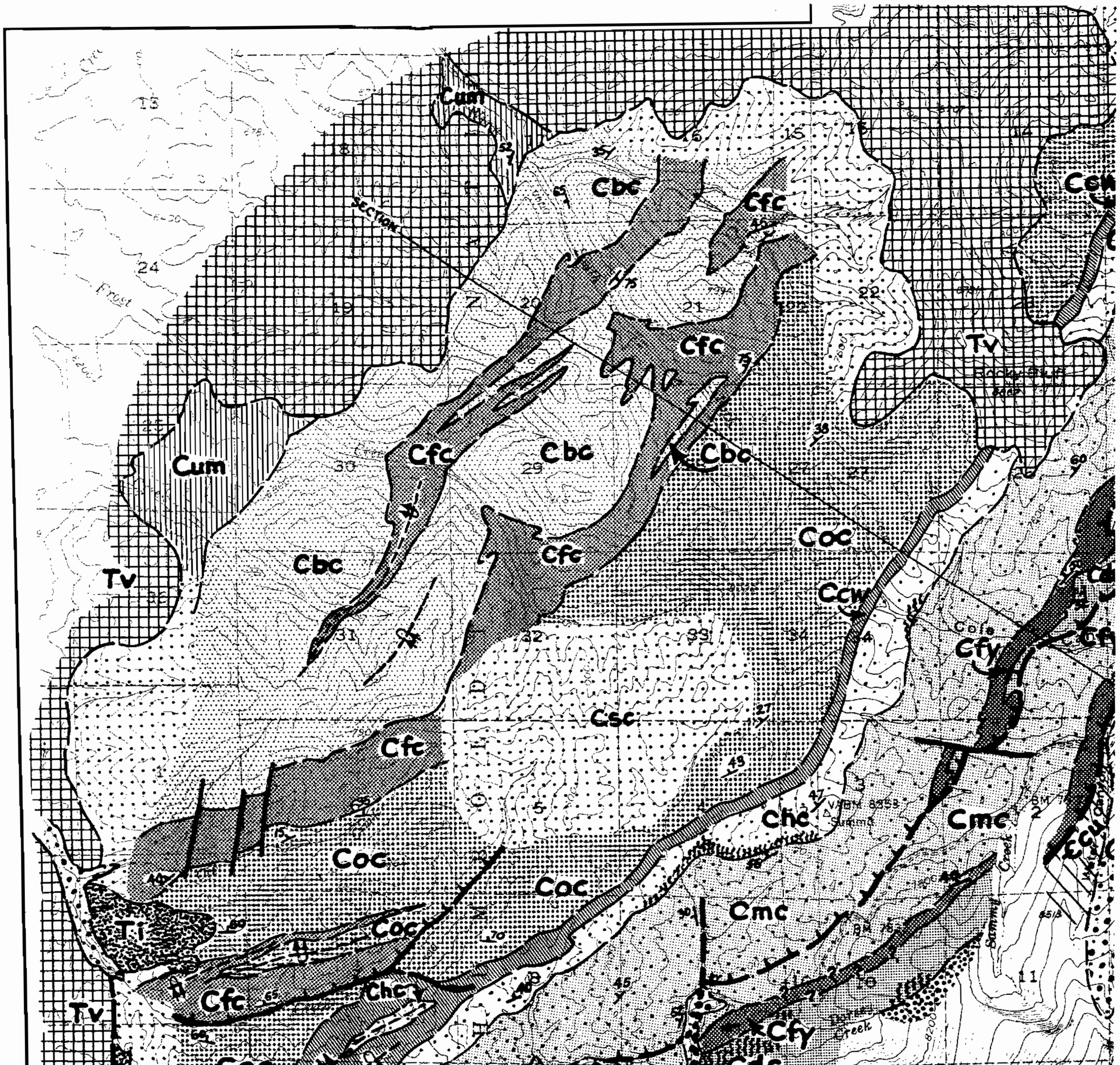


GEOLOGIC MAP OF PORTIONS OF THE BULL RUN AND WILDHORSE

FAGAN, PLATE 1

Geological Society of America Bulletin, volume 73

JOHN J. FAGAN *City College of New York, New York, N. Y.*

Carboniferous Cherts, Turbidites, and Volcanic Rocks in Northern Independence Range, Nevada

Abstract: Rocks of eugeosynclinal origin in the northern Independence Range, Elko County, Nevada (Wildhorse and Bull Run quadrangles) compose the Schoonover Formation which includes eight named and two unnamed members. The formation is, in part, Mississippian, and about 9000 feet in maximum thickness. The rocks, allochthonous with respect to a Carboniferous and Cambrian terrane of miogeosynclinal facies, have been folded and thrust from the northwest during the late Mississippian or post-Mississippian but prior to the Miocene. Principal rock types include (1) argillaceous lutites, (2) bedded cherts, (3) arenites and conglomerates, and (4) andesite lavas.

The bedded cherts appear to have been pelagic accumulations of siliceous organic debris, mostly radiolarian fragments, on the sea floor. Bedded cherts grade from those clearly composed of solid organic debris to those in which the finer radiolarian fragments have merged into a featureless silica continuum. Partial solution and interstitial crystallization during diagenesis and accompanying compaction are considered the essential mechanisms of lithification.

The arenites show graded bedding and flute casts and consist mainly of poorly sorted, poorly rounded quartz grains and once-argillaceous finer material. They are turbidites intermittently deposited by currents from the west. The cherts are products of brief flourishings and settlings of siliceous plankton. Layers of pebbly mudstone (tilloid) record chaotic submarine slides into the relatively deep-water site of sedimentation. The source of the turbidites and slide deposits was a tectonic land not far to the west, composed of rocks formed in the eugeosyncline.

CONTENTS

Introduction . . . 596
Acknowledgments . . . 596
Areal geology . . . 597
  Paleozoic rocks . . . 597
  Tertiary rocks . . . 597
  Pleistocene glaciation . . . 597
Stratigraphy of the Schoonover Formation . . . 598
  General statement . . . 598
  Lower member . . . 598
  Dorsey Creek Member . . . 598
  Fry Creek Member . . . 600
  Mikes Creek Member . . . 600
  Harrington Creek Member . . . 600
  Cap Winn Member . . . 600
  Ott Creek Member . . . 600
  Frost Creek Member . . . 601
  Bailey Creek Member . . . 601
  Upper member . . . 601
Petrology of the rocks of the Schoonover Formation . . . 601
  Argillaceous lutites . . . 601
  Arenites . . . 601
  Conglomerates . . . 603
  Pebbly mudstone . . . 603
  Bedded cherts . . . 603
  Quartzose siltites and limestones . . . 607
  Contemporaneous volcanic rocks and tuffs . . . 607
Environment of deposition . . . 608
Summary and conclusions . . . 610
References cited . . . 610

Figure
1. Index map showing northern Independence Range, Nevada . . . 596
2. Generalized stratigraphic column: Schoonover Formation . . . 599
3. Typical outcrop of interbedded chert and argillaceous lutite . . . 602
4. Composition of Schoonover arenites . . . 602
5. Hypothetical stages in formation of bedded cherts . . . 605
6. Two chert specimens showing knobby bedding planes . . . 606
7. Specimen of bedded chert showing penetration structures . . . 606
8. Intrastratal contorted laminae in calcareous quartzose siltite . . . 607
9. Organic markings in calcareous quartzose siltite 608
10. Hypothetical paleogeography during Mikes Creek time . . . 609

Plate — Facing
1. Geologic map of portions of the Bull Run and Wildhorse quadrangles, Nevada . . . 595
2. View north of North Fork of Humboldt River; outcrops of folded Schoonover cherts and pebbly mudstone; photomicrograph and sketch of turbidite laminae . . . 606
3. Bedded cherts and arenites, Schoonover Formation, Northern Independence Range, Nevada . . . 607

Table
1. Pebble counts, pebbly mudstone . . . 604

Geological Society of America Bulletin, v. 73, p. 595–612, 10 figs., 3 pls., May 1962

INTRODUCTION

Northern Nevada west of about 117° longitude was, during most of the Paleozoic, the site of a eugeosyncline. This geosyncline gained dominantly siliceous sediments by pelagic accumulation and by resedimentation mechanisms. In the miogeosyncline to the east dominantly carbonate sediments accumulated in shallow water. Miogeosyncline-eugeosyncline relationships in central Nevada were studied by Kay (1960), who also provided basic descriptions of the western geosynclines (1951).

In the late Devonian the eastern part of the eugeosynclinal belt was affected by thrust faulting and folding which apparently continued into the Permian and moved rocks of the eastern margin of the eugeosyncline eastward over rocks of the miogeosyncline. Both of these facies are found exposed in a number of mountain ranges in northern Nevada. Most of the rocks of eugeosynclinal origin are early Paleozoic (Ordovician and Silurian); later Paleozoic rocks are less common. The broad stratigraphic relationships of Paleozoic rocks in north-central Nevada have been summarized by Roberts and others (1958).

