Geology of the Rodeo Creek NE and Welches Canyon Quadrangles, Eureka County, Nevada

GEOLOGICAL SURVEY BULLETIN 1473

Depository
RECEIVED
OCT 13 1980
O.S.U. LIBRARIES

OHIO STATE UNIVERSITY
OCT 14 1980
LIBRARY

QE75
B9
no.1473

Geology of the Rodeo Creek NE and Welches Canyon Quadrangles, Eureka County, Nevada

By JAMES G. EVANS

GEOLOGICAL SURVEY BULLETIN 1473

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1980

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, *Secretary*

GEOLOGICAL SURVEY

H. William Menard, *Director*

Library of Congress Cataloging in Publication Data

Evans, James George, 1938-
Geology of the Rodeo Creek NE and Welches Canyon quadrangles, Eureka County, Nevada.

Bibliography: p.
Supt. of Docs. no.: I 19.3:1473
1. Geology--Nevada--Eureka Co. I. Title.
II. Series: United States. Geological Survey. Bulletin ; 1473.
QE75.B9 no. 1473 [QE138.E8] 557.3s [557.93'32]
80-607142

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington, D. C. 20402

CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY OF THE RODEO CREEK NE AND WELCHES CANYON QUADRANGLES, EUREKA COUNTY, NEVADA

By JAMES G. EVANS

ABSTRACT

The Lynn Window in the Roberts Mountains thrust exposes 2,572 m of strata, predominantly carbonate rock, of Cambrian through Late Devonian age (carbonate, or eastern, assemblage). These strata include Hamburg Dolomite, Pogonip Group, Eureka Quartzite, Hanson Creek Formation, Roberts Mountains Formation, and Popovich Formation. The upper plate of the Roberts Mountains thrust is predominantly shale and chert (siliceous, or western, assemblage) or Ordovician and Silurian age that could represent at least 3,000 m of section. Thrust slices of an Upper Devonian limestone with abundant sand-sized clasts of quartz and chert (transitional assemblage) occur within the upper plate. The total known thickness of this limestone is 915 m.

Several kinds of igneous rock intruded the Paleozoic sedimentary rocks, possibly as early as Paleozoic time and as late as Tertiary. Most of the intrusions are minor. In the Cretaceous, however, granodiorite (121±5 m.y.) and quartz monzonite (106±2 m.y.) intruded Paleozoic rocks, producing large contact metamorphic aureoles. In the early Tertiary, granodiorite (37±0.8 m.y.) and quartz latite (36.6±0.7 m.y.) intruded the siliceous rocks south of the Lynn Window, producing narrow contact metamorphic aureoles.

Rhyodacite flows of Cretaceous or early Tertiary age were deposited on the Paleozoic siliceous rocks south of the Lynn Window. Rhyolitic welded tuff (14.2±3 m.y.) was deposited just west of the Lynn Window, probably contemporaneously with part of the Carlin Formation (sandstone, siltstone) of Regnier on the east side of the window. Deposits of late Tertiary and Quaternary age occur on both flanks of the window.

The Antler orogeny in Late Devonian to Early Mississippian time produced the earliest deformation recorded in the area. The allochthonous siliceous and transitional assemblages were imbricated and brought into the area in the upper plate of the Roberts Mountains thrust. Large and minor folds in the allochthon are predominantly gently plunging to the north-northeast and south-southwest. During this episode, the autochthonous carbonate assemblage was severely deformed by thrusting. In the late Paleozoic or Mesozoic the carbonate assembage was folded into a broad asymmetric anticline plunging 20° N.15° W. The west side of the anticline is overturned and thrust over the siliceous assemblage along the West Lynn thrust. Relatively minor, steep faults postdate the Antler orogeny and faulting occurred throughout the Mesozoic and Tertiary. The largest of these post-Antler faults, the Tuscarora fault, is along the east side of the southern Tuscarora Mountains; it is partly Pliocene in age.

Fossils identified are Ordovician to Late Devonian in age.

INTRODUCTION

LOCATION AND GEOLOGIC INTEREST

In the Rodeo Creek NE and Welches Canyon quadrangles of the southern Tuscarora Mountains (fig. 1), Paleozoic sedimentary rocks rise 610 m above flanking alluviated valleys that contain Tertiary and Quaternary deposits. The structurally lowest Paleozoic rocks, exposed in the Lynn Window of the Roberts Mountains thrust, constitute an autochthonous section of predominantly carbonate rocks of Cambrian to Late Devonian age. This section is significant because of

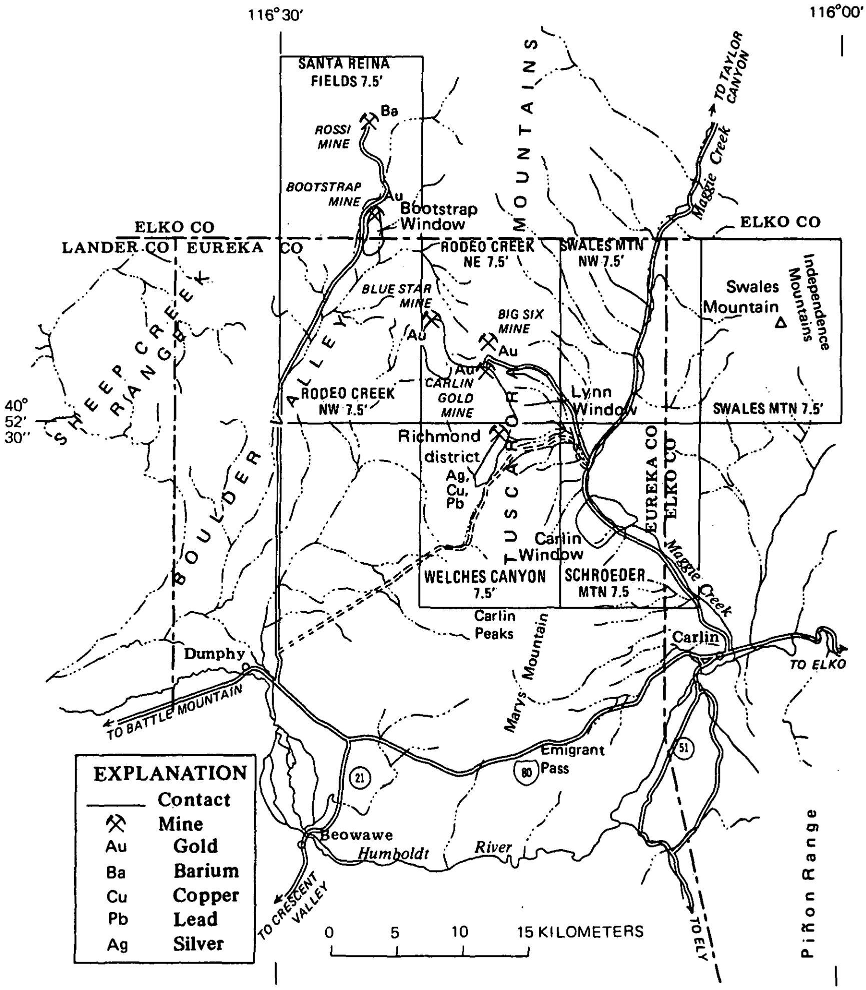


FIGURE 1.—Study area in north-central Nevada showing location of Rodeo Creek NE and Welches Canyon quadrangles and adjacent areas.

its completeness and because it is farther west (116° 15′ W. long) than most Paleozoic autochthonous carbonate sections previously described in northern Nevada. The Paleozoic stratigraphy of the Lynn Window and environs adds to our understanding of lower and middle Paleozoic facies relations in north-central Nevada. Geologic mapping in the Lynn Window area provides additional information concerning the character of regional thrust faulting during Late Devonian and Early Mississippian time.

In the 1960's, exploration and development of the Carlin gold mine, a large low-grade disseminated gold deposit in the northern end of the Lynn Window, attracted much attention to this part of the Tuscarora Mountains and prompted detailed geologic studies of the area.

PREVIOUS WORK

Early reconnaissance reports by King (1878), Emmons (1910), and Vanderberg (1936, 1938) mention the Lynn mining district and nearby areas. Regional studies of Eureka County by Lehner, Tagg, Bell, and Roberts (1961) and Roberts, Montgomery, and Lehner (1967) provide additional details about the geology of the southern Tuscarora Mountains. Roen (1961) was the first to describe the Lynn Window in detail; his work was included in the geologic map of Eureka County (Roberts and others, 1967). Subsequently, geologic maps of the Rodeo Creek NE and Welches Canyon quadrangles covering the Lynn Window (Evans, 1974a, b, scale 1:24,000) and of parts of these two quadrangles (Radtke, 1974, scale 1:12,000) were prepared. Hardie (1966) studied the Carlin gold mine area soon after excavation of the main ore body began. More detailed studies of the chemistry and petrography of the Carlin deposit were undertaken by Hausen (1967) and Hausen and Kerr (1968). The U.S. Geological Survey, in cooperation with the CarliniGolj Mine Co. and the U.S. Bureau of Mines, undertook studies of the ore deposit (Akright and others, 1969; Radtke and Scheiner, 1970; Radtke, 1973, 1980). Operations at the Carlin gold mine were described by McQuiston and Hernlund (1965). An account of the placer deposits of the Lynn district, north of the mine, was prepared by Johnson (1973, p. 26–28).

ACKNOWLEDGMENTS

T. E. Mullens, R. J. Ross, Jr., S. C. Creasey, C. T. Wrucke, T. G. Theodore, R. R. Coats, and A. S. Radtke visited the author in the field and shared their views on the geology of the area. Subsequent informative discussions with E. H. McKee and Rudy Kopf helped in evaluation of the stratigraphy of the Lynn Window. The cooperation of personnel of the Carlin Gold Mine Co., a subsidiary of Newmont

Mining Corp., is gratefully acknowledged, especially the many courtesies offered by Mel Essington, former staff geologist.

Rapid-rock analyses of 23 samples of igneous rocks were done by P. L. D. Elmore, Hezakiah Smith, Gillison Chloe, James Kelsey, and J. L. Glenn; semiquantitative six-step spectrographic analyses for 30 elements were done by Chris Heropoulos. Gold was analyzed by atomic absorption methods by R. N. Babcock, J. G. Friskin, K. E. Kulp, R. M. O'leary, Z. L. Stephenson, and A. A. Wells, Denver; mercury by detector by S. M. Erickson, J. Fowlkes, and D. G. Murrey.

GENERAL STRATIGRAPHY OF PALEOZOIC ROCKS

Two widely different lower through middle Paleozoic rock assemblages, the carbonate (or eastern) assemblage and the siliceous (or western) assemblage, have been described from north-central Nevada by numerous geologists (see discussion in Roberts and others, 1958; Roberts, 1964, p. 7–11). These two sedimentary rock assemblages, interpreted to have been deposited in the eastern and western parts of the Cordilleran geosyncline, were separated by a zone in which rocks of intermediate lithologic character, the transitional assemblage, were deposited. During Late Devonian and Early Mississippian time, these time-equivalent assemblages of widely different lithology were tectonically juxtaposed by regional movements along the Roberts Mountains thrust (Kirk, 1933, p. 31; Merriam and Anderson, 1942; Gilluly and Gates, 1965; Gilluly and Masursky, 1965; Smith and Ketner, 1968). This thrusting, which is related to the Antler orogeny, brought the siliceous and transitional assemblages into northeast Nevada from the west.

The stratigraphy of the Paleozoic rocks of the Rodeo Creek NE and Welches Canyon quadrangles is summarized as figure 2. The carbonate assemblage in the Lynn Window includes 2,572 m of strata of Cambrian through Late Devonian age that occur below the Roberts Mountains thrust. Included in this section are at least 246 m of Hamburg Dolomite, 598 m of Pogonip Group, at least 508 m of Eureka Quartzite, 325 m of Hanson Creek Formation, 473 m of Roberts Mountains Formation, and at least 424 m of Popvich Formation. The siliceous assemblage, mostly shale and chert, occurs in thrust slices, some containing several thousand meters of strata, and includes the Vinini Formation. One sequence at least 2,470 m thick occurs 1.6 km north of the Lynn Window. Another at least 1,403 m thick is directly west of the window. Strata assigned to the transitional assemblage occur with the siliceous assemblage in the Roberts Mountains allochthon south of the Lynn Window. The transitional assemblage is at least 915 m thick and is mostly limestone with chert clasts and

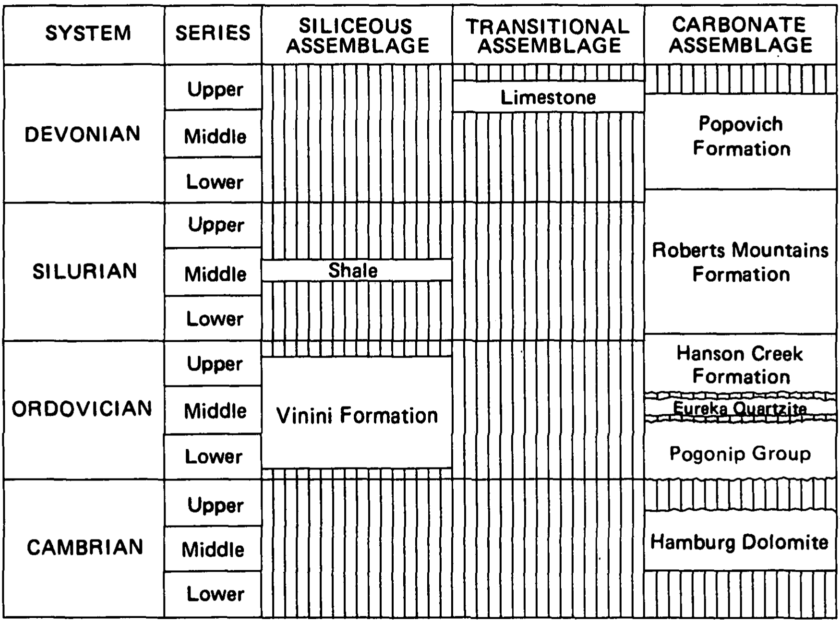


FIGURE 2.—Stratigraphic column showing Paleozoic rocks of Lynn Window, Rodeo Creek NE and Welches Canyon quadrangles. Vertical lines indicate hiatus. Irregular horizontal lines indicate unconformity.

beds of chert and shale. Locations of fossil collections made in this and other studies of the area are shown in plates 1 and 2. Stratigraphic thicknesses were measured with a Jacob staff and an Abney level. Thicknesses of poorly exposed sections were estimated by using map relations.

DESCRIPTIONS OF THE PALEOZOIC ROCKS

CARBONATE (EASTERN) ASSEMBLAGE

HAMBURG DOLOMITE

The Hamburg Dolomite was first described by Hague (1883, p. 255; 1892, p. 39–41), who called it the Hamburg Limestone for the Hamburg mine in the Eureka mining district, 157 km south of the Lynn Window. The formation was later renamed the Hamburg Dolomite (Wheeler and Lemmon, 1939, p. 25). The Hamburg Dolomite occurs on the east flank of Richmond Mountain (pls. 1, 2), where the rocks typically form slopes underlain by gray regolith but crop out boldly on steep slopes and in canyon bottoms.

Hamburg Dolomite is characteristically blue gray and thin to thick bedded (beds 2.5–60 cm); locally it is massive. In places, white dolomite seams as thick as 2.5 cm occur at intervals of 2.5–7.5 cm parallel to bedding. A few quartz siltstone beds less than 2.5 cm thick are interbedded with the dolomite. The base of the formation is not exposed; the top is unconformable with the overlying Pogonip Group (NW¼ sec. 36, T. 35 N., R. 50 E.) with a relief of as much as 15.3 m.

In most places, the rock is more than 90 percent dolomite in crystals 0.01–0.5 mm across but contains minor amounts of calcite, mostly in veins, and rounded to subangular quartz clasts as much as 2 mm across. Much of the formation has been metamorphosed to garnet, pyroxene, hornblende, richterite, biotite, serpentine veins, termolite, and talc. Near the small quartz monzonite stock in the Richmond district, the metamorphism and recrystallization of the dolomite has obliterated the bedding and the formation is altered to a calc-silicate hornfels. In places, the dolomite contains white quartz veins as much as 1 m across. Yellow-brown pyritiferous gossan occurs locally.

Hamburg Dolomite in the Lynn Window is at least 244 m thick as estimated using map relations.

