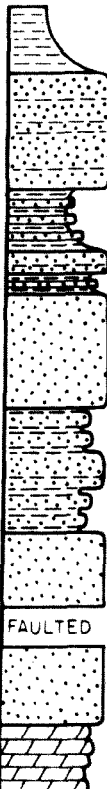
LITHOLOGY	STRATIGRAPHIC UNITS		THICKNESSES OF UNITS, IN METERS											
	SATURDAY MOUNTAIN FM. Lower Shaly Unit		SECTION U		SECTION F V		SECTION W		SECTION F X		SECTION F Y		SECTION Z	
	UPPER QUARTZITE MEMBER 27m		?Fault? ≥14 25?		?Fault? ≥21		29		≤35 ?Fault?		26		Present In Cliffs	
	Upper Shaly Marker 15m	MIDDLE MEMBER 25m	~15 B	25	15 F B	21	14 F	25	~22 F	23? F	≤35	Present In Cliffs		
	Ozt. Marker 5m		~5 B		2 B		5 F		Partly Covered	8 B		?		
	L. Sh. Marker 5m		5 B		4 B		6 F		Covered	4 B		?Absent?		
	Top Quartzite 26m	LOWER QUARTZITE MEMBER ≥72m	25? ? Fault?	≥55	≥25 B Covered	≥25 B Covered	26	≥70	Faulted And Partly Covered	28 ≥41	≥46 ≥54?			
	Shaly Quartzite 29m		≥30 B B		28		Faulted Faulted Faulted							
	Basal Quartzite ≥17m		Covered ? Fault?		≥16 Covered Faulted Covered									
	ELLA DOLOMITE ~213m (Hobbs, Hays, Ross 1968)				ELLA	ELLA								
			KINNINIKINIC QUARTZITE, Total ≥124m											

FIGURE 5.—Composite type of Kinnikinic Quartzite with details of individual measured sections. B = burrows; F = fossils.

deformation in silt-shales throughout the unit, we found little evidence for structural deformation at the base of the Middle Member.

In comparison, quartzites of the shaly quartzite unit of the Lower Quartzite Member are coarser grained, overall, than quartzites of the Middle Member, and shales are much less common. Similarly, the top quartzite of the Lower Quartzite Member differs from the Upper Quartzite Member in its higher overall content of coarse-grained sand, its lesser content of shaly partings, its smaller number of dark gray quartzites, and its greater number of apparent burrowed beds.

The above evidence suggests that deposition of the Middle and Upper Members took place under quieter, less oxygenated marine conditions than the two similar units in the Lower Quartzite Member. The field evidence does not clearly indicate eastward displacement of the Middle and Upper Members relative to the Lower Quartzite Member. Thus, the vertical sequence in the composite type section suggests three major pulses of transgression, culminating in deposition of the lower shaly unit of the Saturday Mountain Formation. The quartzites in the Kinnikinic below, between, and within the shaly sequences probably represent shallow-shelf, open-marine sands derived from the craton, possibly from the Lemhi Arch along the present Idaho-Montana border (cf. Ross 1976; Ruppel 1976, 1978; James and Oaks 1977).

The lower shaly marker of the Middle Member appears to thin or pinch out to the south in the cliffs between sections Y and Z. Possibly it becomes more sandy and less distinct southward, or it may be thinned tectonically. In these cliffs, therefore, the quartzite marker of the Middle Member could not be differentiated readily from the Lower Quartzite Member in several places on the aerial photos. The quartzite marker of the Middle Member also becomes more shaly and less distinct northward so that its top is gradational in section U. The upper shaly marker of the Middle Member becomes more sandy toward the middle so that its top is gradational in sections V and W. This shaly marker appears to thicken rapidly near section Y and westward near the axis of the Ridge Line anticline (fig. 5). Also, shales begin to dominate in the section, and some contortion is apparent. We attribute this local southward thickening and increase in shales, in part, to compression. The Upper Quartzite Member becomes more shaly northward.