This paper provides a basis for reconstruction of the environment of deposition of some of the sediments laid in the little-known late Paleozoic eugeosyncline. Petrologic and stratigraphic studies have been made of rocks of eugeosynclinal origin, Mississippian in part, in the northern Independence Range[1], Elko County, Nevada (Fig. 1). These rocks compose a folded, allochthonous sequence which includes argillaceous lutites[2], bedded cherts formed largely by accumulation of siliceous organisms, arenites and conglomerates deposited by turbidity currents, pebbly mudstones (tilloids) emplaced by submarine sliding, and contemporaneous sea floor volcanic rocks.

D. W. Folger (1958, M.A. thesis, Columbia Univ.) mapped a portion of the Bull Run 15-minute topographic quadrangle. R. W. Decker (1958, unpub. ms., Nevada Bureau of Mines, Reno, Nevada) mapped the geology of the entire Bull Run quadrangle but did not study in detail rocks of eugeosynclinal origin.

ACKNOWLEDGMENTS

The field work and research embodied in this report were made possible by National Science Foundation fellowships and by support from the Kemp Fund of Columbia University. The problem was suggested and progress aided and encouraged by Prof. Marshall Kay of Columbia University. Profs. John Imbrie and Fred Donath of Columbia University and Drs. Ralph J. Roberts and Reuben J. Ross, Jr., have criticized the manuscript. The writer benefitted from field discussions with Drs. Preston Cloud, Robert Coates, Stanislaw Dzulynski, Reuben J. Ross, Jr., and especially Martin Kirchmayer. John Allington, of Nebraska University, Sylvia Robinson Fagan, and others assisted in the field. Mr. Andrew McIntyre directed the photomicrography.

Fossil identifications were made by the writer except as acknowledged in the text.

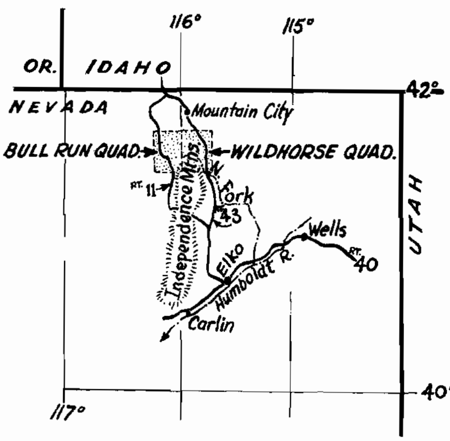


Figure 1. Index map showing northern Independence Range, Nevada

[1] The Independence Mountains is the name commonly given to high peaks which extend from the Humboldt River near Carlin northeasterly and end just south of the headwaters of the North Fork of the Humboldt River. In this paper, the hills to the north and northwest between Trail Creek and the North Fork will be considered as part of the northern Independence Range.

[2] Grabau's terms (Pettijohn, 1957, p. 233) are used for many rocks described in this paper. "Lutite" is used for rocks of mud-sized particles; "shale" is reserved for a lutite characterized by regular fissility; "chert" is a dominantly siliceous lutite of dense and vitreous aspect but it will be excluded when the term "lutite" is used. "Arenite" refers to rocks of sand-sized particles (mean size), and "siltite" to rocks of silt-sized particles. Other terms are those of common usage (*e.g.*, "limestone" refers to all dominantly calcareous sedimentary rocks and has no textural implication).

AREAL GEOLOGY

Paleozoic Rocks

McAfee and other high peaks in the southwest corner of the Wildhorse quadrangle (Pl. 1) are formed principally of light-colored, massive orthoquartzites of questionable age. These extend into the Bull Run quadrangle and are associated with Ordovician graptolitic strata at the head of Chicken Creek south of the quadrangle boundary. In places, light-colored argillaceous lutites and cherts are interbedded with the quartzites, and the sequence is probably of eugeosynclinal origin. Ralph J. Roberts (Personal communication, 1960) believes that the orthoquartzites are correlative with the Ordovician Valmy Formation of the Battle Mountain area, a judgement based on lithic resemblance and graptolites in immediately underlying strata. The writer has not studied these orthoquartzites in detail, but field relationships suggest that the orthoquartzite sequence is overlain by the adjacent Schoonover Formation, defined herein[3].

The hills north and northwest of the orthoquartzite sequence are underlain by rocks of the Schoonover Formation, which is allochthonous with respect to a third Paleozoic terrane of Carboniferous limestones and clastic rocks lying unconformably on Cambrian limestones (Kay, 1960). The Carboniferous of this third terrane may be correlative with the Tonka Formation of Dott (1955) in the Carlin area. The unnamed Cambrian-Carboniferous rocks along the North Fork of the Humboldt (Wildhorse quadrangle) appear to have been overridden by the Schoonover Formation but are now in contact in most places with the Schoonover along high-angle faults (Pl. 1). The only exposure of a thrust fault between the two terranes can be seen just above the north bank of the North Fork of the Humboldt between Beadles Creek and Water Canyon (Pl. 1).

The Schoonover Formation is structurally complex. Almost all large outcrops of bedded cherts and lutites show folding (Pl. 2, fig. 2). However, detailed structure could be mapped only where good outcrops and exceptional lithic contrast permitted—*e.g.*, the contact of the Frost Creek and Bailey Creek members (Pl. 1). The axial planes of larger folds generally incline toward the north and northwest; the Schoonover is considered to have been thrust from that direction in late Mississippian or post-Mississippian time prior to the Miocene.

The dating of the thrusting as well as correlation of the Schoonover with other rocks is largely dependent upon the Mississippian age of brachiopods in the Dorsey Creek Member, the lowest named unit of the formation. Approximately 9000 feet of the Schoonover Formation is exposed; about 8000 feet is younger than the Dorsey Creek fossil zone, so that the upper parts of the formation may be younger than Mississippian.

No correlative units are known in nearby areas. Age, rock types, and the sequence, and thickness of rock types, suggest correlation with the Inskip Formation in the East Range; similar rock types are also reported in the Pumpernickel Formation (Mississippian or older) in the Sonoma Range and in an unnamed Late Mississippian formation in the Osgood Mountains (Roberts and others, 1958). These units, in the upper plates of thrusts, were probably deposited originally in western Nevada.

Tertiary Rocks

Most of the Wildhorse quadrangle is underlain by thick Tertiary volcanic rocks which are generally rhyolitic with the texture of welded tuffs. R. W. Decker (1958, unpub. ms., Nevada Bureau of Mines, Reno, Nev.) mapped these as Miocene in the Bull Run quadrangle; outcrops are continuous in the two quadrangles (Pl. 1). The typical volcanic at Rocky Bluff, Wildhorse quadrangle, is pale red and cryptocrystalline with phenocrysts of quartz, sanidine, and biotite, but in a few outcrops a darker facies occurs. Where they are preserved, the volcanic rocks unconformably overlie the Paleozoic rocks (Pl. 2, fig. 1).

Pleistocene Glaciation

The most striking topographic features are the glaciated heights of the Independence Range: McAfee Peak (10,439 feet) is the highest point (Pl. 1). Pleistocene glaciers established on the northwest and southeast slopes formed cirques, arêtes and U-shaped valleys such as

[3] Marshall Kay (Personal communication, 1961) and associates have recently found conglomerates forming the basal portion of the Schoonover Formation lying unconformably on the orthoquartzite-bearing sequence which forms McAfee and other high peaks. The contact can be seen along Schoonover Creek east of Jack Creek. These workers consider the orthoquartzite-bearing sequence to be Ordovician: thus the Schoonover Formation unconformably overlies Ordovician strata.

those of Chicken Creek, both forks of Mill Creek, McAfee Creek, and Beadles Creek. Lateral moraines are clearly displayed along Chicken and Mill creeks. Rock glaciers presently line some of these valleys.

STRATIGRAPHY OF THE SCHOONOVER FORMATION

General Statement

The name Schoonover Formation, taken from Schoonover Creek, is proposed for the chert-clastic-volcanic rock sequence in the Bull Run and Wildhorse quadrangles north and northwest of McAfee Peak. Bedded cherts and argillaceous lutites are ubiquitous in the formation; less common rock types, such as coarse clastic rocks, red chert, pebbly mudstone, and volcanic rocks, characterize certain members (Fig. 2). The formation is subdivided into the Dorsey Creek, Fry Creek, Mikes Creek, Harrington Creek, Cap Winn, Ott Creek, Frost Creek and Bailey Creek members as well as upper and lower unnamed members; its named members aggregate a maximum thickness of about 7850 feet, its unnamed members as much as 1200 feet. The total exposure is at maximum about 9000 feet. Recurrence of similar rock types, and complex folding of the incompetent strata, make it difficult to determine the original thicknesses of many of the units.

Plate 1 presents the areal distribution of members within the Schoonover Formation; only major structures are indicated.

Lower Member

The strata in contact with the massive orthoquartzites of the high peaks and underlying the Dorsey Creek Member make up the lowest part of the Schoonover Formation. They crop out on the ridge between the mouth of Sammy Creek and Water Canyon on the Wildhorse quadrangle and just northwest of the northeast-trending portion of the east fork of Mill Creek on both quadrangles (Pl. 1).

The predominant rock type is ledge-forming medium-bedded chert[4] ranging from light olive gray[5] to black, having some thin, dark argillitic interbeds. Chert beds in the lower part of this member contain quartz-silt laminae, and the lowest strata exposed are quartz arenites and conglomerates containing boulders identical to the orthoquartzites of the high peaks. The actual lower boundary is hidden by quartzite debris so that thickness cannot be determined[6]. The upper boundary is the lowest occurrence of the volcanic rocks or distinctive lutites of the Dorsey Creek Member.