No fossils were found in the Hamburg Dolomite at the Lynn Window. The correlation of these rocks with the type Hamburg Dolomite of the Eureka district is based on their lithologic resemblance to the type Hamburg Dolomite and to their stratigraphic position below rocks identified as Pogonip Group. In the Eureka district, Hamburg Dolomite is dated as Middle and Late Cambrian on the basis of trilobite faunas (Nolan and others, 1956, p. 18).

POGONIP GROUP

NAME AND LOCATION

The name Pogonip was originally used by King (1878, p. 188) in the 40th Parallel Survey. Nolan, Merriam, and Williams (1956) elevated the Pogonip to group status in the Eureka district, Nevada, where the group lies between the Cambrian Windfall Formation (absent in the Lynn Window) and the Middle Ordovician Eureka Quartzite. The Pogonip Group near Eureka is subdivided into three formations, in ascending order, the Goodwin Limestone, the Ninemile Formation, and the Antelope Valley Limestone (Nolan and others, 1956, p. 25–29). Formation-rank units within the Pogonip Group have not been identified in the Lynn Window because poor exposures, complex faulting, and metamorphism make detailed stratigraphic analysis difficult. The history of the name Pogonip is discussed in further detail by Nolan and others (1956, p. 23–25) and by Merriam (1963, p. 17–19).

The Pogonip Group occurs in the south-central part of the Lynn Window on the southeast flank of Richmond Mountain, where the rocks form slopes covered by a thick gray soil containing only scattered limestone clasts. Some rocks crop out on steep slopes and in canyon bottoms.

STRATIGRAPHY AND LITHOLOGY

The informal units of the Pogonip Group are best observed in section 1 (fig. 3), located in NW¼ sec. 36, SE¼ sec. 25, and SE¼ sec. 26, T. 25 N., R. 50 E. (both quadrangles), on the west side of a steep fault striking north-northeast. Here unit A, the lowest member of the Pogonip Group, overlies the Hamburg Dolomite. The contact is interpreted to be unconformable, with about 15 m of relief on the unconformity. Unit A is characterized by blue-gray thin-bedded (beds 2.5–15.2 cm) fine-grained limestone that contains variable amounts of terrigenous silt. This unit (A) is overlain by cherty limestone assigned to unit B. The carbonate of unit B is fine grained, pale blue gray, and laminated to thin bedded (beds as much as 10 cm). Tabular lenses of gray chert 2.5 to 15.2 cm thick are interbedded with the limestone. Overlying unit B is a thin- to thick-bedded (beds 5–107 cm) fine-grained limestone designated unit C. The limestone beds have ribbony shale partings that weather to pale brown. Some of the thick beds contain sand-sized quartz and carbonate grains and sparse poorly preserved gastropods.

An incomplete and thinner stratigraphic section through the Pogonip Group occurs just east of section 1, on the east side of the steep north-northwest-striking fault, shown as section 2 on figure 3. Here the stratigraphic sequence consists largely of pale-blue-gray fine-grained limestone that is lithologically indistinguishable from unit A. A 3-m-thick bed of massive white chert with pale-orange calcite nodules occurs 355 m above the base in the thin-bedded limestone. Thin-bedded limestone occurs above the chert bed. Overlying this upper thin-bedded limestone is unit D, a gray thin-bedded (2.5–12.5 cm) fine-grained dolomite containing angular to rounded sand-sized detrital quartz grains (5 percent or less) and poorly preserved cephalopods, corals, and brachiopods.

Unit A can be identified in sections 1 and 2. Unit B in section 1 may be lithologically equivalent to the massive chert bed and adjacent thin-bedded limestones of section 2. Unit D of section 2 is stratigraphically equivalent to, but lithologically different from, limestone beds in the lower part of unit C. Thin-bedded dolomite identical to unit D occurs elsewhere in the Lynn Window directly below the Eureka Quartzite, but its stratigraphic significance is not clear; it may be a product of diagenesis below the quartzite after the section faulted.

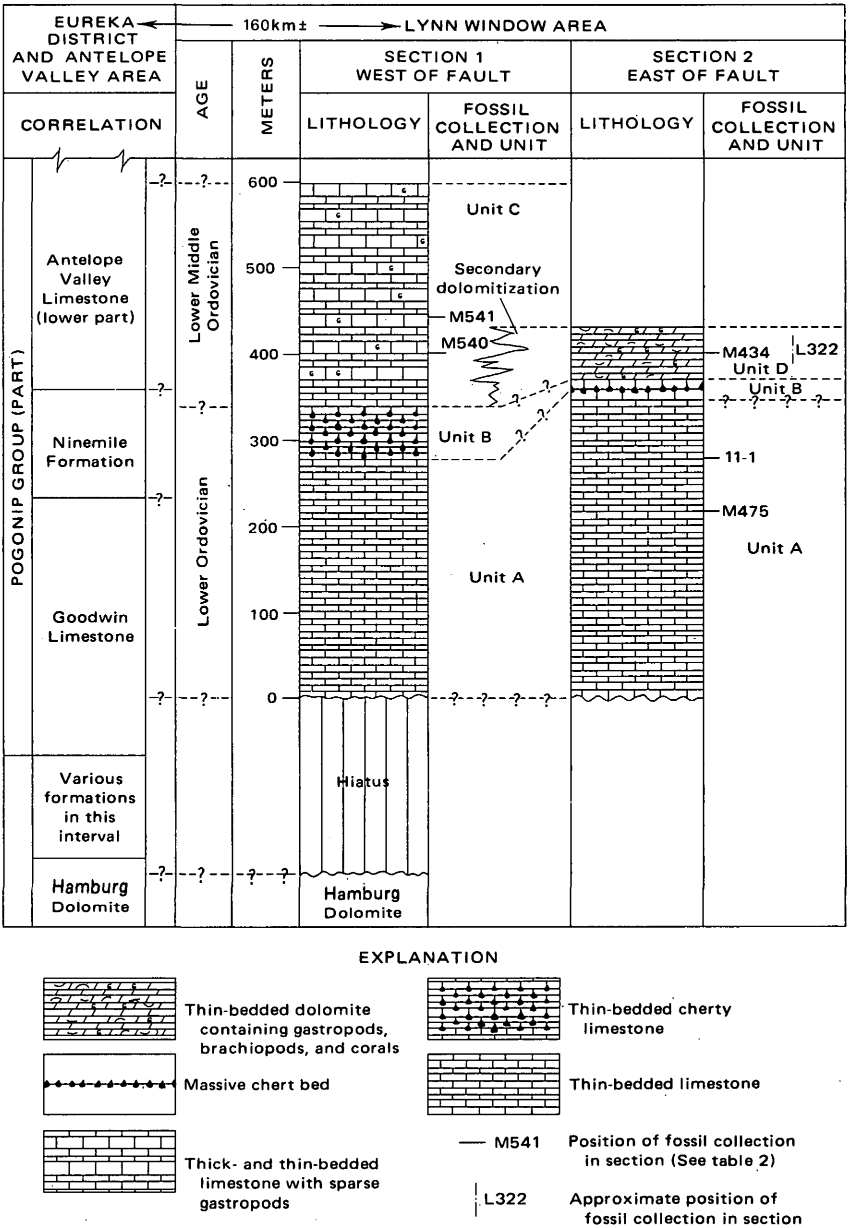


FIGURE 3.—Diagrammatic stratigraphic sections of Pogonip Group showing positions of fossil collections in section. Sections 1 and 2 in the Lynn Window area are located west and east of a steep fault striking north-northwest (NW¼ sec. 36, SE¼ sec. 25, and SE¼ sec. 26, T. 35 N., R. 50 E., Rodeo Creek NE quadrangle).

Thicknesses of the four units were estimated by using map relations. In section 1, unit A is 275 m thick; unit B, 61 m; unit C, 262 m. In section 2 unit A is 343 m thick; unit B, 23 m; unit D, 61 m. Section 1, the thicker section consisting of units A, B, and C, is 598 m thick; section 2, of units A, B, and D, is 427 m thick.

The top of the Pogonip Group in the Lynn Window is truncated by the Richmond Mountain thrust for most of its extent. In SE¼SE¼ sec. 35, T. 35 N., R. 50 E., dolomite assigned to unit D of the Pogonip Group is interpreted to be overlain by Eureka Quartzite with a slight angular unconformity.

The Pogonip Group, like the Hamburg Dolomite, has been partly metamorphosed. The intensity of bleaching, recrystallization, and neomineralization generally decreases away from the quartz monzonite plug in the Richmond district. Pyroxene, grossularite-rich garnet (identified from X-ray diffraction patterns), plagioclase, biotite, hornblende, muscovite, talc, idocrase, chlorite, serpentine, tremolite, scapolite, and wolframite were identified in rocks of the Pogonip Group.

AGE AND CORRELATION

The fossils found in the Pogonip Group in the Lynn Window, mainly conodonts and brachiopods, are shown on the geologic map (pl. 1) and listed in table 1. The approximate positions of the fossil collections in the stratigraphic sections are shown on figure 3.

The conodont assemblage M475 from beds in section 2 equivalent to the upper part of unit A is Early Ordovician in age (J. W. Huddle, written commun., 1969). Conodont assemblages from collections M540 and M541 in unit C indicate an early Middle Ordovician age (J. W. Huddle, written commun., 1969). According to Huddle, M540 could be equivalent in age to the lower part of the Angelope Valley Limestone, and M541 contains a faunule that occurs in the lower part of the Antelope Valley Limestone at Dobbin Summit, Monitor Range, and at Antelope Peak about 210 km south of the Lynn Window.

Brachiopods of the genus *Orthambonites* were identified in collections L322 and M434 (R. J. Ross, Jr., written commun., 1969). Both localities are in dolomite just below the Richmond Mountain thrust. Locality M434 is near the middle of unit D. According to Ross, the brachiopod species *Orthambonites* cf. *O. marshalli* Wilson in L322 is common in the basal part of the Antelope Valley Limestone.

Collection L322 also contained a lenticular gastropod about which E. L. Yochelson (written commun., 1969) stated "No age significance

TABLE 1.—*Fossils from Pogonip Group*

[Conodonts identified by J. W. Huddle (written commun., 1970), brachiopods by R. J. Ross, Jr. (written commun., 1969). Fossils collected by J. G. Evans]

USGS fossil colln. No.	6902CO	6966CO	6965CO	D2178CO	
Field colln. No.	M475	M540	M541	L322	M434
Species					
Conodonts					
Acodus deltatus Lindström	8	------	------	------	------
A. n. sp. d	------	------	------	3	------
A. 2 spp	------	------	2	------	------
Acontiodus staufferi Furnish	------	5	------	------	------
A. n. sp. (Ethington and Cark, 1965)	16	------	------	------	------
A. sp.	------	3	------	------	------
Distacodus stola Lindström	8	------	------	------	------
D. cf. *D. stola* Lindström	------	------	63	------	------
Drepanodus proetus Lindström	------	------	7	------	------
D. suberectus (Branson and Mehl)	------	8	44	------	------
D. n. sp	------	------	11	------	------
D. sp	21	------	14	------	------
D. ?sp	------	1	------	------	------
Oistodus lanceolatus Pander	------	------	3	------	------
O. 4 spp	13	------	------	------	------
O. 2 spp	------	------	45	------	------
O. sp	------	1	------	------	------
Scandodus sp	------	1	4	------	------
Scolopodus rex rex Lindström	14	------	------	------	------
S. rex paltodiformis Lindström	6	------	------	------	------
S. triplicatus Ethington and Clark	------	------	6	------	------
S. cf. *S. rex* Lindström	------	4	------	------	------
S. sp	------	------	4	------	------
Brachiopods					
Orthambonites cf. *O. marshalli*	------	------	------	×	------
O. sp	------	------	------	------	×

Fossil locations:
M475, NW¼ sec. 25, T. 35 N., R. 50 E.
M540, M541, SE¼ sec. 26, T. 35 N., R. 50 E.
L322, SW¼ sec. 35, T. 35 N., R. 50 E.
M434, E½ sec. 26, T. 35 N., R. 50 E.

can be derived from this form. By the same token, the form is one that occurs in the Pogonip."

Roen (1961, p. 38, 39) collected brachiopods from three localities in the Pogonip Group of the Lynn Window: 4–4; 5–1 near L322; and 11–1. At 5–1, Roen identified *Orthidiella*, a genus characteristic of the Antelope Valley Limestone. Locality 11–1 is located high in section 2 in strata equivalent to the boundary between units A and B of section 1. There Roen collected the Early Ordovician brachiopod *Archeorthis costellata* Ulrich and Cooper (identified by G. A. Cooper). Ross (1970, pl. 21) found this brachiopod 19 m above the base of the Ninemile Formation in a complete section of the Pogonip Group in Antelope Valley. The same brachiopod was identified at locality 4–4, which is in a fault sliver.

Assignment of these rocks to the Pogonip Group appears reasonable on general lithologic and paleontological grounds. Most of unit A is stratigraphically equivalent to the Goodwin Limestone (fig. 3). Unit B and possibly parts of upper unit A are equivalent to the Ninemile Formation. Unit C is lithologically similar to the Antelope

Valley Limestone and is time-correlative with the lower part of that formation as it occurs in the Eureka-Antelope Valley area (fig. 3). The dolomite beds of unit D in section 2 are equivalent to part of the Antelope Valley Limestone.

EUREKA QUARTZITE

NAME AND LOCATION

The name Eureka Quartzite was first applied by Hague to a prominent white quartzite in the vicinity of Eureka, Nev. (Hague, 1883, p. 262; 1892, p. 54–57). About 50 years later, Kirk (1933, p. 34) proposed that the type locality be at Lone Mountain, 24 km northwest of Eureka; this proposal has been generally accepted (Nolan and others, 1956, p. 29).

Eureka Quartzite caps part of Richmond Mountain and forms a low ridge along the southeast flank of the mountain. Blocks of the quartzite occur along Sheep Creek Canyon northwest of Richmond Mountain. In most places the quartzite forms bold rusty-brown outcrops except near faults where it has been brecciated and is uncemented.

The Eureka Quartzite on Richmond Mountain lies mostly in the upper plate of the Richmond Mountain thrust. The thrust truncates the Pogonip Group and younger carbonate rocks described below (Roberts Mountains Formation and Popovich Formation).

STRATIGRAPHY AND LITHOLOGY

The Eureka Quartzite in SE¼SE¼ sec. 35, T. 35 N., R. 50 E., rests on the Pogonip Group with a slight angular unconformity.

Three main lithologic associations occur in the Eureka Quartzite in the Lynn Window: (1) white thick-bedded to massive quartzite; (2) interbedded white, gray, and black quartzite that is thin to thick bedded and locally friable; (3) gray fine-grained dolomite that contains detrital quartz sand grains.

The most complete section of Eureka Quartzite, described below, was measured across summit 7041 on Richmond Mountain, where a thickness of 507.8 m was determined. The section is divided into a lower and an upper part by an interval of 53 m that is not exposed. Interbedded white, gray, and black quartzites make up the lowest 134.9 m of the measured section, and this lithologic association occurs in the upper part for 158.5 m above the covered interval. White quartzite predominates in the 45 m below the covered interval and in the uppermost 115.9 m of the measured section.

Hanson Creek Formation.
Covered. Presence indicated by chips of dolomite and of dark-gray and black chert.
Contact not exposed.
Eureka Quartzite:

	Meters
Covered. Thick layer of white quartzite chips and slabs	3
Quartzite, white, pale-blue and gray-mottled	.9
Quartzite, white; beds 0.3–0.9 m thick, vermiform structures on bedding, mostly straight, 10 cm long, composed of silty quartzite, easily weathered	21.96–22
Quartzite, white; beds 5 cm–0.9 m thick; crossbedding; friable beds	90
Quartzite, brown; silty; beds to 2.5 cm thick	.9
Quartzite, light-gray; beds 2.5–15.2 cm thick	12
Quartzite, interbedded white and gray; beds 5 cm–61 cm thick; some friable horizons	24
Quartzite, gray; beds 5–15.2 cm thick; intraformational breccia and thin, anastomosing sandstone dikes	6
Quartzite, interbedded gray and white; beds 2.5–5 cm thick; friable	4.6
Quartzite, white; beds 5 cm–0.9 m thick	13
Quartzite, dark-gray	1.5
Quartzite, dark-gray to black; 2.5 cm–0.9 m thick; some friable beds	6
Quartzite, light-gray mottled; beds 0.3–0.9 m thick	7
Quartzite, interbedded gray and white; beds 2.5–61 cm thick; stylolites outlined in red hematite	13
Quartzite, gray to black; beds 2.5–61 cm thick; some friable beds	13
Quartzite, white; beds 0.6–1.2 m thick	7
Covered	30
Quartzite, gray; beds 2.5–61 cm thick; some friable beds	15
Covered	53
Quartzite, white; beds 0.6–1.2 m thick	45
Quartzite, light-brown; mottled; beds 0.3–0.9 m thick	5.2
Quartzite, white; beds 5–91 cm thick	15
Quartzite, interbedded white, gray, and black; beds 2.5–1.5 m thick; some friable beds; crossbedding in gray quartzite; flame structures	24
Quartzite, gray; beds 0.3–0.9 m thick; some friable beds	5
Quartzite, white; beds 46–1.2 m thick	7
Quartzite, gray; mottled	4
Quartzite, interbedded white and pale-gray; beds 2.5–76 cm thick	6
Covered	43
Quartzite, pale-gray mottled; beds less than 25 mm thick in zones 0.9–1.2 m thick alternating with beds as much as 1.5 m thick; intraformational breccia and thin sandstone dikes in thick beds at base of interval	15
Covered	7
Total thickness	507.8

Richmond thrust.
Pogonip Group.