Thus, silt-shales and minor siltstones are intimately interbedded with quartzites (quartz arenites and minor quartz siltites), as previously noted by Patton (1948) and Hobbs, Hays, and Ross (1968). Quartzites associated with shales are generally darker and finer grained than those in the shale-poor sequences. Distinct lateral changes in grain size are noticeable through a north-south distance of only about 1 km in both the Middle Member and the Upper Quartzite Member. The above evidence and the lateral continuity of these units suggest to us that the shales are an integral part of the Kinnikinic sequence. We interpret the shaly markers of the Middle Member and the shaly quartzite of the Lower Quartzite Member as tongues of the lower shaly unit of the Saturday Mountain Formation. The fossil evidence supports this interpretation. We believe that sediments in the type area occupied a transitional position between shelf deposits, more typical of the Kinnikinic farther east and shalier slope deposits of the Phi Kappa Formation farther south near Ketchum (fig. 1; cf. James and Oaks 1977, fig. 15, p. 1508).

REFERENCE SECTION AT ARCO HILLS

C. P. Ross (1937) and all subsequent workers have noted the dissimilarity of the Kinnikinic in the type area with that farther east. Warren Hobbs (written communication 1977) noted, "The designated type area is one of the most westerly known occurrences of the unit and among the thinnest and probably represents the distal edge of Kinnikinic deposition. . . . It probably represents an atypical section and, if so, makes the area doubly unfortunate as a reference section."

For these reasons, we propose to designate the Kinnikinic in the lower, western fault block of the Arco Hills as a new reference section (figs. 6, 7). The section there is complete and contains only a few normal faults of minor displacement.

Although thinner than other known complete sections of Kinnikinic Quartzite in the Lemhi and Lost River Ranges (cf. James and Oaks 1977, appendix), the Arco Hills section displays inorganic sedimentary structures and trace fossils far better than most of the other sections. Furthermore, it is readily accessible. Also, three regionally persistent units, an underlying sandy dolomite (unit 5 of Beutner and Scholten 1967), a pinkish quartzite beneath the dolomite (James and Oaks 1977), and the overlying Lost River Member of the Fish Haven Formation (Churkin 1962), are present and moderately well exposed. Contacts are sharp and locally well displayed.

In its lithology, grain size, sedimentary structures, color, enclosing stratigraphic units, simple structure, and accessibility, the Kinnikinic Quartzite at Arco Hills forms a more typical reference section than the same stratigraphic unit, described above, in the type area. The Arco Hills section will serve a useful function as a new reference section.

SUMMARY

Our discovery of the first body fossils in the Kinnikinic Quartzite in the type area, near Clayton, Idaho, and probable interfingering of this unit with the lower shaly unit of the Saturday Mountain Formation are significant. They firmly establish, for the first time, that the upper part of the Kinnikinic is



FIGURE 6.—New reference section of Kinnikinic Quartzite, Arco Hills. View NNW. Stratigraphic units: Q = pinkish quartzite; D = sandy dolomite; K = Kinnikinic Quartzite; L = Lost River Member, Fish Haven Dolomite; F = main part, Fish Haven Dolomite.