Dorsey Creek Member

The Dorsey Creek Member is the name given to strata exposed on the hilltop south of Dorsey Creek. It consists of two contrasting facies grading laterally into one another. One is mainly a series of thin-bedded siliceous argillaceous lutites with occasional thin chert units and rarer quartzose silt beds. The lutites are generally medium light to medium dark gray or grayish green and weather to various yellow-brown hues. The cherts are of similar color but weather to grayish yellow green. This facies generally does not crop out, but is represented by debris of brownish, fine-grained rocks. Thin intercalated volcanic flows also occur and are represented in the float by amygdular fragments.

The second facies of the Dorsey Creek Member is dominantly volcanic, consisting of successive flows and local agglomerates. Locally, thin black argillaceous lutites and thin black pale-weathering cherts as well as fossiliferous limestone and conglomerate lenses are interbedded with the flows. Lenses of limestone, generally dark gray and aphanitic, appear approximately in the same stratigraphic zone and are invariably underlain and commonly overlain by volcanic rocks. Exposures are poor and are only a few feet thick. One small lens is dominantly composed of large echinoderm columnals; another contains only very recrystallized bryo-

[4] Ingram's (1954) classification is used to describe bedding thicknesses. Thus, very thick-bedded means above 100 cm, thick-bedded is 30–100 cm, medium-bedded, 10–30 cm, thin-bedded, 3–10 cm, and very thin-bedded is 1–3 cm. "Laminated" is used by Ingram for thicknesses below 1 cm; however, in this paper "bedded" is reserved for strata separated by distinct planes of parting; very thin-bedded implies thickness up to 3 cm. "Laminated" is reserved for layered rocks that do not show parting. Thus, a medium-bedded chert may have fine laminae within each bed. The bedding is defined in most cases by weathered planes and the laminae by color differences within the beds.

[5] *See* Rock Color Chart of the National Research Council for all color references of the stratigraphic descriptions.

[6] Marshall Kay (Personal communication, 1961) and associates have recently found conglomerates like those described forming the basal portion of this member and lying unconformably on the orthoquartzite-bearing sequence which forms the high peaks (*See* footnote 3).

zoan fragments. A faunule collected from a lens of dark, shelly limestone along the upper part of Dorsey Creek, Wildhorse quadrangle, contains fossils considered to be Mississippian. It includes:

Brachiopoda:
Spirifer sp. cf. *S. grimesi* Hall
Spirifer sp. cf. *S. increbescens* Hall
Linoproductus sp. cf. *L. ovatus* (Hall)
Dictyoclostus sp.
Bryozoa:
Fenestellid bryozoan
Coelenterata:
Unidentified horn coral
Echinodermata:
Various columnals

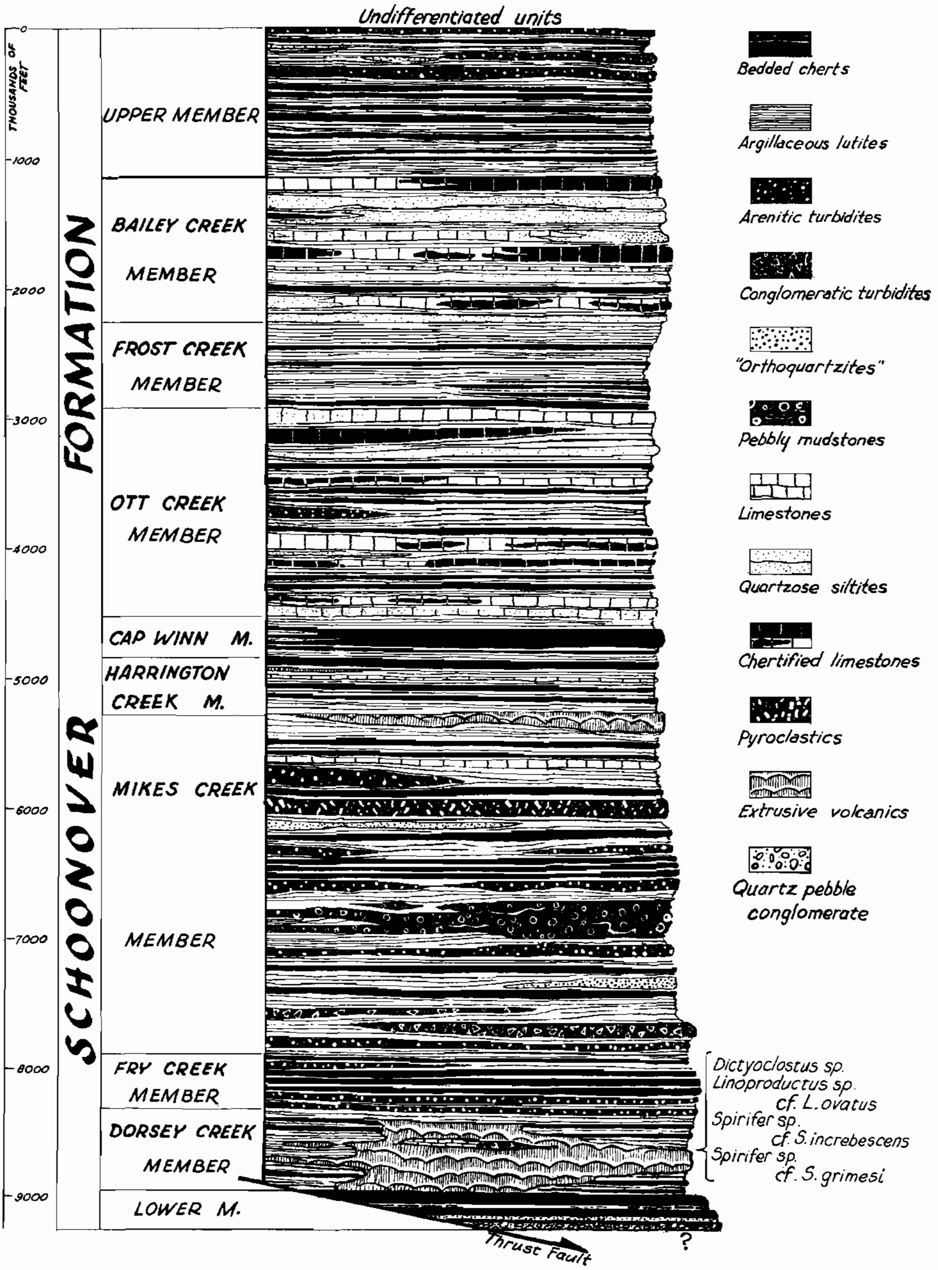


Figure 2. Generalized stratigraphic column: Schoonover Formation

The Dorsey Creek is closely folded, but the thickness is estimated to be 650 feet. The upper boundary is taken as the lowest occurrence of the more massive chert of the Fry Creek Member.

Fry Creek Member

The Fry Creek Member, which has a maximum thickness of 450 feet, is exposed on the ridge east of Fry Canyon in the Wildhorse quadrangle. In most places (*e.g.*, the ridge northeast of Mikes Canyon), this unit overlies the Dorsey Creek Member; in the Bull Run quadrangle rocks of the Fry Creek have not been recognized in some places (Pl. 1) and appear to have been deposited only locally.

Bedded chert forms the major part of the member. It is generally medium dark gray to black, but in places a light-greenish-gray variety, weathering a pale blue green, was noted. Where the unit crosses Cole Canyon south of Rocky Bluff, beds of dark-gray, nondiscoloring chert change in several hundred feet to a sequence of pale cherts, weathering blue green. Bedding planes in the dark variety commonly weather a pale red purple, but pale blue-green weathering is most common in both varieties. The chert is usually thin- to medium-bedded and very fractured and veined. Argillaceous interbeds are uncommon and very thin. Most of the Fry Creek cherts form ridges, being more resistant than other thinner-bedded cherts of the Schoonover Formation. The upper boundary is taken as the lowest occurrence of the coarse arenites of the overlying unit on the ridge east of Fry Canyon.

Mikes Creek Member

The Mikes Creek Member, named from exposures along the upper part of Mikes Canyon, Wildhorse quadrangle, is a thick heterogeneous sequence of strata overlying the Fry Creek Member, consisting mainly of poorly sorted arenites and conglomerates, argillaceous lutites, pebbly mudstones, and thin black cherts.

Some of the arenites and conglomerates are traceable for more than 10 miles, but most pinch out locally. Most of the arenites are dark gray or gray green and tend to weather in hues of brown. The lutites are monotonously dark-colored, and exposures are poor. Some thin-bedded cherts which show conspicuously sandy and silty laminae and penetration structures (described later) compose a traceable unit within the member.

The upper boundary is the lowest occurrence of volcanic rocks forming the base of the overlying unit. Maximum thickness is 2600 feet, but actual thickness is probably considerably less.

Harrington Creek Member

The Harrington Creek Member is best exposed in the hills north of Jack Creek in the Bull Run quadrangle, the name being taken from a creek 2 miles to the west. Very thin-bedded, gray to black, argillaceous lutites and thin, almost black cherts are the most abundant rock types; quartzose siltite and dark-gray limestone beds (commonly chertified) are less common. A single, spiriferoid brachiopod found in black, secondary chert was thought to be Silurian to Mississippian by G. A. Cooper (personal communication, 1958).