The thickest known section of the Eureka Quartzite is at summit 7041 on Richmond Mountain, where it measured 507.8 m, nearly the thickness measured by Ketner (1968, p. B171) in the same area. The possibility exists that the section of Richmond Mountain may be exceptionally thick owing to repetition by faulting. The lower 180 m is mixed gray and white quartzite overlain by a white quartzite zone. A prominent topographic bench marks the upper part of the white quartzite. At about the 180-m level in the section, the topographic slope steepens abruptly, and the largest unexposed interval along the line of section extends upward. Above the covered interval, a white and gray quartzite zone is succeeded upward by white quartzite. The 174.4 m of quartzite above the covered interval could be a partial repetition of the lower 180-m section. If the first 180 m of section is a fault sliver, and if a fault is at the top of the bench, the minimum thickness of unrepeated Eureka Quartzite is 327.8 m, approximately equal to a section of Eureka Quartzite measured in the northern Independence Mountains (Ketner, 1968) about 64 km northwest of Richmond Mountain.

Quartz sandstone in the Eureka Quartzite is texturally and mineralogically very mature. The quartz grains are very well sorted and fine grained; the largest grain diameter is about 0.2 mm. In some samples, the highly spherical quartz clasts are cemented with quartz. In others, the rounded outlines are not visible, and the quartz grains with well-developed strain shadows form a polyhedral mosaic with no interstitial quartz. Accessory minerals include biotite, chlorite, clay, epidote, garnet, hematite, and tourmaline.

Lenses of dolomite were found at three localities in the quartzite: (1) 275 m west and 214 m north of SE. cor. sec. 34, T. 35 N., R. 50 E.; (2) 653 m south and 85 m west of NE. cor. sec. 26, same township; (3) 622 m west and 897 m south of NE. cor. sec. 25, same township. The thickest dolomite lens is at the first locality about 55 m below the top of the formation; it measures 37 m in greatest thickness and is fossiliferous. The other two lenses are at least 3 m thick. Their precise locations in the section are not known, but they probably occur in the upper part of the formation.

AGE AND CORRELATION

Megafossil collection L213 (collected by J. G. Evans) from the thick sandy dolomite in SE¼ sec. 34, T. 35 N., R. 50 E., was examined by C. W. Merriam (written commun., 1968); it includes:

Halysites (probably *Catenipora*) sp.

Ramose branching favositid coral, possibly *Palaeofavosites* but with thick wall-like *Thamnopora*
Streptelasma n. sp. cf. *S. Corniculum* Hall
Bushy, phaceloid, colonial rugose corals, probably the genus *Palaeophyllum*
Abundant fine crinoidal and possibly cystid debris
Bryozoan debris
Brachiopod and molluscan shell fragments

According to Merriam, this poorly preserved coral fauna is Ordovician in age, probably Late Ordovician.

Conodonts from a nearby locality, D2183CO (collected by R. J. Ross, Jr.), in the same dolomite lens from which collection L213 was taken were identified by L. A. Wilson (written commun., 1969). Wilson found two species of *Belodina*, which indicate an Early to Middle Ordovician age.

Discrepancies exist between the age determinations of the fossil collections and the expected age of the Eureka Quartzite on the basis of its stratigraphic position between the Pogonip Group below and the Hanson Creek Formation above. The coral assemblage identified by Merriam as Late Ordovician in age is similar to faunas in the Ely Springs Dolomite and the Hanson Creek Formation. This suggests that the Eureka quartzite in the Lynn Window is correlative with these Upper Ordovician formations. The conodonts identified by Wilson, on the other hand, appear to be too old in light of the age of the Eureka Quartzite elsewhere in Nevada (late Middle Ordovician). Possibly the poor preservation of the corals and conodonts has led to errors in age determinations based on the fossils. The fact that the fossils are of Ordovician age eliminates the possibility that the quartzite can be confused with either the Prospect Mountain Quartzite (Precambrian Z and Cambrian) or the quartzite in the Oxyoke Canyon Sandstone Member of the Nevada Formation (Devonian). The stratigraphic position of the quartzite below beds assignable to the Hanson Creek Formation and above the Pogonip Group together with the general similarity with the distinctive Eureka Quartzite, indicates that the correlation of this quartzite with the Middle Ordovician Eureka Quartzite of central and southern Nevada is correct.

HANSON CREEK FORMATION

NAME AND LOCATION

In the southern Tuscarora Mountains, the strata between the Eureka Quartzite and the Roberts Mountains Formation, largely dolomite, have been assigned to the Hanson Creek Formation by Roen (1961) and Roberts and others (1967). The name Hanson Creek Formation was proposed by Merriam (1940, p. 10–11) for strata containing both dolomite and limestone (although at the type section along the middle fork of Pete Hanson Creek in the Roberts Mountains abut 110 km south of the Lynn Window, it is predominantly dolomite). The resistant dolomite unit above the Eureka Quartzite in the southern Tuscarora Mountains is actually more similar to the Ely Springs Dolomite in east-central Nevada (Westgate and Knopf, 1932). Nevertheless, despite the lithologic differences between the type Hanson Creek Formation and the equivalent strata in the Lynn Window, the name Hanson Creek Formation is retained here for these reasons: (1) at some localities, the type section for example, the Hanson Creek Formation is predominantly dolomite (Dunham, 1977); (2) the name Hanson Creek is used for equivalent strata in the region north and south of the Lynn Window; and (3) substitution of the name Ely Springs Dolomite at this point in time would be confusing in view of the past use of the name Hanson Creek Formation for these rocks in the Lynn Window.

The Hanson Creek Formation underlies the high ridges of north-central Richmond Mountain and the low hills south of the quartz monzonite plug in the Richmond district. An isolated block of the formation occurs west of Sheep Creek Canyon, about 1.6 km west of the Carlin gold mine.

STRATIGRAPHY AND LITHOLOGY

The basal contact of the Hanson Creek Formation with the Eureka Quartzite is interpreted to be a disconformity. Above the slightly irregular contact surface, the Hanson Creek Formation consists principally of dark-gray to black fine-grained thin- to thick-bedded massive dolomite (fig. 4) that in places contains thin beds of black chert 1.25–7.5 cm thick. Fossil debris is abundant locally and includes crinoid stems and plates a few millimeters to one-half centimeter across, fragments of horn and chain corals, and brachiopods to 5 cm across. Many of the fossils are partly replaced by silica. Thick-bedded to massive blue-gray dolomitic limestone lenses 6.1–21.4 m thick occur near the top of the formation. The largest is 320 m long. The limestone contains poorly preseved trilobites and brachiopods. The formation is capped in most places by a light-gray thick-bedded to massive sandy dolomite with quartz sand 15.3–36.6 m thick. In places this dolomite also contains intraformational breccia consisting of angular fragments of light- and dark-gray dolomite, dolomitic limestone, and chert to 10 cm long.

FIGURE 4.—Typical exposure of dark-gray thick-bedded Hanson Creek Formation. Beds dip northwest (left). White markings on rock are lichen colonies. White ruler is 15 cm long. SE¼ sec. 34, T. 35 N., R. 50 E., Welches Canyon quadrangle.

The following section of Hanson Creek Formation was measured in the SE¼ sec. 34, T. 35 N., R. 50 E:

Roberts Mountains Formation.
Dark-gray massive dolomite.
Fault.

Hanson Creek Formation (top):	*Meters*
Dolomite, light-gray; beds 1.5–6.1 m thick; locally massive; rounded quartz sand grains common throughout; lower 16.7 m contains angular fragments to 10 cm long of dark-gray dolomite, black chert, and dolomitic limestone similar to the kind described below; scattered infrequent chert nodules; quartz veins are common	36
Limestone, dolomitic, blue-gray; beds 15.2–25.4 cm thick; weathers tan; contains numerous fossil fragments a few millimeters long and poorly preserved trilobites and brachiopods	21
Covered. Probably same lithology as below	15.3
Dolomite, gray to black; beds 0.6–1.5 mthick; locally massive; white bioclastic fragments to one-half cm across consist principally of crinoid plates and stem sections; contains numerous white quartz veins and a few barite veins up to several millimeters thick; silica boxwork is developed locally	11.4
Dolomite, gray to black; beds 0.3–0.9 m thick; generally massive; beds defined chiefly by zones of irregularly shaped chert nodules and lenses 2.5–7.5 cm thick	16
Dolomite, dark-gray to black; generally massive; numerous white angular bioclastic fragments up to a few millimeters across; other fragments to about 5 cm across include chain corals, horn corals, and brachiopods, partly silicified; white quartz veins several millimeters wide are common locally	11
Covered	4.6
Total thickness	325

Contact. Obscured by float.
Eureka Quartzite.
White massive to thick-bedded quartzite.

Most of the Hanson Creek Formation is composed of nearly pure dolomite with grains ranging from 0.01 to 0.1 mm across. Quartz, a minor constituent, occurs as grains less than 0.01 mm across in chert nodules and beds and as rounded or angular detrital grains to 0.4 mm across in dolomite. The chert beds contain a greater proportion of detrital quartz grains than the black dolomite. The Hanson Creek Formation in the southern Lynn Window (secs. 2, 3, and 10, T. 34 N., R. 50 E.) is blue gray and coarser grained (dolomite grains greater than 0.1 mm) than elsewhere in the Lynn Window and contains pyroxene and serpentine. Intensity of neomineralization and recrystallization in the Hanson Creek Formation generally decreases away from the quartz monzonite plug in the Richmond district.

The measured thickness of the Hanson Creek Formaton is 325 m. The section here is almost twice as thick as the Hanson Creek Formation at the type section (Merriam, 1940, p. 11) and more than three times as thick as sections of formation in the vicinity of the Eureka district (Nolan and others, 1956, p. 33).

AGE AND CORRELATION

Fossils from the Hanson Creek Formaton are mainly conodonts, brachiopods, and corals, as listed in table 2. The position of the fossil collections in the section is shown in figure 5. The conodont fauna of collection L95 from a locality 55 m above the base indicates a probable Trentonian (late Middle Ordovician) age. Collection M418 from 105 m below the top of the formation contains corals, brachiopods, and conodonts, probably late Middle or Late Ordovician. The collection D2184CO, brachiopods and conodonts, is probably high in the Hanson Creek Formation, but its exact stratigraphic position is not known. These fossils are probably Late Ordovician (R. J. Ross, Jr., written commun., 1969).

The brachiopod *Chaulistomella*? and the trilobite *Anataphrus* or *Bumastoides* sp. from locality L408 are thought to be time-correlative with the middle part of the Hanson Creek Formation at localities farther south (Roberts Mountains area, Monitor Ridge at Copenhagen Canyon) (R. J. Ross, Jr., written commun., 1969). Yet these fossils were found in dolomitic limestone near the top of the measured section of Hanson Creek Formation.

At locality TM–F–21–70 at the top of the Hanson Creek Formation, conodonts of Early Silurian age were found (Mullens and Poole, 1972). Several pelmatazoan columnals were found at locality L220 close to the upper contact of the Hanson Creek Formation, southern Lynn Window (A. R. Palmer, written commun., 1969). The columnals have star-shaped axial canals, typical crinoid features (Moore and Jeffords, 1968). According to Palmer, the columnals in Moore and Jeffords' work most like the ones at L220 belong to Silurian species. Accordingly, the fossils point to a range in age for the Hanson Creek Formation in the Lynn Window from late Middle Ordovician to Early Silurian.

ROBERTS MOUNTAINS FORMATION

NAME AND LOCATION

The Roberts Mountains Formation was defined by Merriam (1940, p. 11) to include the beds between the Hanson Creek Formation and the Lone Mountain Dolomite. The type section of Roberts Mountains

TABLE 2.—*Fossils from Hanson Creek Formation*

[Conodonts identified by L. A. Wilson and J. W. Huddle, brachiopods and trilobite by R. J. Ross, Jr., corals by C. W. Merriam. L95, L408, M418 collected by J. G. Evans, D2184C0 by R. J. Ross, Jr., TM-F-21-70 by T. E. Mullens]

USGS fossil colln. No. / Field colln. No. / Species	D2025CO L95	D2241CO L408	D2151CO M418	D2184CO	8823CO TM-F-21-70
Conodonts					
Acontiodus sp	------	------	------	×	------
Belodina compressa (Branson and Mehl)	------	------	×	------	------
B. inclinata (Branson and Mehl)	------	------	×	------	------
B. sp	×	------	------	×	------
Dichognathus sp	×	------	------	------	------
Drepanodus cf. *D. aduncus* Nicoll and Rexroad	------	------	------	------	2
D. homocurvatus Lindström	×	------	------	------	------
D. sp	×	------	×	×	------
Hindeodella sp	------	------	------	------	1
Icriodina irregularis Branson and Branson	------	------	------	------	1
Ligonodina cf. *L. kentuckyensis* Branson and Branson	------	------	------	------	9
Neoprioniodus sp	------	------	------	------	3
Oistrodus inclinatus Branson and Mehl	------	------	×	------	------
Ozarkodina cf. *O. maxima* (Stauffer)	×	------	------	------	------
O. sp	------	------	×	------	2
Paltodus dyscritus Rexroad	------	------	------	------	17
Panderodus feulneri (Glenister)	------	------	×	------	------
P. sp	------	------	×	------	60
Prioniodina sp	------	------	------	------	------
Scolopodus sp	------	------	------	×	------
Synprioniodina sp	------	------	------	------	1
Trichonodella cf. *T. exacta* Ethington	×	------	------	------	------
T. aff. *T. papilo* Nicoll and Rexroad	------	------	------	------	2
T. sp	×	------	------	------	------
Brachiopods					
Chaulistomella?	------	×	------	------	------
Glyptorthis sp	------	------	×	------	------
Lepidocyclus sp (a large tumid shell)	------	------	------	×	------
L. ? sp	------	------	×	------	------
Leptillina sp	------	------	×	------	------
Paucicrura sp	------	------	×	------	------
Plaesiomys? sp	------	------	×	------	------
Rhynchotrema sp	------	------	×	×	------
Thaerodonta sp	------	------	×	------	------
Zygospira cf. *Z. recurvirostrus*	------	------	×	------	------
Corals					
Halysites (*Catenipora*) sp	------	------	×	------	------
Palaeofavosites sp	------	------	×	------	------
Palaeophyllum cf. *P. thomi* (Hall)	------	------	×	------	------
Streptelasma sp (small nonangulate form)	------	------	×	------	------
Trilobite					
Anataphrus or *Bumastoides* sp	------	×	------	------	------

Fossil locations; age:
- L95, E½ sec. 34, T. 35 N., R. 50 E.; Ordovician, probably Trentonian (Wilson)
- L408, SE¼, same section; low in Hanson Creek Formation or high in Copenhagen Formation
- M418, SW¼ sec. 23, same township; late Middle or Late Ordovician (Wilson)
- D2184CO, SW¼ sec. 15, same township; probably Late Ordovician (Wilson)
- TM-F-21-70, NE¼ sec. 23, same township; Early Silurian but probably not earliest Silurian (J. W. Huddle, written commun., 1971)

Formation lies between the middle and south forks of upper Pete Hanson Creek on the west side of the Roberts Mountains. In the Tuscarora Mountains, the Lone Mountain Dolomite is absent.