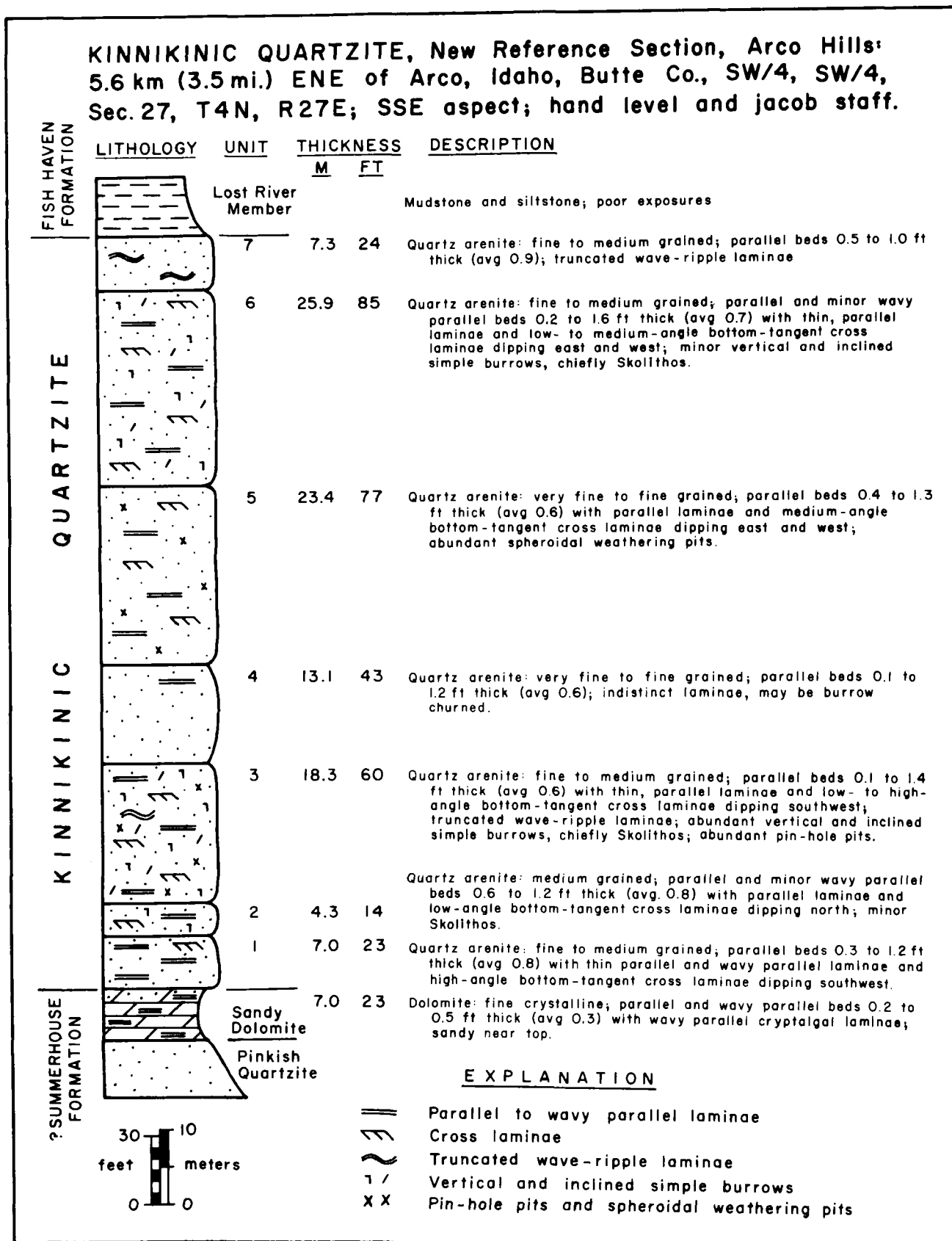


FIGURE 7.—New reference section of Kinnikinic Quartzite, Arco Hills, with details of measured section.

late Middle Ordovician. Our findings also establish a probable tectonic setting near the shelf edge for the Kinniginic in the type area. The style of later deformation by reverse faulting, indicating approximately east-west compression, followed by normal faulting, is partly outlined by our detailed structural mapping. Finally, a more typical and accessible reference section near Arco, Idaho, is nominated and described.