Complex folding and a lack of distinctive units prevent a close estimation of thickness; the maximum is probably 450 feet. The lower boundary of this member, in the valley three-quarters of a mile north of the Dorsey Creek-Jack Creek junction, is taken as the base of the only volcanic unit; it is locally absent and is about 100 feet thick. The upper boundary is the lowest occurrence of the medium-bedded to thick-bedded white, varicolored, or red chert of the overlying unit, 1 mile north of the Dorsey Creek-Jack Creek junction.

Cap Winn Member

The Cap Winn Member is named for a creek in the Bull Run quadrangle. It is best seen along the divide ridge between the tributaries of Deep and Jack creeks and consists of a distinctive red, jasperoid chert and other rock types. Extremely rapid change occurs in places from grayish-red to dusky-red chert to gray and grayish-green chert. There are argillaceous lutites of similar colors and also bluish-gray, white, and varicolored cherts. The cherts are thin- to very thick-bedded. A red chert bed more than 1 m thick is exposed south of the upper end of Frost Creek.

The member is approximately 350 feet thick. The upper boundary is the contact of red chert with the lowest limestone of the overlying unit.

Ott Creek Member

The Ott Creek Member, which consists of alternating chert and limestone units, is exposed on the slopes and ridge immediately south of Ott Creek. The cherts are medium gray, ferruginous-stained, weathering grayish yellow green, and thin- to very thin-bedded with interbeds of thinner-bedded, gray to black, shaly, argillaceous lutites. The limestones, most of which are dark gray and aphanitic, contain varying amounts of quartzose silt and commonly pass laterally into quartzose siltites. Many are chertified and tend to be extremely broken and veined with calcite; they weather to light gray where not chertified. It is uncertain how much of the repetition of chert and limestone units is due to original deposition and how much is due to structural complications.

The original thickness of this member is estimated to be a maximum of 1600 feet. The upper boundary is taken as the lowest occurrence of either the distinctive, pale lutite or the olive chert and lutite facies of the overlying unit.

Frost Creek Member

The Frost Creek Member along the upper half-mile of Frost Creek on the Bull Run quadrangle consists of a sequence of distinctive pale-olive, siliceous argillaceous lutites which are thin-bedded or shaly in places. The lower part of the member, just north of Ott Creek, is of uniformly bedded, light olive-gray chert with argillaceous interbeds and fewer thicker quartzose siltite beds which weather to brown hues.

The contact between this member and the overlying limestone-bearing (Bailey Creek) unit seen at the head of Ott Creek is easily mappable and shows the many folds in the northwest part of the map area (Pl. 1). The thickness of the formation cannot be more than 650 feet but it is commonly extremely thickened by folding.

Bailey Creek Member

The Bailey Creek Member is exposed on the hilltop (elevation 7904 feet) south of the head of Bailey Creek and consists predominantly of limestone, black secondary chert, and calcareous quartzose siltstone. Some bedded (primary) cherts are present as well. The limestones, aphanitic to finely phaneritic, are dark gray and weather to light gray. The calcareous quartzose siltites are similar in appearance. Both show cross-laminations and intrastratal convolutions. Black chert has irregularly replaced portions of limestone beds and some entire beds. There are some lenses of well-sorted, well-cemented quartz arenite. Exposures of thin-bedded, dark, shaly, argillaceous lutites are poor.

Total thickness does not exceed 1100 feet. The upper limit of the member is not invariably clearly exposed and is mapped as the highest bed of limestone, massive quartzose siltite, or black chert below the greenish cherts and lutites of the younger, unnamed member along Cap Winn Creek.

Upper Member

The strata above the Bailey Creek Member are neither continuously exposed nor well-exposed (Pl. 1). These rocks can be seen below the Tertiary cover south of Frost Creek and along Cap Winn Creek downstream from the junction with its south fork. A maximum of 750 feet is exposed—dominantly gray chert weathering grayish yellow green and locally moderate yellowish green, with lutite interbeds. Above these, at Cap Winn Creek, is a sequence of arenites and conglomerates of unknown thickness.

PETROLOGY OF THE ROCKS OF THE SCHOONOVER FORMATION

Argillaceous Lutites

Argillaceous lutites, extremely abundant throughout the Schoonover Formation, range from pale olive to black, the darker colors being most common. Red argillaceous lutites are associated with red cherts. Most of the lutites contain fine, scattered silt particles, mainly of quartz. These are particularly abundant in light-colored lutites. X-ray analysis of a typical light-colored argillaceous lutite indicates the presence of illite, chlorite, and quartz (D. W. Folger, 1958, M.A. thesis, Columbia Univ., p. 11).

Argillaceous lutites normally occur as interbeds, no more than a few centimeters thick, between chert layers (Fig. 3). Fine fissility (shale structure) is uncommon. Thicker accumulations, uninterrupted by chert beds, also occur.

It is believed that the bulk volume of the argillaceous lutites is at least 30 per cent of that of the entire formation. They are considered to represent the normal product of very slow settling from nonturbulent water, presumably below wave base in relatively deep water.

Arenites

Here are included those clastic rocks in which the mean diameter of recognizable grains falls within sand size on the Wentworth scale. The arenites are separated from conglomerates for convenience; there seems to be complete textural and compositional gradation between the two. Within the arenites themselves there is wide range in sorting and composition; some might be called graywackes. Almost all thin sections of rocks studied are from the Mikes Creek Member.

TEXTURE: The arenites are poorly sorted mixtures of mud (clay)-, silt-, and sand-sized material. Authigenic addition of minerals is rare and minor. Rounding appears to be better in the coarser grades within a sample but is generally poor (Pl. 3, fig. 1). The degree of rounding varies with stratigraphic position and location.

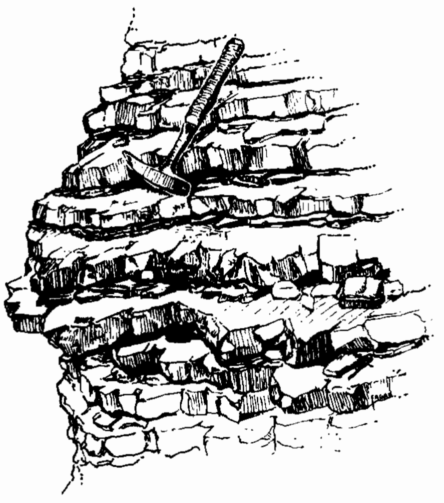


Figure 3. Typical outcrop of interbedded chert and argillaceous lutite

"MATRIX": The finest material consists of an intergrown mixture of fibrous sericite and platy chlorite, within which occur clastic quartz grains; the finer sizes of these are difficult to distinguish from the sericite or chlorite which represent alteration of the original argillaceous mud. It has been convenient to consider all grains below 0.04 mm diameter as "matrix." The average percentage of matrix is 28 per cent.

COMPONENT GRAINS: Quartz is the most abundant mineral (Fig. 4) and averages 0.21 mm in apparent greatest diameter. Mean roundness value for this average size falls high in the subangular class of Pettijohn (1957, p. 57). Chert and feldspar grains are, on the average, larger and smaller respectively than quartz grains.

Most of the quartz appears as clear, non-aggregate grains, with inclusion or bubble trails. Replacement occurs only in finer sizes where the matrix chlorite and sericite appear to have "eaten into" the edges. Most of these grains show undulatory extinction.

Chert grains occur only as sand-sized and larger particles. Many contain radiolarian remains; most have an internal grain size coarser than normal chert.

Feldspar grains are scarce, averaging about 4 per cent in the sections examined. In most cases they are small grains partly replaced by sericite. Microcline, albite, and oligoclase have been recognized, as well as a few coarse sand grains of fine, dark volcanic rock. Content of pyrite and magnetite, both seemingly allogenic, in a few sections reaches 1 per cent. Worn rutile, zircon, and probable tourmaline grains are less abundant.

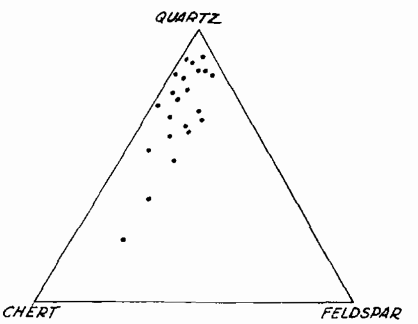


Figure 4. Composition of Schoonover arenites. Triangular diagram based on composition of grains more than 0.04 mm in diameter in 22 thin sections

ORGANIC CONTENT: The arenites contain few clear organic remains. A few echinoderm columnals and brachiopod casts have been found. Macerated plant remains occur in the Mikes Creek Member in a number of places, particularly in a light-colored arenite on the ridge just west of Sammy Creek, Wildhorse quadrangle.

PRIMARY STRUCTURES AND ASSOCIATIONS: Graded bedding is common, particularly in the coarser arenites. Many single thick beds contain several reversals of gradation, and many thin sections of the finer arenites show banding of finer and coarser material.