The Roberts Mountains Formation is exposed along the north, northeast, and west flanks of Richmond Mountain, in the low hills

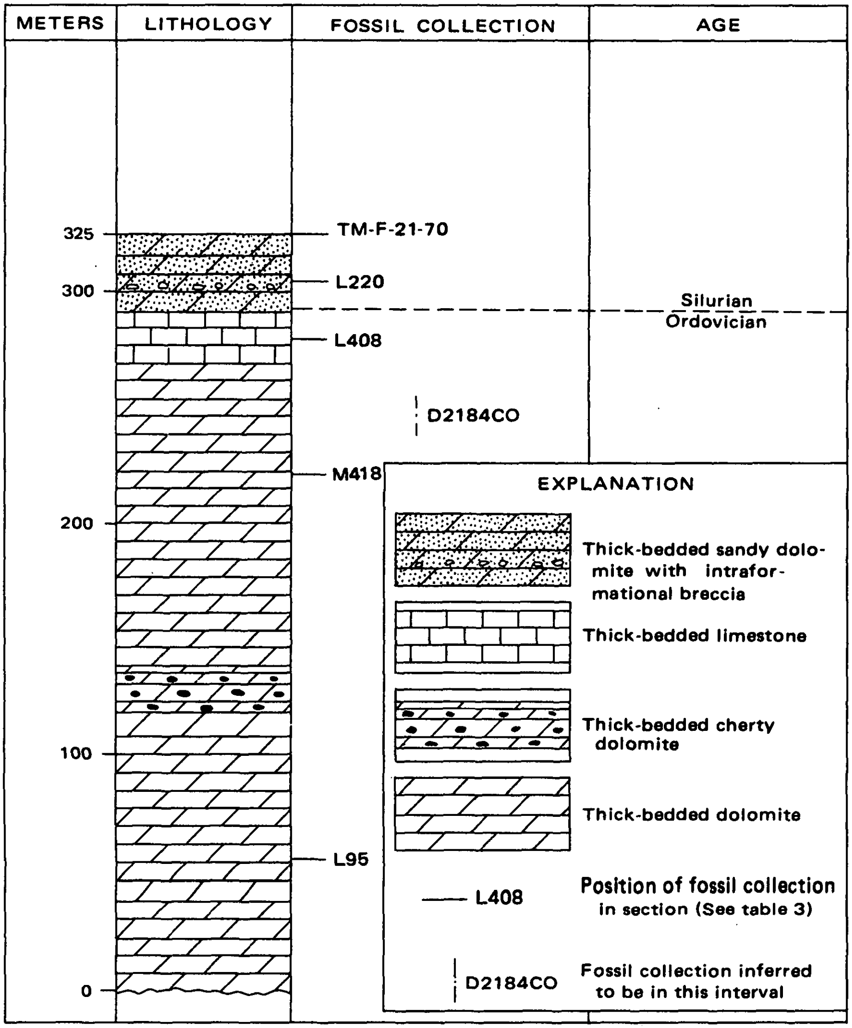


FIGURE 5.—Columnar section of Hanson Creek Formation showing positions of fossil collections in section.

west of southern Little Boulder Basin and Sheep Creek Canyon, and in the southern part of Richmond Mountain. In most of these areas, the Roberts Mountains Formation is poorly exposed. Slopes underlain by the rock are typically covered with a gray or pale-gray-brown soil containing angular slabs of limestone. Many of the outcrops occur where the formation has been partly silicified.

STRATIGRAPHY AND LITHOLOGY

The base of the Roberts Mountains Formation is at the laminated black chert and gray dolomite zone overlying the thick-bedded dolomite of the Hanson Creek Formation. At one locality, the black chert interval is 9.2 m thick. The Roberts Mountains Formation is typically a dark-gray fine-grained laminated dolomitic limestone containing terrigenous silt. This rock weathers to light blue gray and breaks easily into polygonal plates ½–2 cm thick (fig. 6). Other limestone in the formation is laminated but does not weather into thin plates, although it splits along some laminae. Beds 2.5 to 30 cm thick composed of fine-grained limestone, some of it bioclastic, occur locally near the base and in the upper half of the formation. Sparse black cherty shale beds are poorly exposed but can be identified from small black chips in the regolith. The top of the Roberts Mountains Formation was drawn where thick-bedded limestone breccia is a major lithologic constituent in the section. In most places, this horizon is the first limestone breccia bed more than 1.5 m thick.

FIGURE 6.—Typical exposure of Roberts Mountains Formation. Laminated limestone breaks into thin plates as much as 30 cm across. Locality TM–F–52–69 near center sec. 27, T. 35 N., R. 50 E., Rodeo Creek NE quadrangle.

The following section of Roberts Mountains Formation was measured along a line nearly coincident with the boundary between secs. 9 and 16, T. 35 N., R. 50 E., Rodeo Creek NE quadrangle:

Popovich Formation.
Interbedded thick-bedded limestone breccia and platy laminated dolomitic limestone.
Contact not exposed.

Roberts Mountains Formation (top):	Meters
Covered	22.9
Limestone, dolomitic, blue-gray; silty; laminated; plates ½–2 cm thick; black cherty shale interbeds less than 3 cm thick	61
Limestone, dolomitic, blue-gray; silty; laminated; platy; contains zones to 61 cm thick of thin-bedded bioclastic limestone that is more calcareous than the laminated limestone	91.5
Limestone, dolomitic, blue-gray; silty; laminated; platy; contains zones to 61 cm thick of thin-bedded bioclastic limestone that is more calcareous than the laminated limestone	91.5
Limestone, dolomitic, blue-gray; silty; laminated; platy; interbedded with zones of thin-bedded limestone to 30 cm thick	45.8
Limestone, dolomitic, blue-gray; silty; laminated; platy; laminated platy jasperoid present	61
Siliceous siltstone	15.2
Limestone, dolomitic, blue-gray; silty; laminated; platy; partly silicified	30.5
Covered	83.8
Limestone, dolomitic, blue-gray; silty; laminated; platy; partly silicified; numerous lenses of thin-bedded bioclastic limestone	30.5
Limestone, dolomitic, blue-gray; silty; laminated; locally dolomitic; platy; contains limestone beds to 10 cm thick; thin-bedded limestone is sandy and silty; laminated limestone partly silicified; black cherty shale beds less than 5 cm thick	15.2
Limestone, dolomitic, blue-gray; silty; laminated; platy; surficial silicification	7.6
Limestone, dolomitic, blue-gray; silty; laminated; platy	7.6
Total thickness	472.8

Contact; abrupt change in lithology.
Hanson Creek Formation.
Thick-bedded light-gray dolomite.

There are no marker horizons in the monotonous section of laminated and thin-bedded limestone. The interbedded dolomite and black chert characteristic of the base of the Roberts Mountains Formation in other parts of the area studied are not present in the measured section. The 15.3-m-thick zone of siliceous siltstone in the measured section has no stratigraphic significance because similar rocks occur in many parts of the Roberts Mountains Formation. Black cherty shale beds and lenses occur near the bottom and top of the formation.

The laminated limestone typical of the Roberts Mountains Formation contains calcite and dolomite in varying proportions (calcite-dolomite ratios 3⅛ to 1:9). Grains of carbonate are 0.05 mm in diameter. Angular to subangular detrital quartz grains make up 5 to 40 percent of the rock. Some of the quartz clasts are rounded and as much as 0.1 mm across, and as much as 50 percent is less than 0.01 mm. The detrital fraction of the rock includes minor amounts of chlorite, clays (chiefly illite with minor kaolinite), collophane, epidote, hornblende, plagioclase, potash feldspar, and tourmaline. The clays are more abundant in rocks with a higher detrital fraction. Pyrite, hematite, jarosite, and barite (in veins) are present. The carbonate in the thick-bedded limestone is chiefly calcite (90 percent). Some of this limestone contains sand-sized quartz grains. Near the Richmond district, the Roberts Mountains Formation has been metamorphosed and does not exhibit the platy character typical of the formation elsewhere in the area (fig. 7). Like the other rocks of the southern Lynn Window, the Roberts Mountains Formation has been bleached, recrystallized, and contains minerals of metamorphic origin: augite (as much as 65 percent), poikiloblastic plagioclase (as much as 10 percent), and minor hornblende and muscovite.

The measured section of Roberts Mountains Formation described is 472.8 m thick.

AGE AND CORRELATION

Fossils collected from the Roberts Mountains Formation, listed in tables 3 and 4, are mainly graptolites, but conodonts, brachiopods, and ostracods were collected. The position of the fossil collections in the section is shown in figure 8. Graptolite collections L412A and Tm–F–52–69A were taken at the base of the Roberts Mountains Formation and were dated as late Llandoverian (*M. spiralis* Zone). A poorly preserved graptolite from locality 69–RJ–82 near the base of the partly metamorphosed Roberts Mountains Formation in southern Lynn Window was collected by R. J. Ross, Jr.; W. B. N. Berry (written commun., 1970) identified the graptolite as *Monograptus*, possibly *hercynicus* type. M437 was collected about 4.6 m above the base, collection TM–F–52–69B 12–15 m above the base. Both graptolite faunas are placed in the Wenlockian. The graptolites from locality M420, inferred to be probably mid- to late Wenlockian, occur in a fault sliver. Graptolites at locality TM–F–52–69C occur 65.5 m above the base and are late Wenlockian, *M. testis* Zone. The locality M174, 91.5 m above the base of the formation, represents the span Wenlockian to Ludlovian. The youngest graptolites from locality TM–F–53–69 in the Carlin gold mine are high in the Roberts Mountains Formation and inferred to be Early Devonian, probably Siegenian. At locality TM–F–53–69, an Early Devonian graptolite fauna is 17 m below the top of the Roberts Mountains Formation (graptolite identifications by W. B. N. Berry, written commun., 1970.).

FIGURE 7.—Metamorphosed rock of Roberts Mountains Formation, southern Richmond Mountain (SW¼SW¼ sec. 3, T. 34 N., R. 50 E., Welches Canyon quadrangle). Platy weathering characteristic of the formation is absent. Bedding laminae are visible. Hammer is 30 cm long.

The conodonts in the rock at TM–F–14A–69 occur at the top of the Roberts Mountains Formation. They are dated as Late Silurian or Early Devonian. The conodonts and brachiopods in fauna from localities 69–FP–268F and M424B are from strata not precisely located

TABLE 3—*Graptolites from Roberts Mountains Formation*

[Identifications and age interpretations by W. B. N. Berry (written commun., 1969, 1970). Collection numbers prefaced by L and M collected by J. G. Evans. Collection numbers prefaced by TM collected by T. E. Mullens]

USGS fossil coll. No.	D253SD	D322SD	D275		D270SD		D241	D254	D255
Field coll. No	TM-F-52-69A	L412A	M437	TM-F-52-69B	M420	TM-F-52-69C	M174	TM-F-53-69	TM-F-54-69
Species									
Cyrtograptus lapworthi Tullberg	×	------	------	------	------	------	------	------	------
C. sp. (may be *C. lapworthi*)	------	×	------	------	------	------	------	------	------
C. sp	------	------	------	×	×	×	------	------	------
Dendrograptus sp	------	------	------	------	------	------	------	------	×
Linograptus sp	------	------	------	------	------	------	------	×	------
Monograptus flemingii (Salter)	------	------	×	------	×?	------	------	------	------
M. cf. *M. frequens* (Jaekel) v. close to *M. d. dubius* Suess	------	------	------	------	------	------	×	------	------
M. sp. similar to *M. ludensis* Murchison	------	------	------	------	------	------	×	------	------
M. sp. of the *M. dubius* group	------	×	------	------	------	×	------	------	------
hercynicus Perner	------	------	------	------	------	------	------	------	×
M. sp. of the *M. hercynicus* group	------	------	------	------	------	------	------	×	------
M. cf. *M. praedubius* (Boucek)	------	------	------	×	------	------	------	------	------
M. praehercynicus Jaeger	------	------	------	------	------	------	------	×	------
M. sp. somewhat similar to *M. pseudodubius* (Boucek)	------	------	------	------	------	------	------	×	------
M. priodon (Brown)	------	------	------	------	×	------	------	------	------
M. cf. *M. priodon* (Brown)	------	×	------	------	------	------	------	------	------
M. sp. (*M. priodon* group)	×	------	------	------	------	------	------	------	------
M. spiralis (Geinitz)	×	------	------	------	------	------	------	------	------
M. sp. (of the *M. spiralis* type)	------	×	------	------	------	------	------	------	------
M. testis (Barrande)	------	------	------	------	------	×	------	------	------
M. vomerinus var. *gracilis* (Elles and Wood)	------	------	------	×	------	------	------	------	------
M. cf. *M. vomerinus gracilis* (Elles and Wood)	------	×	------	------	------	------	------	------	------
M. cf. *M. vomerinus* (Nicholson)	------	------	×	------	------	------	------	------	------
M. sp. (of the *M. vomerinus* group)	------	------	------	------	×	------	------	------	------
Retiolites geinitzianus (Barrande)	------	×	------	------	------	------	------	------	------
R. geinitzianus var. *angustidens* (Elles and Wood)	×	------	------	------	------	------	------	------	------

Fossil locations; age:

TM-F-52-69A, near center sec. 24, T. 35 N., R. 50 E. (locality 69-RJ-82); late Llandoverian *M. spiralis* Zone

E½ sec. 15, same township; Silurian, late Llandoverian *M. spiralis* Zone

L412A, M437, SE¼ sec. 22, same township; Wenlockian

TM-F-52-69B, near center sec. 24, same township; Wenlockian

M420, NW¼ sec. 26, same township; Silurian, Wenlockian, probably mid-late Wenlockian

TM-F-52-69C, near center sec. 24, same township; late Wenlockian *M. testis* Zone

M174, NW¼ sec. 4, T. 34 N., R. 50 E.; a few fragments appear to have small hooks on the thecae. These could be monograptids of the *M. scanicus* type or cyrtograptids. Age: in the span Wenlockian-Ludlovian

TM-F-54-69, E½ sec. 14, T. 35 N., R. 50 E.; Early Devonian

TM-F-53-69, S½ sec. 15, same township; Early Devonian, probably Siegenian

TABLE 4.—*Conodonts, ostracods, and brachiopods from the Roberts Mountains Formation*

[Conodonts identified by J. W. Huddle (written commun., 1970), brachiopods by A. J. Boucot (written commun., 1970) and R. B. Neuman (written commun., 1970). Fossils collected by T. E. Mullens (TM-F-14-69A), J. G. Evans (M424B), and Boucot (69-FP-268F)]

USGS fossil coll. No	8440SD		8453SD
Field coll. No	TM-F-14-69A	69-FP-268F	M424B
Species			
Conodonts			
Acodina sp	2	------	------
Bryantodina remscheidensis (Ziegler)	8	------	------
"*Oneotodus*" *beckmanni* (Bischoff and Sanneman)	10	------	------
Brachiopods			
Atrypa sp	------	×	------
Cortezorthis sp	------	------	×
Isorthis? sp	------	×	------
Megakozloskiella? sp	------	×	------
Reticulariopsis? sp	------	------	×
Atrypids, indet	------	------	×
Rostrospiroids, indet	------	×	------

Fossil locations; age:
TM-F-14-69A, NE¼ sec. 9, T. 35 N., R. 50 E.; probably Early Devonian as indicated by *B. remscheidensis* and "*O.*" *beckmanni*
69-FP-268F, SE¼ sec. 14, same township; probably Gedinnian based on *Megakozloskiella*? (Boucot)
M424B, NE¼ sec. 24, same township; most probably Early Devonian. Possibly an Emsian equivalent (Neuman)

stratigraphically but high in the Roberts Mountains Formation. All are Early Devonian in age (all fossil identifications in 1970, written commun.; conodont identifications by Huddle; brachiopods, by Boucot and Newman).

The Roberts Mountains Formation in the Lynn Window ranges in age from late Llandoverian, in the *M. spiralis* Zone, to Early Devonian. The age of the base of the formation is slightly older than the early Wenlockian date given graptolite collections from the base of the Roberts Mountains Formation in the Lynn Window in an earlier report (Berry and Roen, 1963). Berry and Roen reported that the base of the formation contains a disconformity representing an interval of erosion during Early and Middle Silurian time, but no unconformity was seen.

POPOVICH FORMATION

NAME AND LOCATION

The limestone overlying the Roberts Mountains Formation at the Lynn Window was first described by Roen (1961); he did not name the unit. Devonian rocks, about 60 m thick, exposed at the Carlin gold mine on Popovich Hill were named Popovich Limestone by Hardie (1966, p. 77); this was designated the type locality of the Popovich Formation by Akright and others (1969). A more complete reference section of the Popovich Formation, northwest of the Carlin gold mine in N½ sec. 9, T. 35 N., R. 50 E., is described below.