REFERENCES CITED

- Beutner, E. D., and Scholten, R., 1967, Probable Cambrian strata in east-central Idaho and their paleotectonic significance. *American Association of Petroleum Geologists Bulletin*, v. 51, p. 2305-11.
- Blatt, H., Middleton, G., and Murray, R., 1972, Origin of sedimentary rocks. Prentice-Hall, Englewood Cliffs, N.J., 634p.
- Churkin, M., Jr., 1962, Facies across Paleozoic miogeosynclinal margin of central Idaho. *American Association of Petroleum Geologists Bulletin*, v. 46, p. 569-91.
- , 1963, Ordovician trilobites from graptolitic shale in central Idaho. *Journal of Paleontology*, v. 37, p. 421-28.
- Cook, T. D., and Bally, A. W. (eds.), 1975, *Stratigraphic atlas of North and Central America*. Princeton University Press, Princeton, N.J., 272p.
- Foster, N. H., 1972, Ordovician System. Pages 76-85 in *Geologic atlas of the Rocky Mountain Region*. Rocky Mountain Association of Geologists, Denver, Colorado, 331p.
- Hobbs, S. W., Hays, W. H., and Ross, R. J., Jr., 1968, The Kinniginic Quartzite of central Idaho—redefinition and subdivision. *U.S. Geological Survey Bulletin* 1254-J, 22p.
- Hobbs, S. W., Hays, W. H., and McIntyre, D. H., 1975, Geologic map of the Clayton Quadrangle, Custer County, Idaho. *U.S. Geological Survey Open-File Report* 75-76, Scale 1:62,500.
- James, W. C., and Oaks, R. Q., Jr., 1977, Petrology of the Kinniginic Quartzite (Middle Ordovician), east-central Idaho. *Journal of Sedimentary Petrology*, v. 47, no. 4, p. 1491-1511.
- Ketner, K. B., 1964, Kinniginic Quartzite near Clayton subdivided. In *Geological Survey Research* (1964), U.S. Geological Survey Professional Paper 501-A, p. A90.
- Oaks, R. Q., Jr., James, W. C., Francis, G. G., and Schulingkamp, W. J. II, 1977, Summary of Middle Ordovician stratigraphy and tectonics, northern Utah, southern and central Idaho. In *Rocky Mountain thrust belt geology and resources*. Wyoming Geological Association Guidebook for 29th Annual Field Conference, Teton Village, p. 101-18.
- Patton, W. W., 1948, *Geology of the Clayton area, Custer County, Idaho*. Master's thesis, Cornell University, Ithaca, New York, 43p.
- Ross, C. P., 1934, Correlation and interpretation of Paleozoic stratigraphy in south-central Idaho. *Geological Society of America Bulletin*, v. 45, p. 937-1000.
- , 1937, *Geology and ore deposits of the Bayhorse Region, Custer County, Idaho*. U.S. Geological Survey Bulletin 887, 161p.
- , 1947, *Geology of the Borah Peak Quadrangle, Idaho*. Geological Society of America Bulletin, v. 58, p. 1085-1160.
- Ross, R. J., Jr., 1976, Ordovician sedimentation in the western United States. In *Symposium on geology of the Cordilleran hinge line*. Rocky Mountain Association of Geologists, Denver, p. 109-33.
- Ross, R. J., Jr., and Berry, W. B. N., 1963, Ordovician graptolites of the Basin Ranges in California, Nevada, Utah, and Idaho. *U.S. Geological Survey Bulletin* 1134, 177p.
- Ruppel, E. T., 1976, Medicine Lodge thrust system, east-central Idaho and south-western Montana, U.S. Geological Survey, Open-file Report 76-366, 26p.
- , 1978, Medicine Lodge thrust system, east-central Idaho and southwest Montana. *U.S. Geological Survey Professional Paper* 1031, 23p.
- Stanley, K. O., and Chamberlain, C. K., 1974, Bathymetry and origin of eu-geoclinal quartzites and limestones of the Vinini Formation (Ordovician), north-central Nevada. *Geological Society of America Abstracts with Programs*, Annual Meeting Cordilleran Section, p. 260-61.