Bedding-plane structures are poorly preserved. Jointing has destroyed most external structures, but unbroken structures occur in outcrops of fine arenite beds at the top of the Fry Creek Member. Undersurfaces show straight groove casts, lobate flute casts, and other markings, including trails of organisms. Here a current flow coming from within a few degrees of west is indicated. This was determined from flute casts by considering the beds rotated back to the horizontal around the present line of strike, but as the Schoonover is considered allochthonous, the apparent direction may not indicate true current direction in the former basin of sedimentation.

Most arenites are interbedded with dark, argillaceous lutites, but association of cherts and arenites also occurs (Pl. 3, fig. 2).

ORIGIN: Poor sorting and rounding indicate that the material was moved directly from a weathered source by a mechanism which simultaneously deposited coarse and fine sand, silt and mud(clay) producing flow markings and graded bedding. This picture strongly favors the turbidity-current concept. Following the usage of Kuenen (1957) the term "turbidite" is used for the arenites of the Schoonover Formation.

The larger mean size of the chert grains contrasted with that of the quartz grains may indicate derivation from a terrane in which the quartz was already in small particles, *i.e.*, beds of quartzose arenite. Such a terrane, if it included chert beds, could supply a weathering debris of large chert and small quartz grains. But this is an oversimplified picture as is evidenced by the presence of some feldspar and volcanic grains.

Conglomerates

The term "conglomerate" here refers to rocks in which the mean particle diameter falls above sand size on the Wentworth scale. The Schoonover conglomerates also show graded bedding and poor sorting, but many contain more chert than quartz. Most pebbles consist of subrounded to rounded chert and subordinate rounded to well-rounded white, quartz and quartzite pebbles, as well as a few fine-grained volcanic pebbles. There is usually very little originally argillaceous material, the finest fraction being colorless quartz silt.

The conglomerates have graded bedding and poor sorting, and the term "turbidite" is used for these rocks as well. Conglomerates are found principally in the Mikes Creek Member, where, in places, single beds are nearly 3 m thick. They are much less abundant than arenites.

Pebbly Mudstone

Crowell (1957) discusses the origin of pebbly mudstones, particularly those apparently formed in a turbidity-current environment.

The Mikes Creek Member contains at least one unit of pebbly mudstone. Because of poor exposures it is not possible to ascertain whether the several outcrop bands are structural or stratigraphic repetitions. Folds in the Mikes Creek Member suggest that the pebbly mudstone occurs only at one stratigraphic position in a unit about 300 feet thick; possibly one or two thinner beds are associated (Fig. 2).

DESCRIPTION: The pebbly mudstone has an argillaceous matrix similar to the finest material found in the arenitic rocks but generally less altered to chlorite and sericite. This matrix is dark gray and generally indurated. Like the arenites and conglomerates, the pebbly mudstone contains particles of all sizes, but most of the rock is fine and argillaceous. Within this matrix occur conspicuous clasts (Pl. 2, fig. 3), in most cases unoriented, of pebble size (> 2 mm). The proportion of pebbles and matrix is extremely variable. The average rock consists of about 75 per cent lutite (with minor quartz sand and silt) and about 25 per cent pebbles. Table 1 is a compilation of data on composition and rounding of pebbles of more than 1 cm in diameter. The largest noted was of a fine conglomerate indistinguishable from bedded units elsewhere in the Mikes Creek Member. It was subrounded and 37 inches in greatest diameter.

Contorted beds and groups of beds of arenites and thin-bedded lutites are found within the pebbly mudstone.

ORIGIN: The pebbly mudstone is part of a sequence that includes abundant turbidites, although lack of grading and the included structures indicate that the pebbly mudstone was not introduced by turbidity currents. The rounded, randomly scattered, unoriented clasts and the included contorted beds indicate that a slow-moving mass of mud slid down-slope and pushed up and incorporated soft sea-bottom layers. It is assumed that the slope was in the same position as that which allowed the deposition of older and younger clastic beds by turbidity currents.

The pebbles are composed of different rock types (Table 1), most of which occur lower in the Mikes Creek Member, in older members of the formation or in the orthoquartzite-bearing sequence of McAfee Peak area. Their ultimate source must have been a terrane of diverse rocks.

Bedded Cherts

Bedded cherts compose much of the Schoonover Formation. The minimum total thickness is estimated to be 3000 feet. Bedded cherts do not include the nodular or discontinuous dark cherts which are replacements of limestones.

GENERAL DESCRIPTION: They consist principally of cryptocrystalline to microcrystalline quartz. All have a dense, vitreous appearance but vary widely in color, thickness, and content of included material. Although very resistant to abrasion and solution, they are commonly broken by close-spaced fractures.

The most common color is medium to dark gray. Red chert is a conspicuous rock type characterizing the Cap Winn Member but rare elsewhere. Many specimens of red chert show partial change to greenish chert along cracks and bedding planes, probably indicating hematite reduction by ground-water solutions. The red, or jasperoid, cherts commonly have enough hematite inclusions to appear nearly opaque in thin section. The black cherts are not opaque in thin section and appear to owe their color to organic carbon. The lightest-colored cherts, almost white or pale gray or green, consist almost entirely of quartz.

ORGANIC CONTENT: Structures interpreted as radiolarian remains are present in almost all specimens of Schoonover bedded chert. Most consist only of chalcedonic (microfibrous quartz) spherules (Pl. 3, fig. 4) but are identified as radiolarians by study of better specimens and by the presence of intermediate stages of preservation. The spherules can occasionally be seen by the unaided eye but thin sections about 0.1 mm thick were used for study.

The black or dark-gray cherts afforded the best preservation of organic remains (Pl. 3, figs. 3, 5). They contain smooth or spiny spherules, broken spines, and nonidentifiable fragments of vague outline. Most of these are considered to be radiolarian parts, but some may be broken sponge spicules or other debris. In most of the lighter-colored and red cherts, the finer material is wholly indistinguishable (Pl. 3, figs. 4, 6).

Most of the radiolarians are spherical. In many specimens more than one concentric sphere is preserved. Ellipsoidal forms and spongy, three-armed forms are uncommon. Most appear to be Spumellinids of the division Sphaerellari (Campbell, 1954).

BEDDING AND ASSOCIATIONS: Bedded cherts range from less than 1 cm in thickness to more than 1 m. Most are 8–10 cm thick. Red cherts form the thickest single beds.

The cherts are commonly interbedded with argillaceous lutites, almost invariably thinner than the chert beds, making up a rhythmic sequence (Fig. 3) in many places. Lenses do occur, but the chert is commonly in continuous beds, many of which can be traced for miles

TABLE 1. PEBBLE COUNTS, PEBBLY MUDSTONE

Lithology	Number at locality: A	B	C	D*	Average diam. (inches)	Average rounding
Orthoquartzite (arenite) generally white	13	16	11	20	7.5	Well rounded
Arenitic "turbidite" (poor sorting, etc.)	23	37	27	22	6.1	Subangular to subrounded
Arenite or siltite, uncertain affinities	5	1	3	4	1.4	Subrounded
Argillaceous lutite	1	0	0	3	0.7	Subrounded
Chert, mostly black	56	40	53	42	1.1	Well rounded to subrounded
Igneous rock, generally fine-grained	0	4	1	3	1.5	Subrounded
Limestone, generally aphanitic	1	0	2	0	2.2	Subrounded
Unidentifiable in field	1	2	3	6	1.2	Subrounded

* Totals: 100 in each of four localities along outcrop band of Mikes Creek Member, Wildhorse quadrangle

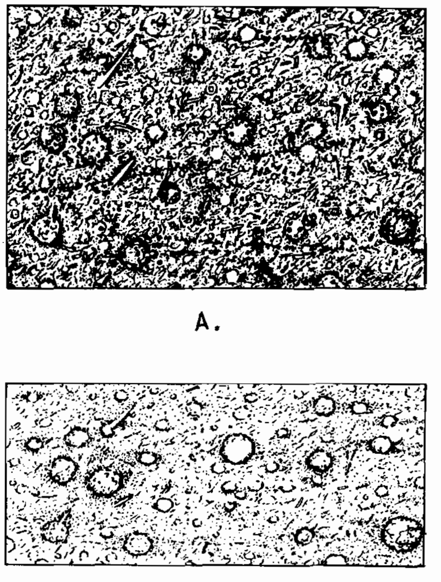
along strike, owing to their resistance to erosion and their thickness, internal structures, or color.

PRIMARY STRUCTURES: Almost all bedded cherts have laminae which resolve under the microscope into slight variations in content of radiolarian tests and spiny debris, carbonaceous material, iron oxide and pyrite flecks, or clastic quartz grains. Some cherts, particularly those of part of the Mikes Creek Member, contain distinct laminae of clastic grains within the individual chert beds, many of which show graded bedding (Fig. 7; Pl. 2, fig. 4). These were first observed by Kirchmayer (1959) who proposed the name *Chertgestein* for chert with such layers and structures. Kirchmayer mentions the existence of possible ripple marks in these clastic laminae. Structures resembling ripple marks were found only in certain areas where the laminae have been pressed down by diagenetic flowage structures (Fig. 7).