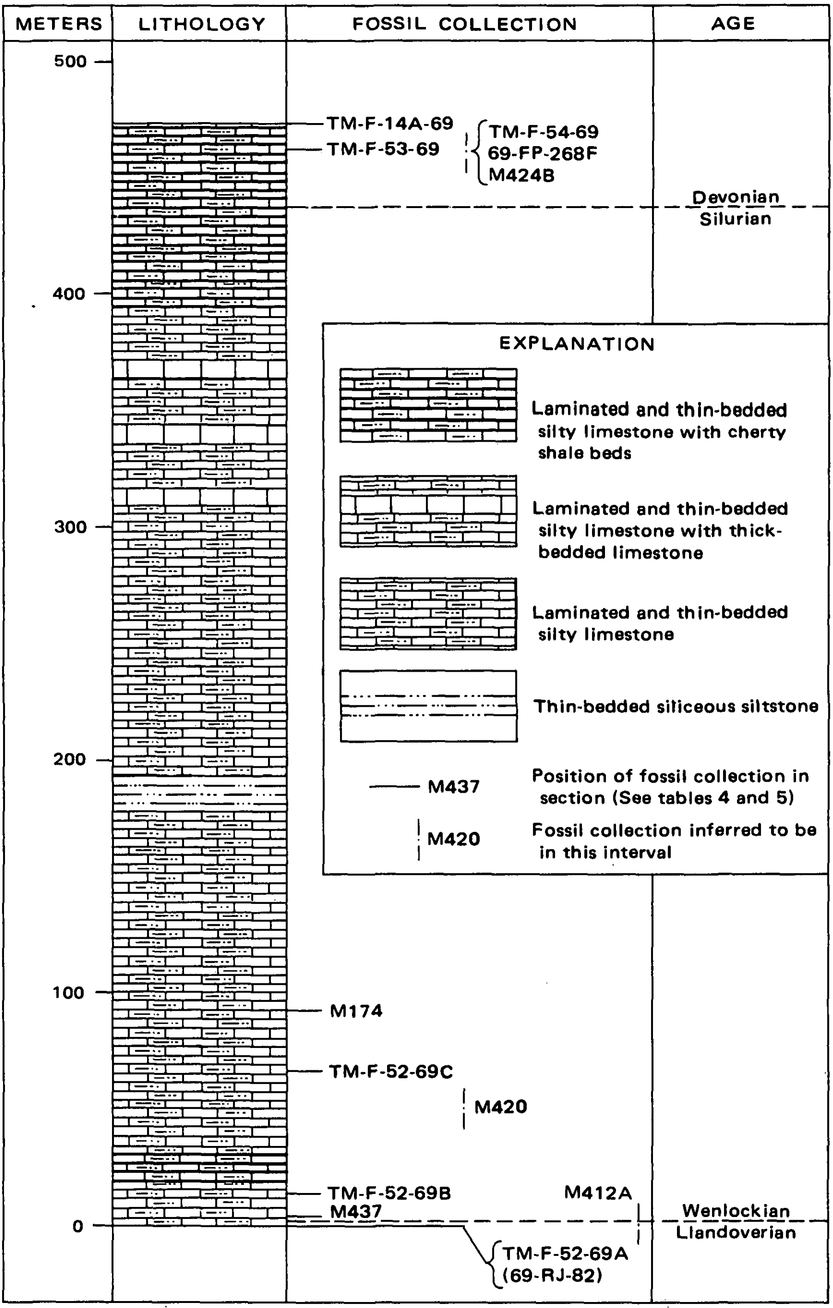


FIGURE 8.—Columnar section of Roberts Mountains Formation showing positions of fossil collections in section.

The Popovich occurs near the west edge of the Rodeo Creek NE quadrangle, west of the Carlin gold mine, on southern Richmond Mountain, in fault slivers at the Carlin gold mine, and on the east flank of the Tuscarora Mountains. The thick-bedded and massive limestone beds in the formation form bold outcrops and ledges that contrast sharply with the smooth gray slopes underlain by the more thinly bedded limestone. Over the range as a whole, the formation is not characteristically a ridge-forming unit.

STRATIGRAPHY AND LITHOLOGY

The basal contact of the Popovich Formation was drawn at the base of the lowest thick-bedded coarse intraformational breccia (fig. 9). Above the contact, the depositional breccia is a characteristic lithology in the limestone. Much of the unit, however, is laminated silty limstone similar to the rock type that characterizes the underlying Roberts Mountains Formation. The coarse breccia beds throughout the Popovich Formation grade laterally to fine-grained limestone with detrital quartz sand or fine-grained thick-bedded limestone, locally with white sand-sized shell fragments. The uppermost 60 m of the Popovich Formation consists of thick-bedded limestone breccia with angular limestone fragments 15 cm across; limestone with medium-grained quartz clasts is common (fig. 9). The top of the limestone is truncated by low-angle faults, possibly segments of the Roberts Mountains thrust.

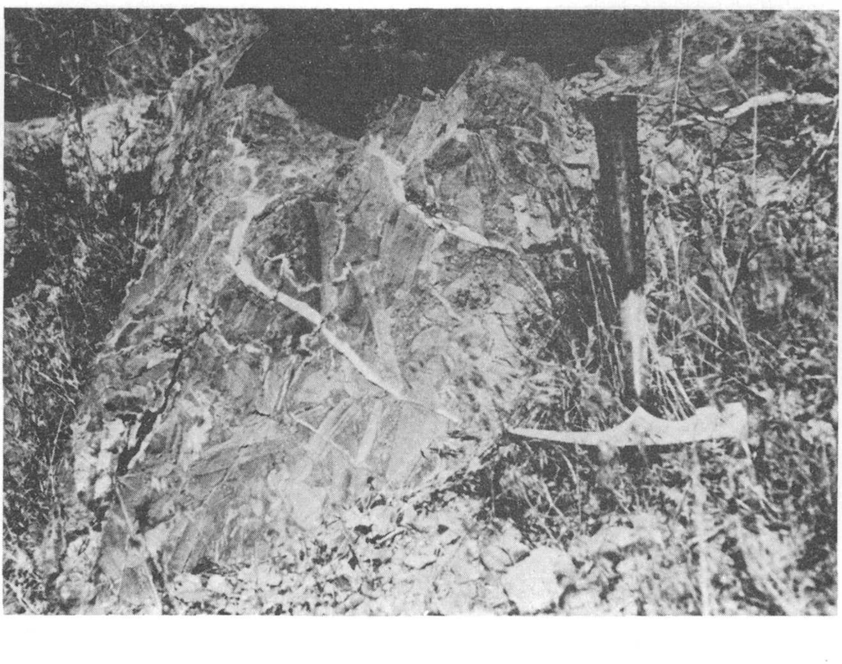


FIGURE 9.—Popovich Formation with intraformational breccia (near center of sec. 5, T. 35 N., R. 50 E., Rodeo Creek NE quadrangle). Hammer is 30 cm long.

The following section of the limestone was measured across the N½ sec. 9, T. 35 N., R. 50 E:

Western assemblage (allochthonous):	
Black thin-bedded chert and shale?	
Contact. Low-angle fault (Roberts Mountains thrust?).	
Popovich Formation:	*Meters*
Limestone, gray; sandy, beds to 61 cm thick; silicified zones several millimeters wide along the fractures and subparallel to bedding	27.5
Limestone, blue-gray; intraformational breccia; angular clasts commonly tabular, of laminated limestone, 15.2 cm long; bioclastic material locally; beds to 76 cm thick; numerous white calcite veins	30
Covered. Possibly thin-bedded limestone	7
Limestone, gray; beds 2.5 cm thick; not well defined; locally massive; white sand-sized bioclastic fragments	3.1
Limestone, gray; intraformational breccia; rounded to subangular limestone clases generally 2.5–10 cm long, tabular; some clasts to 1.8 m long; matrix of fine-grained limestone	3.7
Limestone, gray; beds 30 cm thick	.9
Limestone, gray, sandy; beds to 75 cm thick; contains zones of thin-bedded limestone 15.2–25.4 cm thick	7
Limestone, gray; interbedded thick (61–91 cm) and thin (less than 2.5 cm) limestone with parting subparallel to bedding	6
Limestone, gray; beds less than 2.5 cm thick	7
Covered. Probably mostly thin-bedded limestone	45.8
Limestone, gray; massive	45.8
Covered	22.9
Limestone, gray, silty, laminated; breaks easily into irregular plates to a few centimeters thick	82.4
Limestone, gray; interbedded silty thin-bedded to laminated limestone and thicker bedded limestone with beds to 91 cm thick, containing fossil fragments	19.8
Covered. Probably thin-bedded, laminated limestone	18
Limestone, gray; beds to 46 cm thick; bioclastic	3.1
Covered. Probably thin- to thick-bedded limestone	19.8
Limestone, gray; interbedded laminated limestone and limestone with beds to 46 cm thick; thinner bedded limestone is platy; thin black chert beds; locally bioclastic	22.9
Covered. Some thick-bedded limestone present	21.4
Limestone, gray; beds 15.2–30.4 cm thick; bioclastic zones contain fossil fragments to 0.6 cm across	4.6
Covered	7
Limestone, gray; beds generally 15.2–30.4 cm thick; contains some laminated platy limestone	7
Limestone, gray; beds less than 2.5–30 cm thick; zones of laminated limestone several centimeters thick are interbedded	7
Total thickness	424.2
Contact.	
Roberts Mountains Formation:	
Laminated silty dolomitic limestone.	

In the fine-grained (0.05 mm max) laminated silty limestone beds, calcite is generally more abundant than dolomite. Subangular to rounded silt-sized quartz clasts make up 5 to 50 percent of the rock. In some rocks, clay is a major constituent. The massive limestones are made up of nearly pure calcite grains less than 0.01 mm across. Oolites in the rock attain diameters of 0.1 mm. Quartz, also very fine grained (less than 0.01 mm), occurs in nodules a few tenths of a millimeter long and as coatings on fossil fragments and oolites. In sandy limestone with detrital sand grains, oolites and subangular to rounded fine-sand-sized clasts of limestone, quartz, and minor plagioclase are in a matrix of calcite with grains ranging from less than 0.01 to 0.4 mm across. Shell fragments, partly silicified, are locally abundant. Some of the quartz grains are partly replaced by calcite. Quartz content of the sandy limestone ranges from 5 to 50 percent. Barite (in veins), chlorite, and hematite are present.

On southern Richmond Mountain, the Popovich Formation is metamorphosed; it includes white, gray, and yellow beds of thick-bedded to massive calc-silicate hornfels and marble. Beds of hornfels contain augite (to 65 percent), plagioclase (generally 20 percent), and muscovite (to 15 percent). Minor biotite, chlorite, epidote, garnet, hornblende, and sphene are present.

The measured section of Popovich Formation is 424.2 m thick (fig. 10). This is a minimum thickness because the top of the section is truncated by faults. In southern Richmond Mountain, the section of Devonian Popovich Formation is at least 405.7 m thick.

AGE AND CORRELATION

Ostracods and most corals, brachiopods, and conodonts found in the Popovich Formation, listed on tables 5, 6, and 7, range in age from the Early Devonian, *Quadrithyris* Zone of Johnson (1965, p. 370; 1970, p. 43–48) to the early Late Devonian, upper *Polygnathus asymmetricus* Zone. Conodonts found at localities M536, M484A, M406, M649, and M665 are known to range in age from Silurian into the Early Devonian, but the southeast assemblages from the Lynn Window are considered to be entirely Early Devonian because the underlying Roberts Mountains Formation is partly Early Devonian in age. The approximate position in the section of each of the fossil collections is shown on figure 10.

Corals found at localities M412B, M422, and M476 were identified by C. W. Merriam (written commun., 1969).

The corals at M412B do not provide a basis for a definitive age determination, as they exhibit affinities to corals of Cambrian to Devonian ages. The conodonts found at M412B are Early Devonian. At

M422, the corals suggest a Late Silurian or Early Devonian age. At M476, *Cyathophylloides* n. sp. was identified. The genus is a Late Ordovician and Early Silurian one. As this locality is 7.7 m above the base of the Popovich Formation, the accuracy of the coral identification is in doubt. However, an unidentified thrust fault could be present at this locality.

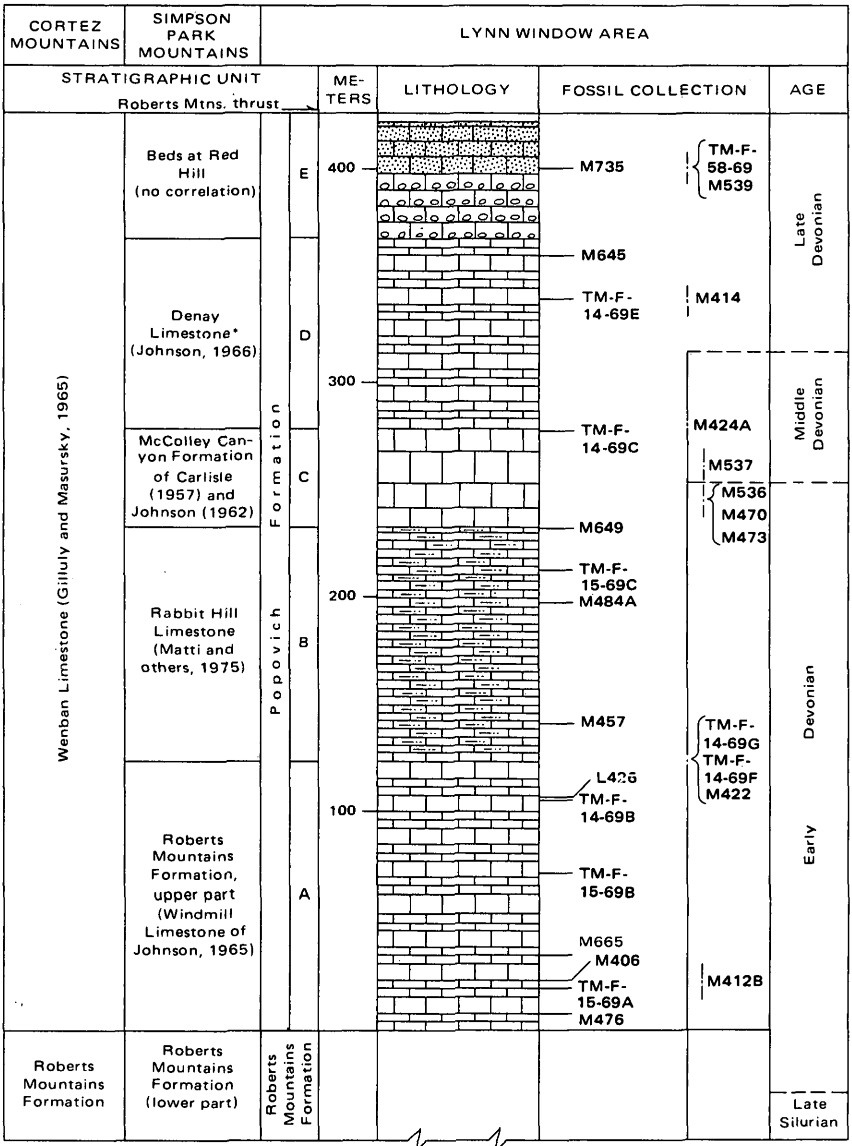
The section of Popovich Formation in the Lynn Window is very similar to the Devonian limestone at Bootstrap Hill, 13 km northwest of the Lynn Window (Evans and Mullens, 1976). Devonian limestones similar in general appearance to those in the Lynn Window occur at Swales Mountain, 24 km east of the Lynn Window. Correlation between these two sections has not been attempted. Gilluly and Masursky (1965, p. 29–38) applied the name Wenban Limestone to a Devonian limestone interval in the Cortez Mountains which is equivalent to the Popovich Formation in the Lynn Window.

The Popovich Formation section in the Lynn Window is informally divided into five units. Four of these units (units A–D) are tentatively correlated with formations recognized 80–176 km to the south.

Unit A is correlated with the upper part of the Roberts Mountains or the Windmill Limestone of Johnson (1965) (type section at Coal Canyon, northern Simpson Park Mountains, 96 km south of the Lynn Window (Johnson, 1965, p. 369–372)).