ORIGIN: The association of radiolarian cherts with volcanic rocks is common, and probably some genetic connection exists between the two. However, as inorganic precipitation of silica from solution requires a concentration of about 100 ppm (amorphous silica has a solubility of 140–150 ppm at 25°C and 50–80 ppm at 0°C: Krauskopf, 1959), this concentration is likely to be reached only locally. Volcanic activity might give rise to such locally extreme concentrations and thereby produce the interpillow chert lenses associated with some volcanic rocks (Krauskopf, 1959). But a concentration of silica at least 10 times greater than that of modern oceans has to be reached over at least tens of square miles to account for bedded cherts with the areal extent of those of the Schoonover Formation. This theoretically furnishes only the smallest amount of silica precipitate. To account for the bed of average thickness, constant addition of silica to sea water has to be made, and this has to be a regular, repetitive event since the sequence contains many thousands of chert beds.

The Schoonover bedded cherts appear to have originated by simple accumulation of siliceous organic debris, formed principally of radiolarian tests and fragments of tests, particularly spines. This origin is much more compatible with oceanic processes and chemistry than inorganic precipitation. The organic origin of cherts is far from a new idea. Bramlette (1946) concluded that diatomaceous deposits of the Monterey Formation became chert during diagenesis by addition of silica dissolved from nearby diatomaceous beds.

The writer has found cherts in all stages of preservation in the Schoonover Formation ranging from cherts seen in thin section to be almost solid organic debris through cherts with few recognizable organic remains to those where only interlocking, silt-sized quartz grains are visible. The varieties grade into each other. Their different appearances are a result of variations in primary textural and compositional characteristics and degree of diagenetic change.



B.

Figure 5. Hypothetical stages in formation of bedded cherts. A. Bed of original, siliceous organic debris. B. The compacted bed after diagenesis

The exceptional black cherts preserve even minute bits of organic debris. But the finely divided opal of these bits was in ideal condition for solution at pressure points and interstitial redeposition during compression, which commonly took place during diagenesis until the end product was the typical chert in which finer organic debris has lost definition and only larger, heavier, whole radiolarian tests remain recognizable. This diagenetic process is illustrated in Figure 5, which also suggests the compaction of the original deposit. The dark cherts, least modified during diagenesis, are represented in Figures 3 and 5 of Plate 3; red and gray chert, showing high degree of diagenetic modification, are represented in Figures 4 and 6 of Plate 3, respectively.

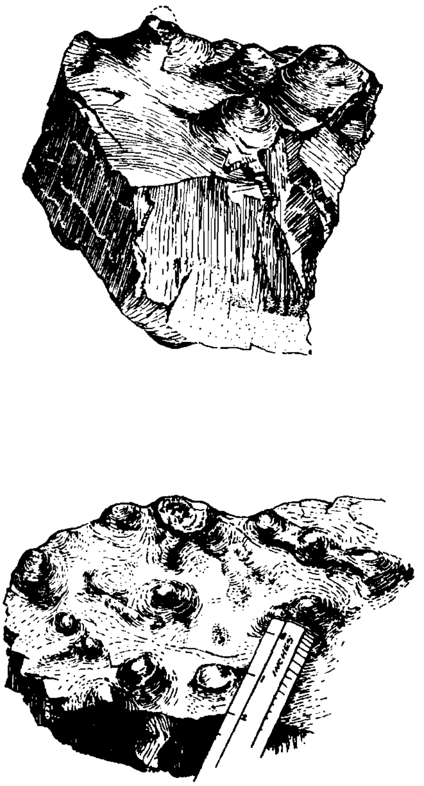


Figure 6. Two chert specimens showing knobby bedding planes. The knobby structures are a result of diagenetic flowage. Approximately ×0.5

Figure 4 of Plate 2 is a photomicrograph of a portion of a gray chert bed containing several silty clastic laminae. The lowermost radiolarians partially embedded in the turbidite substratum indicate that the radiolarians were not entrapped in a pre-existing mass of silica gel. Such clastic laminae within chert beds are further evidence of the origin of the Schoonover cherts by simple accumulation of organic detritus on the sea floor.

DEPTH OF DEPOSITION: Bedded cherts had been early considered as lithified radiolarian oozes and compared with recent oozes of the deep sea (Steinmann, 1925). Other workers objected to this interpretation because of common association with coarse clastic deposits considered to be of shallow-water origin. Davis (1918) and Taliaferro (1943) used this argument to claim the Franciscan cherts as shallow-water sediments. The recent realization of the role of turbidity currents in bringing coarse, terrigenous material far out onto the ocean floor has nullified this argument. Rather, abundant clastic deposits with graded bedding favor an origin at least below wave base.

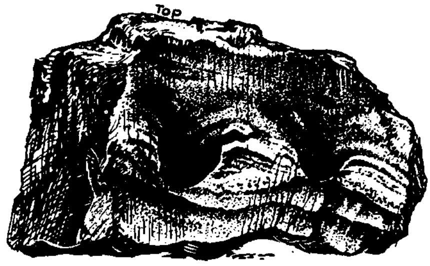


Figure 7. Specimen of bedded chert with penetration structures. These diagenetic structures press down on silty laminae within chert bed. Approximately ×0.5

Riedel (1959) states that,

"Depth *per se* seems not to be an important direct factor in the accumulation of biogenous silica, though it has an indirect effect through its influence on the accumulation of calcium carbonate. . . ."

Much of the radiolarian ooze in the present ocean is not the result of settling from a planktonic biota composed solely of siliceous organisms; rather, the planktonic communities include both calcareous (e.g. *Globigerina*) and siliceous forms. The resulting sea-floor sediment is predominantly siliceous because most calcareous tests are destroyed by solution at depth.

Radiolarian ooze forms only at depths sufficient for calcareous tests to be dissolved—usually below 12,000 feet— leaving a concentration of radiolarians. Since planktonic Foraminifera and other calcareous plankton were almost nonexistent, prior to the Mesozoic, a lithified Paleozoic radiolarian ooze does not necessarily imply deposition at the abyssal depths of modern radiolarian oozes. Paleozoic radiolarian oozes probably accumulated at widely varying depths, including some considerably less than modern sites of ooze accumulation. The Schoonover bedded cherts are considered lithified accumulations of radiolarians like the modern oozes but were not necessarily deposited at similar depths.

Figure 1. Distant view north of North Fork of the Humboldt River. Looking north. Dashed line is unconformable contact. Tertiary volcanic rocks above, northwest-dipping Schoonover Formation below

Figure 2. Folded Schoonover cherts. Mikes Creek Member

Figure 3. Pebbly mudstone outcrop. Mikes Creek Member

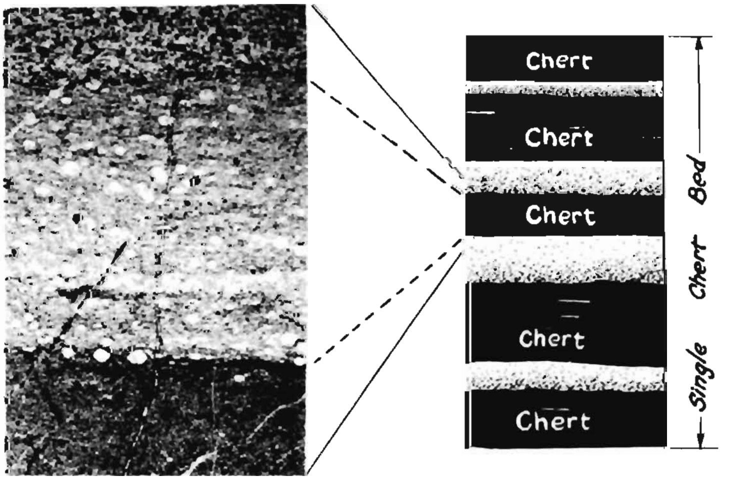


Figure 4. Drawing of chert bed containing four turbidite laminae and photomicrograph of a portion. Photomicrograph approximately ×8. Drawing ×1

VIEW NORTH OF NORTH FORK OF HUMBOLDT RIVER; OUTCROPS OF FOLDED SCHOONOVER CHERTS AND PEBBLY MUDSTONE; PHOTOMICROGRAPH AND SKETCH OF TURBIDITE LAMINAE

FAGAN, PLATE 2
Geological Society of America Bulletin, volume 73

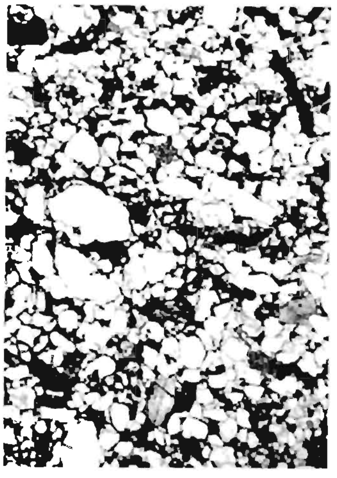


Figure 1. Photomicrograph of an arenite from Mikes Creek Member. This turbidite shows poor sorting and poor rounding. Quartz grains are most abundant. Approximately ×12

Figure 2. Bedded cherts overlying single turbidite bed. Mikes Creek Member

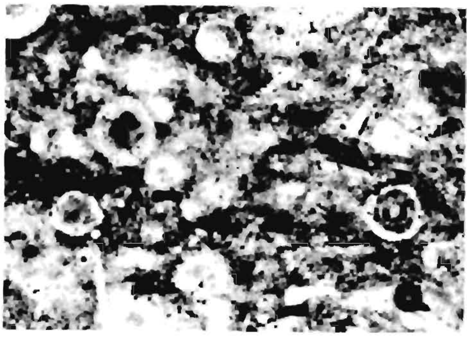


Figure 3. Photomicrograph of dark-gray chert. Radiolarian tests and debris. Approximately ×50

Figure 4. Photomicrograph of red chert. Light areas represent radiolarians. Approximately ×12

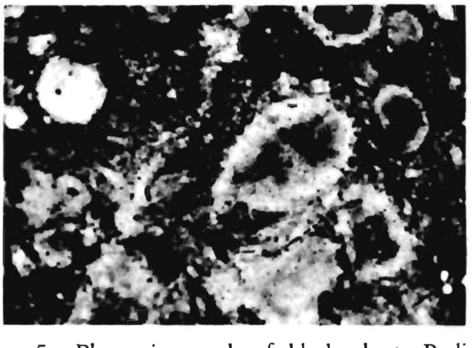


Figure 5. Photomicrograph of black chert. Radiolarian tests and debris. Approximately ×50

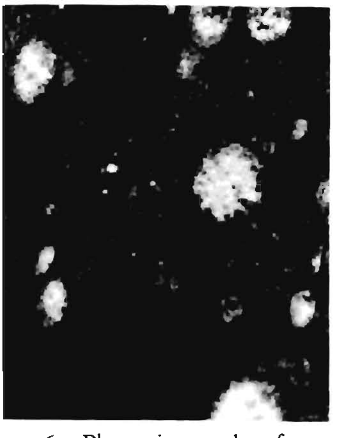


Figure 6. Photomicrograph of gray chert. Here radiolarians have almost lost definition. Contrast with Figures 3 and 5. Approximately ×50

BEDDED CHERTS AND ARENITES, SCHOONOVER FORMATION, NORTHERN INDEPENDENCE RANGE, NEVADA

FAGAN, PLATE 3

Geological Society of America Bulletin, volume 73

DIAGENETIC STRUCTURES: Thin sections normal to bedding of many cherts show radiolarians and other (now chalcedonic quartz) remains concentrated in columnar bodies; these penetrate darker chert containing more nonsiliceous inclusions and fewer whole radiolarians. Such cherts have bedding surfaces covered with knobs and other irregular protrusions penetrating adjacent argillaceous and chert beds (Figs. 6, 7) and commonly corresponding to the internal columns. Kirchmayer (1959) considers these features to be a result of diagenetic flow. Kirchmayer noted that the internal columns, where associated with graded bedding, appear to have penetrated downward. He considered a process of sinking but was puzzled by the lack of contrast of specific gravities; he raised the possibility that the chert body other than the columns may have been composed originally of the less dense mineral, opal. However, external knobs commonly show on both upper and lower surfaces of chert beds, and therefore cannot result from simple sinking of material. The writer considers knobs and internal columns to have formed in the following manner: Originally, siliceous layers of variable proportions of radiolarian tests, broken tests and spines, and argillaceous and other inclusions accumulated. As a result, a series of hydroplastic layers of slightly different viscosities were formed and compressed by overlying layers. The most fluid layers tended to flow and penetrated adjacent, less fluid layers above and below.

This movement of hydroplastic material must have taken place prior to lithification, *i.e.*, during earliest diagenesis. Diagenesis was undoubtedly a long-continued process of elimination of interstitial water and of that in the opaline silica. Kirchmayer (1959) discusses successive stages of diagenesis which appear to be indicated by the chert microstructures.

Quartzose Siltites and Limestones

Beds of calcareous, quartzose siltites and quartz-silty limestones occur principally in the Ott Creek and Bailey Creek members. Both types are generally dark gray to black; the limestones weather to considerably lighter gray. The limestones are aphanitic to finely phaneritic. Both rocks tend to be medium-bedded. There seems to be complete gradation from quartzose siltites, which contain only about 20 per cent calcite, to limestones with very minor amounts of quartz silt. Thus, the two are described together. Neither show clear grain-size gradation from top to bottom of beds, but most have fine internal laminae which, on weathered surfaces, may show intrastratal contortions and cross-laminae (Fig. 8). The contortions invariably disappear toward the two bounding bedding surfaces. Recent work by TenHaaf (1956) has related such intrastratal folding or convolute laminae to the action of currents. These convolutions differ from gravitational slumping phenomena in the lack of piling up of rolled masses; they occur in beds of uniform thickness. According to TenHaaf

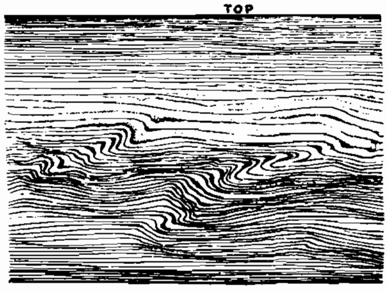


Figure 8. Intrastratal contorted laminae in calcareous quartzose siltite. Single bed from Bailey Creek Member (×0.5)

their formation requires the influence of slight differential stresses, probably induced by a turbidity current on a growing, hydroplastic bed. Such convolutions are essentially current ripples, accumulated and preserved by growth of the silt beds. The flattening out toward the top of the bed is attributed to the waning of the current.

The direction of overturning of intrastratal folds should be in the downstream direction. Although the direction of current flow changed in the Schoonover terrane, it was invariably within 10° of due east. This flow from the west is also supported by direction of inclination of cross-laminae.

Some quartzose siltites and quartz-silty limestones have had their normal, fine laminae destroyed by burrowing organisms of the infauna, probably worms, which have left dark markings (Fig. 9). These are probably carbon-rich castings left by the moving animals which partially digested and concentrated the dead organic matter in which darker laminae were richest.

Contemporaneous Volcanic Rocks and Tuffs

LAVAS: Volcanic flows in the Dorsey Creek

Member attain a maximum thickness of about 500 feet southeast of the junction of Jack and Dorsey creeks; along strike this unit splits into several thinner flows. Volcanic rocks in the base of the Harrington Creek Member reach a maximum thickness of approximately 100 feet.

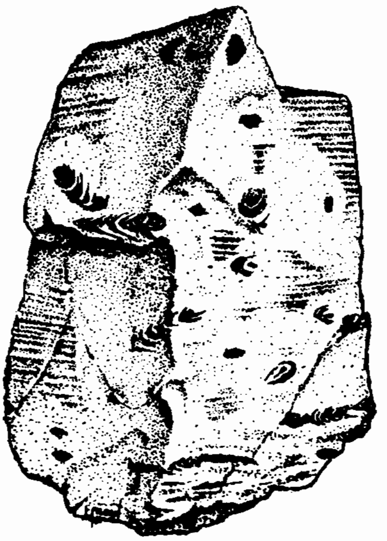


Figure 9. Organic markings in calcarous quartzose siltite. The laminae have been interrupted by burrowing organisms which left the markings shown (×0.75)

Thicknesses are difficult to determine because of lack of bedding evidences, and original composition of the lavas is obscured by alteration. The matrix and phenocrysts, where present, are commonly altered to a fine pepper and salt mixture of chlorite, clay minerals, sericite, and epidote. Some specimens contain partially altered phenocrysts of andesine plagioclase. Most of the flows are fine-grained and amygdular, appear brownish-gray, and weather to various hues of purple, brown, and yellow. Some appear dark greenish gray on fresh surface.

TUFFS: Near the top of the Mikes Creek Member appear light-colored, medium- to thick-bedded strata of volcanic material of sand size. These seem to be water-laid pyroclastic accumulations. Broken and unbroken crystals of potassic feldspar, sodic plagioclase, and quartz grains are set in a sericitic and chloritic groundmass. The rock is well indurated and, in outcrop, strongly resembles a graywacke. These tuffs are the only reasonably clear examples of pyroclastic accumulation found in the Schoonover Formation.

ENVIRONMENT OF DEPOSITION

GENERAL STATEMENT: The marine rocks that make up the Schoonover Formation contain contemporaneous volcanic rocks and are considered to have been deposited in a eugeosyncline. More than 9000 feet of sediments may be present, undoubtedly representing different environments of deposition. The calcareous rocks are almost entirely confined to the upper part of the section, whereas the coarser turbidites are mainly concentrated in the lower. But re-occuring bedded cherts and argillaceous lutites of similar appearance and the almost complete lack of benthonic fossils suggest similar conditions in the geosynclinal basin through Schoonover time. The environment of deposition for the formation can be reconstructed in a general way from the evidences of the various rock types.

DEPTH: The scarcity of fossils other than radiolarians is evidence against deposition in very shallow water. Although Paleozoic radiolarian cherts may have formed at depths shallower than at recent sites of radiolarian-ooze accumulation, the lack of benthonic fossils in the cherts favors a relatively deep-water origin.

The poor sorting, graded bedding, and particle angularity of the arenites and conglomerates support the thesis of deposition by turbidity currents. The preservation of graded bedding is considered evidence of deposition below wave base. The mechanism of sedimentation visualized for the pebbly mudstones requires a shallow-water shelf origin, a subaqueous slope, and a relatively deep site of accumulation. Slide deposits and abundant turbidites suggest relative proximity of land (Fig. 10).