Unit B is tentatively correlated with the Rabbit Hill Limestone (type section at junction of Whiterock Canyon with Copenhagen Canyon, Monitor Range; Merriam, 1963, p. 42–44; Matti and others, 1975, p. 16–25). At its type section the Rabbit Hill Limestone consists of a lower, thin-bedded, evenly laminated limestone member with minor chert and an upper member of both thin-bedded, laminated limestone and medium- to thick-bedded bioclastic graded limestone. Only the thin-bedded laminated limestone, the dominant lithology of the Rabbit Hill Limestone in its type section, is present in unit B.

Unit C is tentatively correlated with the interval occupied by the McColley Canyon Formation, described originally by Carlisle, Murphy, Nelson, and Winterer (1957, p. 2181) as a member of the Nevada Formation and elevated to formation rank by Johnson (1962). At its type section at McColley Canyon in the northern Sulphur Spring Range 75 km south-southeast of the Lynn Window, the McColley Canyon Formation is as much as 192 m thick and consists of dolomitic limestone, dolomite, and argillaceous quartz-sand-bearing limestone. In the Lynn Window, unit C is massive- to thick-bedded limestone about 48 m thick and compares better with a more calcareous facies of the McColley Canyon Formation near Coal Canyon in the northern Simpson Park Mountains (Johnson, 1965, 1970). Johnson described the McColley Canyon as being entirely Early Devonian in age and



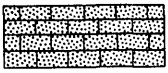
* Unit D is lithologically similar to Denay Limestone although the latter is restricted to Middle Devonian in Simpson Park Mountains and Roberts Mountains area.

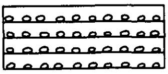
FIGURE 10.—Columnar section of Popovich Formation showing positions of fossil collections in section.

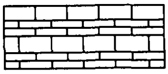
unconformably overlain by Middle Devonian rocks. At the Lynn Window unit C may be partly Middle Devonian.

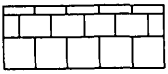
Unit D is lithologically similar to the Denay Limestone (Johnson,

EXPLANATION


Thick-bedded sandy limestone


Thick-bedded limestone with intraformational conglomerate


Thick- and thin-bedded limestone


Massive limestone


Laminated and thin-bedded silty limestone

—— M735 Position of fossil collection in section (See tables 6, 7, and 8)

M537 Fossil collection inferred to be in this interval

FIGURE 10.—Continued.

1966, p. 154–157), although the Denay is considered to be Middle Devonian in age (in the northern Simpson Park Mountains and the Roberts Mountains) whereas unit D is Middle and Late Devonian in age.

SILURIAN AND DEVONIAN LIMESTONE UNDIFFERENTIATED

Carbonate rock or probable Silurian and Devonian age, chiefly limestone, occurs in and near the epithermally altered rocks at the Carlin gold mine, and near the Gold Strike Claims (unit DS1 on map). Southeast of the Carlin gold mine this limestone is generally massive and fine grained and usually well exposed. Conodonts and ostracods from this limestone unit at locality M527 indicate a Late Silurian or Early Devonian age (table 8). West of the Blue Star mine, the limestone is thin to thick bedded and interlayered with beds of limestone conglomerate. Rocks of similar sedimentary lithologies in the Roberts Mountains Formation and in the Popovich Formation suggest a correlation of the limestone with these formations. Locally, the limestone is altered to calc-silicate hornfels. Near the Gold Strike Claims, slivers of carbonate rock altered to medium- to coarse-grained marble and calc-silicate hornfels occur at the margins of the Cretaceous granodiorite stock. This carbonate rock was probably metamorphosed and faulted during intrusion of the granodiorite.

TABLE 5.—*Conodonts from Popovich Formation*

[Conodonts identified by J. W. Huddle (written commun., 1970, 1971 Collections with numbers prefaced by Land M collected by J. G. Evans. Collections with numbers prefaced by TM collected by T. E. Mullens]

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Acodus? sp	--	--	--	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Acrodina sp	1	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ancryodella rugosa Branson and Mehl	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4
A. r. rotundiloba (Bryant)	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1	--	--	--	--	--
Anguldodus sp	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Apatognathus sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
Belodella devonica (Stauffer)	--	--	1	--	--	--	--	--	3	--	--	--	--	--	1	1	--	--	--	--	--	--
B. triangularis (Stauffer)	1	--	--	--	--	--	--	2	--	--	--	--	1	8	1	2	--	--	--	--	1	--
B. sp	--	--	--	--	--	1	1	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--
Bryantodina boucoti (Kapper)	--	--	--	--	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B. fundamentus (Bischoff and Sannemann)	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B. inclinatus wurmi (Bischoff and Sannemann)	--	--	--	--	--	7?	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B. johnsoni (Klapper)	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B. remscheidensis (Ziegler)	--	--	--	--	--	7	--	--	10	--	--	--	--	--	--	--	--	--	--	--	--	--
B. cf. *B. remscheidensis* (Ziegler)	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--
B. cf. *B. sagitta* (Walliser)	--	--	--	--	--	--	--	--	--	--	--	--	29	--	--	--	--	--	--	--	--	--
B. steinhornesis (Ziegler)	--	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B. wurmi (Bischoff and Sannemann)	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B. sp	--	2	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--
Bryantodus radiatus (Hinde)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5	--	--	--	--	--	--	--
B. sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
Distacodus sp	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hibbardella sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1
Hindeodella sp	3	--	--	3	10	7	3	3	2	1	--	--	--	6	19	--	4	--	--	1	1	2
H. nodosus (Huddle)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4
H. pesavis Bischoff and Sanneman	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	--	--	--
H. cf. *I. pesavis* Bischoff and Sanneman	--	--	--	--	--	--	--	--	--	--	--	--	4	--	--	--	--	--	--	--	--	--
H. sp	--	--	--	--	2	--	--	--	--	--	1	1	--	--	2	--	--	--	--	--	--	--
Ligonodina sp	--	1	1	--	2	--	--	--	--	--	--	--	3	--	--	--	--	--	--	1	--	--
Lonchodina cristagalli Ziegler	--	--	--	--	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
L. dialata (Bryant)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2
L. greilingi Walliser?	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
L. torta Huddle	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
L. walliseri Ziegler?	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
L. sp	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
Neoprioniodus bicurvatus (Branson and Mehl)	--	--	--	--	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	--	--
N. excavatus (Branson and Mehl)	--	--	--	--	2	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
N. sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	3	--	--	--
Nothognathella sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5	--
N. n. sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1

"*Oneododus*" *beckmanni* Bischoff and Sannemann	--	--	--	--	1	--	--	--	--	--	--	22	--	--	--	--	--	--	--	--	--	--
Ozarkodina denckmanni Ziegler	--	--	--	--	3	--	--	--	2	--	--	--	12	--	--	--	--	--	--	--	--	--
O. cf. *O. fundementata* Walliser	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
O. aff. *O. fundementata* Walliser	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--	--	--	--	--	--	--	--
O. media Walliser	--	--	--	--	8	3	--	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--
O. aff. *media* Walliser	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
O. cf. *O. ortus* Walliser	--	--	--	--	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
O. sp	--	--	1	--	--	--	--	--	1	--	--	--	--	--	1	--	1	--	3	1	--	--
Palmatolepsis punctata (Hinde)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9
Panderodus sp	3	--	--	4	34	--	--	9	--	--	1	--	--	1	--	--	--	--	1	--	--	--
Plectospathodus extensus Rhodes	--	--	--	--	--	8	--	8	--	--	--	--	1	--	--	--	--	--	--	--	--	--
P. sp	--	1	--	--	2	--	--	--	1	--	--	--	--	1	--	--	--	--	--	--	--	--
Prioniodina sp	--	--	--	--	--	--	--	1	--	1	--	--	--	--	--	--	--	--	--	--	--	--
Polygnathus asymmetricus asymmetricus Bischoff and Siegler	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	20	3
P. asymmetricus ovalis Ziegler and Kapper	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	--
P. crystatus Hinde	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5	--
P. decorosus Stauffer	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	14	--
P. dengleri Bischoff and Ziegler?	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
P. dubius Hinde	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	--	2	--	15
P. kockelianus Bischoff and Ziegler	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	7	--	--	--	--	--	--
P. linguiformis Hinde	--	--	--	--	--	--	14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P. linguliformis Hinde	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	2	--	--	--	--	--	--
P. aff. *P. linguliformis* Hinde	--	--	--	--	--	--	--	--	--	--	--	--	--	--	14	--	--	--	--	--	--	--
P. linguliformis linguliformis Hinde	--	--	--	--	--	--	--	--	--	--	--	--	--	8	--	--	--	--	--	--	--	--
P. normalis Miller and Youngquist?	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--
P. pennatus Hinde	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--
P. pseudofoliatus Wittekindt	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P. robusticostatus Bischoff and Ziegler	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--
P. cf. *transversus* Wittekindt	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5	--	--	--	--	--	--
P. trigonicus Bischoff and Ziegler	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--
P. cf. *P. tuburculus* Hinde	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3
P. varcus Stauffer	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	--	--	--	--	--	--
P. cf. *P. webbi* Stauffer	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5
P. sp	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--
Scolopodus sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
Spathognathodus inclinatus Rhodes	--	--	--	10	--	--	--	5	--	--	--	--	--	--	--	--	--	--	7	--	--	--
S. johnsoni Klapper	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--	--
S. remscheidensis Ziegler	--	--	--	--	--	--	--	--	--	9	--	--	--	--	--	--	--	--	--	--	--	--
S steinhornensis s. l. Ziegler	--	--	3	--	--	--	--	?3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S. transitans Bischoff and Sannemann	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
S. sp	--	--	--	--	--	--	--	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S. 2 sp	--	--	--	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Synprioniodina bicurvata (Branson and Mehl)	--	--	--	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S. cf. *excavata* (Branson and Mehl)	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S. sp	--	--	--	--	--	--	1	--	--	1	--	--	--	2	1	--	1	--	--	--	--	--
Trichonodella excavata (Branson and Mehl)	--	--	--	--	--	--	--	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T. symmetrica (Branson and Mehl)	--	2	--	--	3	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T. sp	--	--	1	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 5.—*Conodents from Popovich Formation*—Continued.

USGS fossil colln. No.	*Field colln. No.*	*Age*	*Fossil locations*
1. 8446SD	TM-F-15-69A	*I. pesavis* suggests Early Devonian, Siegenian Age (*Quadrithyris* Zone)	S½ sec. 15, T. 35 N., R. 50 E.
2. 8450SD	M412B	Early Devonian, presumably early Siegenian, *Quadrithyris* Zone	E½, same section, same township
3. 8471SD	M406	Silurian or Early Devonian	S½, same section, same township
4. 8862SD	M665	Possibly Early Devonian. Species range from Middle Silurian to Middle Devonian	S½ sec. 9, same township
5. 8447SD	TM-F-15-69B	Probably Early Devonian	S½ sec. 15, same township
6. 8441SD	TM-F-14-69B		N½ sec. 9, same township
7. 8855 SD	L426	Probably Middle Devonian	Boundary between secs. 9 and 10, T. 34 N., R. 50 E.
8. 8426SD	M484A	Conodonts range in age from Late Silurian to Early Devonian	SW¼ sec. 4, T. 35 N., R. 50 E.
9. 8448SD	TM-F-15-69C	Early Devonian	S½ sec. 15, same township
10. 8861SD	M649	Probably Early Devonian. Possibly Late Silurian	Near center sec. 15, same township
11. 8473SD	M536	Conodonts suggest Devonian age, but might be Silurian	NW¼ sec. 30, T. 35 N., R. 51 E.
12. 8445SD	TM-F-14-69G	Probably Early Devonian	N½ sec. 9, T. 35 N., R. 50 E.
13. 8444SD	TM-F-14-69F	Probably Early Devonian	Do.
14. 8442SD	TM-F-14-69C	Probably Middle Devonian	Do.
15. 8469SD	M537	Middle Devonian	NW¼ sec. 30, T. 35 N., R. 51 E.
16. 8425 SD	M424A	Five species of *Polygnathus*, late Eifelian, Germany. Middle Devonian	NE¼ sec. 24, T. 35 N., R. 50 E.
17. 8443SD	TM-F-14-69E	Early Late Devonian	N½ sec. 9, same township
18. 8807SD	M414	Probably early Late Devonian	S½ sec. 15, same township
19. 8860SD	M645	Early Devonian—*Springerina* Zone or *Icriodus pesavis* Zone	N½ same section, same township
20. 8863SD	M735	Late Devonian. *Polygnathus asymmetricus* Zone	NW¼ sec. 9, same township
21. 8221SD	TM-F-58-69	Late Devonian. Frasnian; lower *Polygnathus asymmetricus* Zone	NE¼ sec. 14, same township
22. 8470SD	M539	Early Late Devonian and probably upper *Polygnathus asymmetricus* Zone	SW¼ sec. 19, T. 35 N., R. 51 E.

TABLE 6.—*Ostracods, brachiopods, and trilobites from Popovich Formation*

[Ostracods identified by J. M. Berdan (written commun., 1970), brachiopods by J. T. Dutro, Jr., (written commun., 1970), trilobites by R. J. Ross, Jr., (written commun., 1969). Fossils collected by J. G. Evans]

USGS fossil colln. No. Field colln. No. Species	D273SD [1]M470	8430SD M473	8472SD M536
Ostracods			
Abditoloculina? sp	×	×	----
Acanthoscapha sp. cf. *A. Navicula* (Ulrich)	×	----	----
Aechmina sp	×	×	×
Berounella sp	×	×	----
Birdsallella sp	×	×	----
Chironiptrum sp	----	×	----
Falsipollex sp	×	×	----
Hanaites sp	----	×	×
Hesslandella? sp. cf. *H. tomtchumyschensis* Polenova	----	----	×
Hollinella sp	----	×	----
Jonesites? sp. cf. aff. *J.? circa* (Coryell and Cuskley)	× aff.	----	× cf.
Kirkbyella sp	----	×	----
Tetrasacculus sp	----	×	----
Thlipsura sp. aff. *T. furcoides* Bassler	×	×	×
Thlipsuroides? sp	----	×	----
Tricornina sp	----	×	----
Ulrichia sp	×	×	×
Brachiopods			
Anoplia? sp	×	----	----
Leptocoelia infrequens (Walcott)	×	----	----
Strophochonetes filistriata (Walcott)	×	----	----
Trilobites			
Phacops (Phacops) claviger Haas	×	----	----
P. (Reedops) sp	×	----	----

[1]M470 also contains (1) *Strophochonetes filistriata* (Walcott) (2) *Leptocoelia infrequens* (Walcott) (3) *Anoplia?* sp. (4) *Phacops (Phacops) claviger* Haas (5) *Phacops (Reedops)* sp. Age from brachiopods: first two species are abundant in the *Eurekaspirifer pinyonensis* Zone and suggest a late Emsian age.

Ostracods: Early Devonian; trilobites: late Helderbergian equivalency. M536 age: Definitely Early Devonian, probably same age as M473 and M470.

M470, boundary between secs. 8 and 9, T. 35 N., R. 50 E.
M473, NW¼ sec. 22, same township
M536, NW¼ sec. 30, T. 35 N., R. 51 E.

EPITHERMALLY ALTERED SILURIAN AND DEVONIAN LIMESTONE

Epithermal alteration (oxidation, leaching of carbonate minerals, silicification of carbonate rock, and argillic alteration) is common in broad areas of the southern Tuscarora Mountains, especially in the Roberts Mountains Formation and in the Popovich Formation. Two zones of altered Silurian and Devonian carbonate rocks so altered that the formations to which they belong cannot be identified occur in the northern part of Lynn Window: (1) a northwest-trending zone to 0.8 km wide from the east front of the Tuscarora Mountains 4 km south of Simon Creek Canyon to the Carlin gold mine; (2) a north-northwest-trending band from the south end of Little Boulder Basin to the vicinity of the Blue Star mine. Characteristically, the slopes underlain by the altered rock are covered with soil of varying shades

TABLE 7.—*Fossil collections from Popovich Formation (not listed in tables 6 and 7)*

[Collected by J. G. Evans]

Field colln. No.	Fossil
M476	*Cyathophylloides* n. sp., cf. *C. burksal* Flower *C. burksal* is a Late Ordovician species from the Aleman Formation of the Montoya Group in New Mexico. This one nearly identical to one described by Merriam from Silurian coral zone A., Early Silurian, at Ikes Canyon. Toquima R. There it is associated with *Arachnophyllum* and *Neomphyma* in a section with other coral zones. *Cyathophylloides* is more commonly a Late Ordovician than an Early Silurian genus. This might possibly be Hanson Creek (C. W. Merriam, written commun., 1969).
M457	Favositid tabulate coral Stropheodont brachiopods—possibly *Stropheodonta* (Brachyprion) —possibly *Strophonella* (large form) ventral values of medium-sized brachiopod. Could be *Parmorthis, Catazyga,* or *Anastrophia* but lacks weak fold of the last one. Various orthoid brachiopods, possibly dalmanellids fragments of possible *Rhynchospirina* like *R. baylei* (Davidson). Age: More likely Silurian or Devonian than Ordovician because of presence of stropheodonts (C. W. Merriam, written commun., 1970).
M422	?*Heliolites* sp. ?*Chaetetes* sp. ?*Chonophyllum* sp. *Australophyllum* n. sp. *Australophyllum* n. sp. resembles but is not conspecific with new subgenus and species Merriam described from Rabbit Hill Limestone (Early Devonian—Helderbergian). Associated corals are perhaps a little more suggestive of Late Silurian. A species similar to this one occurs in the higher beds of the Owens Valley, Calif., Vaughan Gulch Limestone, which is Late Silurian or Early Devonian(?) (C. W. Merriam, written commun., 1969).
M412B	*Dalmanophyllum*? sp. digitate favositid (Cladopora? or Thamnopora) fragmentary brachiopods including ventral value of possible *Atrypina spirigerina* sp. *Cyrtina* sp. *Protocortezorthis* sp. *Clorinda*? sp. The silicified *Dalmanophyllum*? shows fairly well preserved internal structure in thin section, having an incipient axial structure. Streptelasmatidae of this kind range from Late Ordovician to Silurian. This coral also suggests the Devonian genus *Scenophyllum* to a somewhat lesser degree. This collection is probably younger than Ordovician to judge from the favositid. I am inclined to favor a Silurian age (C. W. Merriam, written commun., 1969).
M424A	Ramose tabulate corals, possibly *Coenites* *Australophyllum*? sp. *Entellopnyllum*? sp. *Palaeophyllum*? sp. The framentary brachiopods are not identifiable, but may include *Atrypa,* ribbed and smooth pentameroids. The *Australophyllym*? sp. may be the same as that from locality M422 but is too fragmentary for thin sectioning (C. W. Merriam, written commun., 1969).

Fossil locations:
M476, S½ sec. 15, T. 35 N., R. 50 E.
M457, E½ sec. 16, same township
M422, SW¼ sec. 19, T. 35 N., R. 51 E.
M412B, E½ sec. 15, T. 35 N., R. 50 E.
M424A, NE¼ sec. 24, same township

TABLE 8.—*Late Silurian or Early Devonian conodonts and ostracods from Silurian and Devonian limestone undifferentiated*

[Sample M527 (8468 SD) collected by J. G. Evans, NE¼ sec. 24, T. 35 N., R. 50 E. Age assigned conodonts by J. W. Huddle (written commmun., 1970). Age assigned ostracods by J. M. Berdan (written commun., 1970).]

Conodonts:	
Neoprioniodus excavatus (Bramson and Mehl)	2
Ozarkodina cf. *O. media* Walliser	1
Panderodus sp.	2
Spathognathodus inclinatus (Rhodes)	5
Trichanodell summetrica (Branson and Mehl)	3
Ostracods:	
Beyrichia sp.	
Graniella sp.	
Libumella sp.	
Marginia? sp.	
Miraculum? sp.	
Scaphina? sp. terminal dorsally directed spines	
Strepula? sp.	
Tricorniana sp.	
Tubulibairdia sp.	
beyrichracean, indet.	

of brown. The few outcrops of the altered rock typically consist of laminated siliceous siltstone, some forming cliffs.

The siltstone and siliceous siltstone, products of leaching of carbonate minerals and deposition of silica in the rock, make up most of the unit. The altered rock was probably originally thin-bedded and laminated silty limestone of the Roberts Mountains Formation and Popovich Formation. The altered rock is multicolored: the somewhat friable, porous, somewhat calcareous siltstone is white or creamy yellow (fig. 11); the siliceous siltstone is white, black, maroon, violet, yellow, brown, and green. As much as 30 percent of the siltstone and siliceous siltstone consists of clear angular quartz clasts as much as 0.05 mm across. These clasts are in a matrix of quartz grains less than 0.01 mm in diameter. Rhombic and oval grains of dolomite (5–35 percent) to 0.05 mm across are scattered throughout the rock. Clays, chiefly illite and less abundant montmorillonite, are generally minor constituents. Hematite is a common accessory mineral. Carbonaceous material occurs in minor amounts. Impressions of graptolites occur in the siltstone but are not well enough preserved to be identified.

SILICEOUS (WESTERN) ASSEMBLAGE

The siliceous assemblage rocks of the southern Tuscarora Mountains include the Ordovician Vinini Formation as described by

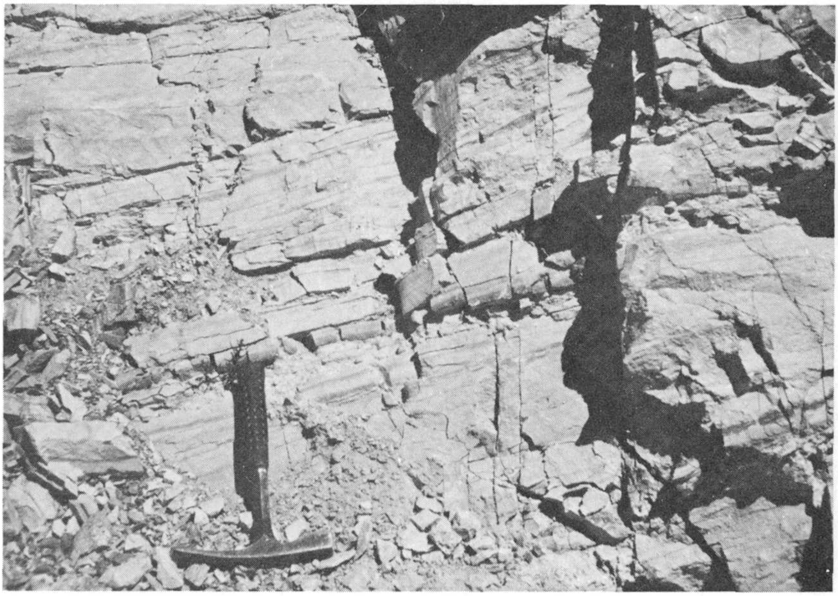


FIGURE 11.—Epithermally altered Silurian and Devonian limestone. White to pale-yellow calcareous siltstone exposed in main pit at Carlin gold mine. Hammer is 30 cm long.

Merriam and Anderson (1942, p. 1693–1698) and unnamed strata of Silurian age.

The siliceous assemblage occurs north, west, and south of the Lynn Window. The rocks are in general much fractured and deeply weathered. Consequently, the slopes underlain by the siliceous assemblage are characteristically rounded and covered by dark-brown soil with black angular chips of siliceous shale and chert. The rocks crop out mainly as resistant chert ledges except where the slopes are exceptionally steep and in stream cuts where the less resistant shale beds are exposed.

The siliceous assemblage consists principally of shale and chert. The dark-gray to black laminated siliceous shale, locally white, green, brown, or red with well-developed bedding fissility, is interlayed with black, gray, brown, white, and blue-green laminated to thin-bedded and nodular chert (figs. 12, 13). The chert beds in the shale are typically no more than 6.1 m thick. Zones of chert more than 305 m thick were mapped in the siliceous assemblage. Minor lithologic types in the siliceous assembalge are quartzite, argillite, siliceous siltstone, limestone, and dolomite. The fine-grained, gray, blue-gray, and white quartzite 3 km north of the Carlin gold mine

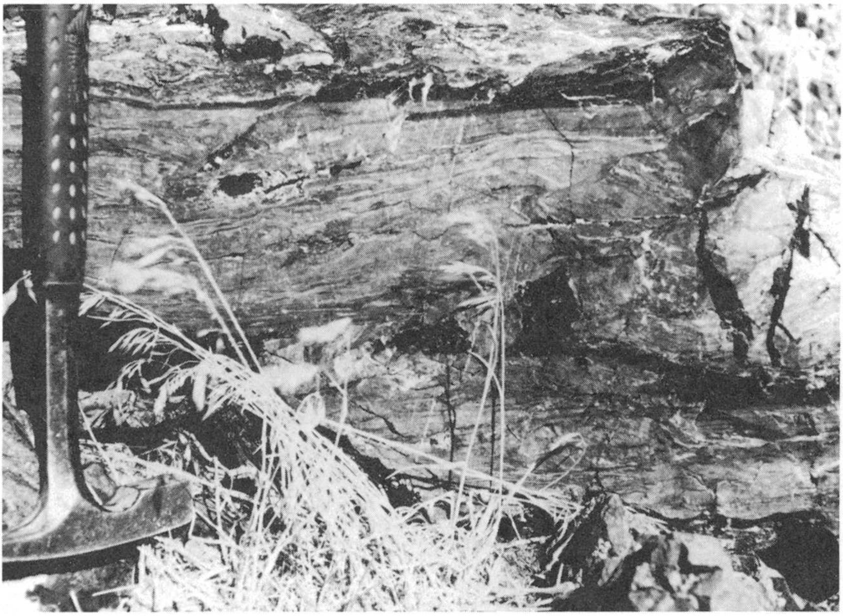


FIGURE 12.—Laminated chert, siliceous assemblage. Float in SW¼ sec. 21, T. 34 N., R. 50 E., Welches Canyon quadrangles. Hammer is 30 cm long.

includes recrystallized chert. Smaller dark-gray to black and blue-gray beds of quartzite occur in the vicinity of the Big Six mine and along the margin of the Roberts Mountains thrust along the north side of the Lynn Window. Limestone within the siliceous assemblage is of numerous varieties: limestone with terrigenous silt interbedded with shale; limestone with quartz sand grading to friable quartz sandstone; intraformational limestone breccia beds; thin-bedded fine-grained limestone with grit, sand, and silt-sized clasts, locally laminated and platy much like the Roberts Mountains Formation; fine-grained thick-bedded to massive limestone with silty and shaly interbeds in which bedding is poorly preserved. The thickest limestone west of the Lynn Window is approximately 122 m thick (fig. 14). Dolomite is thin to thick bedded, pale gray violet, and dark gray. Some of the dolomite is iron rich. The largest lens, in the NE¼NE¼ sec. 5, T. 34 N., R. 50 E., is 3 m thick and 3.5 m long along strike.

The following two sections of the siliceous assemblage seem to be relatively unfaulted; one is directly north of the Lynn Window in N½ sec. 19, S½ sec. 18, T. 35 N., R. 51 E; sec. 11, 12, T. 35 N., R. 50 E.; the other is west of Richmond Mountain, in SW¼SW¼ sec. 35, T. 35 N., R. 50 E.; N½ sec. 5, T. 34 N., R. 50 E.:

FIGURE 13.—Typical exposure of black chert, siliceous assemblage. Thin-bedded to laminated nature of chert is obscure. Bedding slightly thicker in fold hinge. Fold axis plunges gently north-northeast. Hammer is 30 cm long. NW¼ sec. 11, T. 35 N., R. 50 E., Rodeo Creek NE quadrangle.

FIGURE 14.—Thin-bedded limestone with chert lenses, siliceous assemblage. Fold axis plunges gently to north-northwest. Compass is 10 cm long. NE¼ sec. 5, T. 34 N., R. 50 E., Welches Canyon quadrangle.

Section north of the Lynn Window.
Alluvium of Little Boulder Basin.
Contact.

Siliceous assemblage:	*Meters*
Quartzite, gray to white; weathers brown; beds 2.5–25.4 cm thick; locally massive	610
Chert, gray, white, and black; beds 2.5–5 cm thick; commonly laminated; locally nodular	336
Shale, gray and black; laminated; contains zones of thin-bedded black chert to 6.1 m thick	763
Shale, gray, brown, and black; laminated; interbedded with thin-bedded to laminated limestone and silty limestone; intraformational breccia and sandy limestone occur about 305 m above the base of the section	763
Total thickness	3472

Contact.
Alluvium of Maggie Creek Valley.
Section west of Richmond Mountain.
Carbonate assemblage.
West Lynn thrust.

Siliceous assemblage:	*Meters*
Interbedded thin-bedded chert, shale, and minor limestone (shown on map as SOw); beds 2.5–7.5 cm thick; intraformational breccia near the top of the section	183
Interbedded gray and black chert and cherty shale (on map included with above unit); beds 2.5–5 cm thick; also laminated	275
Shale, gray, black, and brown; well-developed bedding fissility; dolomite lens 3 m thick occurs 91.5 m below top of interval	336
Limestone, black-gray; beds generally 2.5–15.2 cm thick; locally bedding is thicker than 15 cm or massive; contains grit, sand, and silt-sized clasts of chert and quartz; some black chert and siliceous siltstone beds to 5 cm thick	122
Interbedded black and brown chert and shale; becomes more shaly toward the top of the interval; grades into silty and shaly limestone at top	488
Total thickness	1,404

Contact.
Alluvium of Boulder Valley.

The section north of the Lynn Window is assumed to be right side up with quartzite on top. Beds in the section west of Richmond Mountain, however, dip steeply and could be overturned, as rocks of the carbonate assemblage in the area are overturned.

Shale in the siliceous assemblage is composed chiefly of very fine grained, semiopaque, nearly cryptocrystalline material surrounding subangular quartz grains 0.01–0.05 mm across. The quartz grains generally constitute less than 20 percent of the rock. From X-ray diffraction patterns, quartz is clearly the principal constituent and must be a major component of the extremely fine grained portion of the rock. Illite, the other major constituent (to 50 percent), occurs with carbonaceous material, which gives the rock its generally dark color. Common accessory minerals are magnetite and also hematite in pseudomorphs after pyrite. In places, the silty shale contains dolomite and grades into dolomitic siltstone.

Chert in the siliceous assemblage is 80–98 percent microcrystalline, nearly cryptocrystalline quartz. As much as 20 percent of the chert consists of clasts (quartz, chert, radiolaria tests, spicules) to 0.1 mm across. Carbonaceous material, present in varying amounts, is responsible for the generally dark color of the chert. Chlorite, clay, epidote, and hematite are common accessories. The quartzite is nearly pure quartz (90–98 percent). Clastic grains, rounded to angular and from 0.05–0.108 mm across, are in a matrix of very fine grained quartz (less than 0.01 mm across). Clay, chiefly illite with less common kaolinite concentrated in bedding laminae, typically constitutes a few percent of the chert. Hematite and partly sericitized plagioclase (clasts) are accessory minerals.

The siliceous assemblage rocks have been partly metamorphosed north of the Lynn Window and in the Welches Canyon area. The partly metamorphosed chert and shale contain biotite (to 15 percent), hornblende (to 5 percent), epidote, idocrase, sphene, and tourmaline. The metamorphosed limestones contain pyroxene (to 40 percent), black and green garnet (to 30 percent), tremolite (to 25 percent), and minor amounts of biotite, fluorite, hematite, hornblende, magnetite, and sphene. Metamorphic effects (bleaching, recrystallization, and neomineralization) are most intense near the granodiorite plug at the Gold Strike Claims and in the vicinity of the intrusions in the Welches Canyon area.

The siliceous assemblage is 2,472 m thick in the section north of the Lynn Window and 1,404 m in the area west of Richmond Mountain, which contains lithologic types not found north of the window. The amount of stratigraphic duplication in the two areas is not known. The siliceous assemblage could be as much as 3,000 m thick in the southern Tuscarora Mountains.

Most of the graptolites from the chert and shale and conodonts from the limestone, listed in tables 9 and 10, are Early to Late Ordovician in age. Some Silurian graptolites were found. The oldest fossils are conodonts of Early Ordovician age in gritty limestone from the section west of Richmond Mountain. Graptolites (see Roberts and others, 1967, p. 128) and conodonts (table 9, loc. M426, M428) from the shale and limestone near the bottom of the section north of the Lynn Window are Middle and Late Ordovician in age. The upper part of the section may range into the Silurian, as Silurian graptolites occur near the Carlin gold mine (loc. HM). The Ordovician strata correlate with parts of the Vinini Formation at its type locality in Roberts Creek Mountain.