The dark limestones and siltites of the Ott Creek and Bailey Creek members lack recognizable fossils other than worm burrows and trails. Small-scale cross-laminae and contorted laminae may be attributed to the action of the depositing current. These features are considered compatible with deposition in relatively deep water. However, calcium carbonate suggests lack of solution and therefore deposition at less than the "compensation level" for the substance—about 15,000 feet in modern oceans. Limestone lenses in the Dorsey Creek Member contain brachiopods and other shallow-water fossils, which may have been introduced by turbidity currents, or may represent shallower conditions during deposition of this member.

RATES OF SEDIMENTATION: The time required for deposition of the Schoonover Formation is not known; absolute rates of sedimentation cannot be determined. By making certain assumptions, one can establish relative rates of sedimentation.

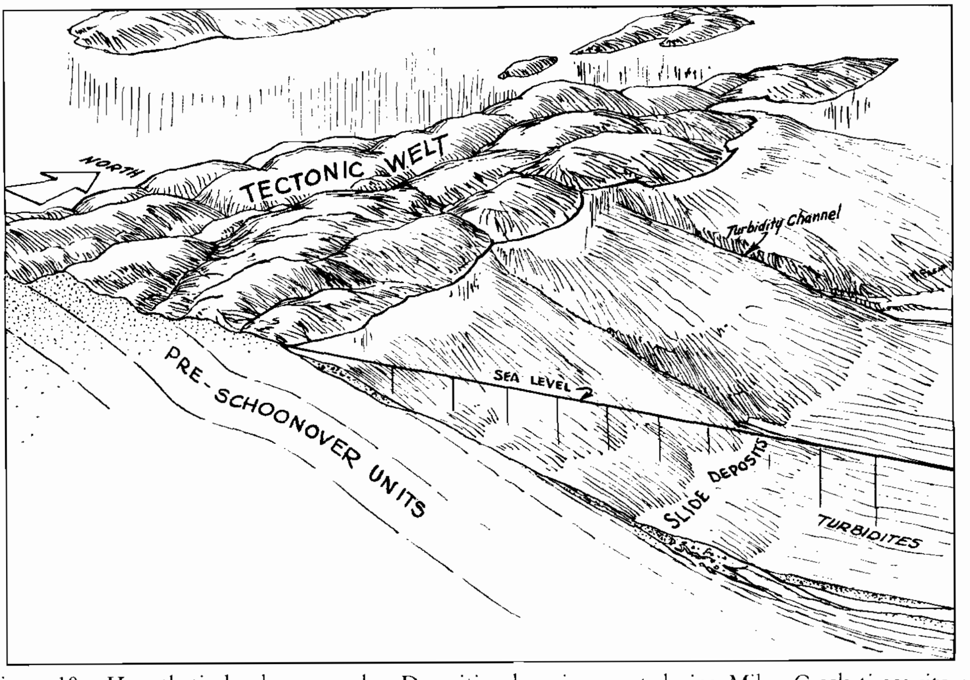


Figure 10. Hypothetical paleogeography. Depositional environment during Mikes Creek time; site of deposition at lower right

As fine clay particles tend to remain suspended for a long time, the rate of deposition of the argillaceous sediments was probably very low. The scarcity of argillaceous material in the bedded cherts indicates that the accumulation of siliceous organisms must have been relatively rapid. Since argillaceous mud probably continued to settle during the settling of the siliceous organisms, similar rates of accumulation would have resulted in rocks with near-equal content of argillaceous and siliceous material. The normal case is a chert with only a few per cent of argillaceous material. Consequently accumulation of these beds should have been much faster than that for argillaceous lutite beds of the same thickness. Lack of radiolarians in the argillaceous lutites and the sharp borders between them and the cherts indicate that the radiolarian "rains" began and ended relatively abruptly.

Most turbidite laminae in a single chert bed contain radiolarians only at the borders (Pl. 2, fig. 4). This indicates a much greater rate of accumulation of turbidity-current-introduced material than of siliceous organic debris.

It seems likely that the fine particles that formed the quartzose siltites settled more gradually than material that formed the coarser turbidites. The latter was carried in by turbidity currents close to the bottom and settled almost instantaneously; the fine silts diffused generally through the sea water upon introduction by less turbid currents and settled more gradually.

The rocks of the Schoonover Formation can be classified according to their rate and mode of deposition as follows:

(1) *Normal pelagic sediments:* Argillaceous lutites formed by slow settling of the finest particles from suspension.

(2) *Episodic or intermittent sediments:* Deposits superimposed upon the normal sediments

and not continuously deposited throughout Schoonover time. Two major types can be distinguished: (A) *bedded cherts*, products of temporally limited flourishings of siliceous organisms, principally radiolarians, probably in the surface waters; (B) *slope-induced sediments*, products of processes more catastrophic, unusual, and abrupt than the other types. Three distinct kinds exist: pebbly mudstone slide deposits (slowest introduction), siltites and limestones, and coarse turbidites (most rapid introduction).

SUMMARY AND CONCLUSIONS

The Schoonover Formation thrust from the northwest, consists of eight named and two unnamed members; it is considered Mississippian on the basis of fossils in the oldest named member, the Dorsey Creek. The thinner beds, severely crumbled and folded, have axial planes inclining toward the west or northwest.

In addition to volcanic rocks, the Schoonover Formation consists of pelagic, relatively continuously deposited sedimentary rocks, argillaceous lutites, and episodic or intermittent sedimentary rocks of two distinct types. These are the bedded cherts and the slope-induced clastic rocks. The bedded cherts are lithified accumulations of siliceous organic debris, principally radiolarians; they are products of intermittent cyclical flourishings of radiolarians in surface waters. The slope-induced deposits are products of less common episodic processes. Three kinds occur—the pebbly mudstones, the siltites and limestones, and the coarse turbidites. The first is a submarine slide deposit; the last two are products of rapidly moving currents of varying densities.

The turbidity currents and slides traveled down a slope located west of the Schoonover basin, indicated by sole markings. The material transported contained unusual amounts of quartz grains. The source of the turbidites and slide deposits seems to have been a tectonic land not far to the west of rocks deposited earlier in the eugeosyncline but containing considerable amounts of orthoquartzite.

The site of deposition was a basin (Fig. 10) having a floor commonly of soft mud, inhospitable to all but burrowing infauna; the sea floor was at variable depth but must have been below wave base throughout most of Schoonover time.

REFERENCES CITED

Bramlette, M. N., 1946, The Monterey Formation of California and the origin of its siliceous rocks: U. S. Geol. Survey Prof. Paper 212, p. 1–57

Campbell, A. S., and Moore, R. C., 1954, Protista 3 (chiefly Radiolaria and Tintinnina), Pt. D of Moore, R. C., Treatise on invertebrate paleontology; Geol. Soc. America and Univ. Kansas Press, 195 p.

Crowell, J. C., 1957, Origin of pebbly mudstones: Geol. Soc. America Bull., v. 68, p. 993–1010

Davis, E. F., 1918, The radiolarian cherts of the Franciscan Group: Univ. California Dept. Geol. Sci. Bull., v. 11, p. 235–432

Dott, R. H., Jr., 1955, Pennsylvanian stratigraphy of Elko and Northern Diamond Range, northeastern Nevada: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 2211–2305

Ingram, R. L., 1954, Terminology for the thickness of stratification and parting units in sedimentary rocks: Geol. Soc. America Bull., v. 65, p. 937–938

Kay, Marshall, 1951, North American geosynclines: Geol. Soc. America Mem. 48, 143 p.

—— 1960, Paleozoic continental margin in central Nevada, western United States: 21st Internat. Geol. Cong. Rept., pt. 12, p. 94–103

Kirchmayer, M., 1959, Beitrage zur Frage des Cherts (= Feuersteins), I. Uber ein Geopetalgefuge im Chert (Flint) von Nevada, U. S. A.: Neues Jahrb. Geologie U. Paläeontologie, v. 5, p. 209–229

Krauskopf, K. B., 1959, The geochemistry of silica in sedimentary environments, p. 4–19 *in* Ireland, H. A., *Editor*, Silica in sediments—a symposium: Soc. Econ. Geologists and Mineralogists Special Pub. No. 7, 185 p.

Kuenen, P. H., 1957, Sole markings of graded graywacke beds: Jour. Geology, v. 65, p. 231–258

Pettijohn, F. J., 1957, Sedimentary rocks, 2d ed.: New York, Harper and Bros., 718 p.

Riedel, W. R., 1959, Siliceous organic remains in pelagic sediments, p. 80–91 *in* Ireland, H. A., *Editor*, Silica in sediments—a symposium: Soc. Econ. Geologists and Mineralogists Special Publ. No. 7, 185 p.

Roberts, R. J., Hotz, P. E., Gilluly, James, and Ferguson, H. G., 1958, Paleozoic rocks of north-central Nevada: Am. Assoc. Petroleum Geologists Bull., v. 42, p. 2813–2857

Steinmann, Gustav, 1925, Gibt es fossile Tiefseeablagerungen von erdgeschichtlicher Bedeutung?: Geol. Rundschau, Bd. 16, p. 435–468

Taliaferro, Nicholas, L., 1943, Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull. v. 27, p. 109–219

TenHaaf, E., 1956, Significance of convolute lamination: Geol. en Mijnb., v. 18, p. 188–194

MANUSCRIPT RECEIVED BY THE SECRETARY OF THE SOCIETY, MARCH 3, 1960