TABLE 9.—*Conodonts from limestones in siliceous assemblage*

[Fossils collected by J. G. Evans. Conodont identifications and age interpretations by J. W. Huddle (written commun., 1969, 1970)]

USGS fossil colln. no Field colln. No. Species	6710 CO L224	6992 CO L386	6754 CO M428	6753 CO M426
Acodus sp	------	1	------	------
Acontiodus sp	------	------	------	1
Cordylodus angulatus Palmer	26	------	------	------
C. cf. *prion* Lindström	5	------	------	------
C. sp	------	------	------	16
C. 2 spp	------	------	22	------
Cyrtoniodus flexuosus (Branson and Mehl)	------	------	11	------
Drepanodus suberectus (Branson and Mehl)	------	8	------	------
D. sp	------	1	------	1
D. ?sp	------	------	1	------
Multioistodus sp. single element	------	6	------	------
M. double element	------	2	------	------
Oistodus sp.	------	2	------	------
Oneotus variabilis Lindström	9	------	------	------
Paltodus sp	------	------	1	------
P. 2 spp	------	------	------	3
Periodon aculeatus Hadding (falodus element)	------	6	------	------
Phragmodus undatus (Branson and Mehl)	------	------	1	------
Plectodina? sp	------	------	1	5
Polyplacognathus sp	------	1	------	------
Scandodus	------	------	1	------
Scolopodus aff. *S. varicostatus* (Sweet and Bergström)	------	2	------	------
Tetraprioniodus sp	1	------	------	------

6710CO–L224 Early Ordovician. These forms occur in Oneota Dolomite and in lowest Ordovician zone in Sweden.
6992CO–L386 Middle Ordovician probably. Indicated by *Polyplacognathus*, which is no older than Middle Ordovician and by *Multioistodus*, which is no younger than Middle Ordovician.
6754CO–M428 } Middle and Late Ordovician *Phragmodus* has been found in uppermost Antelope Valley Lime-
6753CO–M426 } stone, and Copenhagen Formation in Nevada.

Fossil locations:
L224, NE¼ sec. 5, T. 34 N., R. 50 E.
L386, SE¼ sec. 6, T. 33 N., R. 50 E.
M428, NE¼ sec. 19, T. 35 N., R. 51 E.
M426, SW¼ same section, same township

Middle Silurian graptolites occur in shale at three widely separated localities, M193, HM, and L380. M193 is north of the Lynn Window in the SW cor., T. 36 N., R. 51 E., unsurveyed; HM near the Roberts Mountains thrust at the Carlin gold mine; and L380 south of the Lynn Window in sec. 31, T. 34 N., R. 50 E. Locality HM is probably in a thrust slice, and the others may also be in fault slivers. Silurian rocks in the siliceous assemblage occur on Marys Mountain, south of the Welches Canyon quadrangle (Smith and Ketner, 1975, p. A17). The nearest formally recognized Silurian units of the siliceous assemblage are the Elder Sandstone in the Cortez area and in the northern Shoshone Range 75 km southwest of the Lynn Window and the Fourmile Canyon Formation of the Cortez area (Gilluly and Gates, 1965, p. 35–36; Gilluly and Masursky, 1965, p. 54–58). The Elder Sandstone is Silurian in the northern Shoshone Range. The Fourmile Canyon Formation, made up of chert, siltstone, argillite, and shale, is Early Silurian. The siliceous rocks of Silurian age in the southern Tuscarora Mountains are equivalent in age but not in general lithology to the Elder Sandstone.

TRANSITIONAL ASSEMBLAGE

The transitional assemblage, mostly limestone, is poorly exposed in fault slivers south of the Lynn Window. It tends to underlie high points on ridges and forms the high ridge north of James Creek along the east edge of the Welches Canyon quadrangle. Slopes underlain by the transitional assemblage are typically covered by light-gray soil with abundant angular fragments of gray- and light-blue-gray-weathering limestone.

On fresh surfaces, the limestone is dark gray to black. It is fine grained, thin to thick bedded, and laminated. Most of the limestone has siliceous clasts of sand and silt-sized gray, blue-green, and black chert fragments and quartz. Locally the rock is calcareous crossbedded sandstone. Some of the limestone contains angular to subrounded pebbles and cobbles of chert to 10 cm across. Pure limestone and limestone with calcareous clasts are present. Black chert and siliceous shale beds to 15 m thick are common in the easternmost fault sliver of the transitional assemblage. The northern edge of one of the fault slivers is near the Tertiary quartz latite and granodiorite intrusions near Welches Canyon. This limestone has been metamorphosed to a creamy white laminated garnetite with chalcedony filling the cavities between the garnet grains.

The transitional limestone in southeast Welches Canyon quadrangle is estimated to be 885 m thick. An additional 30 m occurs in the part of the section that extends into the adjacent Schroeder Mountain quadrangle, making the total known thickness about 915 m.

Conodonts from the transitional assemblage, listed on table 11, range in age from early Late to middle Late Devonian (J. W. Huddle, written commun., 1971), approximately the same age or younger than the highest Devonian beds in the carbonate assemblage in the Lynn Window. The transitional assemblage appears to be part of a hitherto unrecognized formation deposited between the carbonate and siliceous assemblages and brought into the southern Tuscarora Mountains during the Antler orogeny.

GEOLOGICAL SUMMARY OF PALEOZOIC ROCKS

The history of the deposition of the Paleozoic rocks of the southern Tuscarora Mountains can be inferred for the period from Middle to Late Cambrian to early Late Devonian for the carbonate assemblage; for the Ordovician and Middle Silurian for the siliceous assemblage; and for the Late Devonian for the transitional assemblage. The carbonate assemblage, though cut by many thrusts, is assumed to be virtually autochthonous. The siliceous and transitional assemblages

TABLE 10.—*Graptolithina from the siliceous assemblage*

[Graptolites identified by R. J. Ross, Jr. (written commun., 1969, 1970, 1971) and W. B. N. Berry (written commun., 1970). Fossils collected by J. G. Evans and Homestake Mining (HM)]

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Amplexograptus confertus Lapworth	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
A. cf. *A. confertus* (Lapworth)	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
A. differtus Harris and Thomas	--	×	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
A. sp. (small sp.)	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
A. sp. (2 small sp.)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
A. sp	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Climacograptus cf. *C. minimus* Carruthers	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	×	--	--	--	--	--
C. scharenbergi	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--
C. spiniferus Ruedeman	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--
C. cf. *C. typicalis* J. Hall	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	×	--	--	--
c. n. sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--
C. sp	--	--	--	--	--	--	×	--	--	--	×	×	×	×	×	--	×	--	--	--	--
Cryptolgraptus schäferi Lapworth	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
C. tricornis (Carruthers)	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Diplograptus decoratus var. *amplexograptoides* Ross and Berry	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D. ?sp. (may be var. *Glyptograptus* cf. *G. teretiuscalos*)	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D. sp	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
D. ?sp	--	--	--	--	--	--	×	--	--	--	--	--	--	×	×	--	--	×	--	--	--
Dicaulograptus sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
Dicellograptus cf. *D. caduseus* Lapworth	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
D. cf. *D. gurleyi* Lapworth	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--
D. cf. *D. sextans* var. *exilis* Elles and Wood	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
D. sp. (probably close to *D. sextans* var. *exilis*)	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D. sp. (large)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
or *Dicranograptus* sp	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--
Dichograptid	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
unisenal, 3 spp	--	×	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Didymograptus sp. (extensiform type)	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D. ?sp. (at least 2 sp.)	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Glossograptus hincksii (Hopkinson), poss. n. sp	--	×	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
G. cf. *G. hincksii* var. *fimbriatus* (Hopkinson), poss. n. sp.	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Glytograptus teretiusculus (Hisinger)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
G. sp	--	--	--	--	--	×	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--
G. ?sp	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Orthograptus cf. *O. calcaratus* (Lapworth)	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	×	--	--	--
O. quadrimucronatus Hall	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--
O. of the *O. quadrimucronatus* group	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	×	×	--	--	--
O. ?sp., of *O. quadrimucronatus* type	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
O. ?*truncatus* var. *intermedius*	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--
O. truncatus cf. var. *pauperatus* (Elles and Wood)	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--

?. sp. (of the *O. truncatus* group?)	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--
O. sp. (very small)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
O. ?sp. (may be *Paraglossograptus*)	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
O. ?sp	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pterograptus ?sp	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sigmagraptus sp. (probably new sp.)	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Caryocaris sp	--	×	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--
Cyrtograptus sp	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×
Monograptus cf. *N. praedubius* Boucer	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×
M. spiralis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--
M. testis (Barrande)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×
Monograptids (poss. of *M. dubius* type)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--

USGS fossil colln. No.	*Field colln. No.*	*Age*	*Fossil location*
1. D2133Co	M548	Either Llanvirnian or Llandeilian—Ross	NE¼ sec. 15, T. 35 N., R. 50 E.
2. D2005CO	M278	Highest Llanvirnian or Llandeilian—Ross	Little Jack Creek, T. 36 N., R. 50 E., unsurveyed
3. D2006CO	L266	Highest Llanvirnian or Llandeilian—Ross	NW¼ sec. 21, T. 34 N., R. 50 E.
4. D2157	L364	Early to Middle Ordovician—Berry	NW¼ sec. 32, T. 34 N., R. 51 E.
5. D2156	L363	Early to Middle Ordovician—Berry	SW¼ sec. 29, same township
6. D2002CO	M222	Early Caradocian—Ross	West summit 6784, T. 36 N., R. 50 E., unsurveyed
7. D2004CO	M158	Early to middle Caradocian—Ross	NE¼ sec. 1, T. 35 N., R. 50 E.
8. D2003CO	M159	Early late Caradocian—Ross	Do.
9. D2240CO	L397	Late Caradocian—Ross	SE. cor. sec. 2, T. 33 N., R. 50 E.
10. D2001CO	M180	Early Caradocian Posibly early late Caradocian—Ross	Headwaters Cottonwood Creek, T. 36 N., R. 50 E., unsurveyed
11. D2152	L348	Probably late Middle Ordovician—Berry	SE¼ sec. 2, T. 34 N., R. 50 E.
12. D2160	L377	Late Middle to Late Ordovician—Berry	E¼ sec. 12, T. 33 N., R. 50 E.
13. D2153	L358	Middle to Late Ordovician—Berry	SW¼ sec. 36, T. 34 N., R. 50 E.
14. D2159	L376	Middle to Late Ordovician. Probably Middle—Berry	SW¼ sec. 9, T. 33 N., R. 51 E.
15. D2158	L373	Middle to Late Ordovician. Probably Middle—Berry	E½ sec. 1, T. 33 N., R. 50 E.
16.	L551	Two species seem to indicate zone 14 of Berry, the other zones 11 and 12—Ross	SW¼ sec. 35, T. 34 N., R. 50 E.
17. D2155	L360	Late Middle or Late Ordovician. Zones 13–14—Berry	NW¼ sec. 1, T. 33 N., R. 50 E.
18. D2154	L359	Late Middle to Late Ordovician. Zones 13–24—Berry	Boundary between secs. 35 and 36, T. 34 N., R. 50 E.
19.	HM	Late Llandoverian. *M. spiralis* Zone	Near NE. cor. sec. 15, T. 35 N., R. 50 E.
20. D240SD	M193	Latest Llandoverian-Ludlovian or possibly late Llandoverian-Pridoli—Berry	North of Cottonwood Creek, T. 36 N., R. 51 E., unsurveyed
21. D274	S380	Late Wenlockian—Berry	NE¼ sec. 32, T. 34 N., R. 50 E.

TABLE 11.—*Conodonts from transitional assemblage*

[Conodonts collected by J. G. Evans, identified by J. W. Huddle (written commun., 1971)]

USGS fossil colln. No. / Field colln. No.	8805 SD L371	8802 SD L367	8806 SD L379	8803 SD L368	8801 SD L366	8804 SD L369	8852 SD L276	8859 SD L493	8858 SD L475	8857 SD L473	8856 SD L467
Species											
Acodina sp.	--	--	--	--	4	--	--	--	--	--	--
Ancyrodella curvata (Branson and Mehl)	--	--	3	--	--	--	--	--	--	2	--
A. gigas Youngquist	9	--	--	--	--	--	--	--	--	--	--
A. nodosa Ulrich and Bassler?	--	--	--	--	--	--	5	--	--	--	--
A. rotundiloba (Bryant)	18	22	--	5	--	--	15	--	--	--	22
A. rotundiloba alata (Glenister and Klapper)	9	--	--	--	--	--	--	--	--	--	--
A. rotundiloba aff. *alata* (Glenister and Klapper)	--	--	--	18	--	--	--	--	--	--	--
A. rugosa Branson and Mehl	--	--	--	5	--	--	--	--	--	--	--
A. sp.	--	--	--	--	1	--	--	--	--	--	--
Belodella sp	1	--	--	--	--	--	--	--	--	--	--
Bryantodus collingatus (Bryant)	4	3	--	--	--	--	--	--	--	--	--
B. multidens Ulrich and Bassler	--	--	--	--	--	--	8	9	--	--	--
B. radiatus (Hinde)	--	--	--	--	--	--	8	--	--	--	5
B. retusus (Bryant)	7	8	--	30	--	--	--	--	--	--	--
B. sp	11	--	--	--	--	5	--	4	--	--	--
B. 2sp.	--	--	--	--	11	--	--	--	--	--	--
Dinodus sp	--	--	--	--	--	1	--	--	--	--	--
Diplododella sp	1	--	--	2	--	--	--	--	--	1	--
Fanteognathus sp	--	--	--	--	--	2	--	--	--	--	--
Falcodus gunthari Ziegler?	--	--	--	--	--	--	--	--	--	--	2
Hibbardella sp	--	--	--	1	--	--	--	1	--	--	1
Hindeodella? unca Bischoff	--	--	--	--	--	8	--	--	--	--	--
H. sp	10	--	--	18	1	--	--	--	14	6	11
Icriodus costatus (Thomas)	--	--	--	--	--	--	--	--	14	--	--
I. expansus Branson and Mehl	--	1	--	--	--	--	--	--	--	--	--
I. laticrescens Branson and Mehl	8	--	--	--	--	--	--	5	--	--	7
I. cf *I. laticrescens* Branson and Mehl	--	7	--	--	--	--	--	--	--	--	--
I. nodosus (Huddle)	--	5	--	--	--	--	--	5	--	--	3
I. cf. *I. nodosus* (Huddle)	2	--	--	--	--	--	--	--	--	--	--
I. symmetricus Branson and Mehl	11	--	--	--	--	--	--	--	--	--	--
I. sp	--	--	--	7	--	4	2	--	--	--	--
I. 2sp	35	--	--	--	14	--	--	--	--	--	--
Ligonodina sp	3	--	--	--	1	4	3	3	--	--	3
Lonchodina sp	--	--	1	1	--	--	--	--	--	--	1
Neoprioniodus alatus (Hinde)	--	1	--	--	--	--	--	1	--	--	--
N. sp	--	--	--	--	2	3	--	--	--	1	3
Nothognathella sp	19	4	--	--	--	16	20	1	10	8	11

Ozarkodina sp	6	------	------	------	------	------	------	------	------	------	------
Palmatodella? unca? Sanneman	------	------	------	------	------	1	------	------	------	------	------
Palmatolepsis crepida? Sanneman	------	------	------	------	9	------	------	------	------	------	------
P. decorosus Stauffer	------	------	------	------	------	------	------	------	------	22	------
P. delicatula clarki Ziegler	------	------	------	------	------	5	------	------	------	------	------
P. aff. *P. delicatula clarki* Ziegler	------	------	------	------	------	4	------	------	------	------	------
P. foliacea Youngquist	------	------	------	------	------	------	------	------	------	13	------
P. gigas Miller and Youngquist	------	------	------	------	------	------	------	------	2	34	------
P. minuta Branson and Mehl	------	------	6	------	2	1	------	------	------	------	------
P. cf. *P. minuta* Branson and Mehl	------	------	------	------	------	------	------	------	4	------	------
P. normalis Miller and Youngquist	------	------	------	------	------	------	------	------	------	2	------
P. proversa Ziegler	------	------	2	------	------	------	------	------	------	7	------
P. quadrant modosalobata Sanneman	------	------	12	------	5	------	------	------	14	------	------
P. cf. *P. regularis* Cooper	------	------	14	------	------	------	------	------	------	------	------
P. subperlobata Branson and Mehl	------	------	50	------	3	------	------	------	------	------	------
P. subrecta Miller and Youngquist	------	------	10	------	9	------	------	------	------	------	------
P. cf. *P. transitans* Müller	1	------	------	------	------	------	------	------	------	------	------
P. triangularis Sanneman	------	------	6	------	10	80	------	------	------	------	------
P. unicornis Miller and Youngquist	------	------	------	------	------	------	------	------	5	------	------
Panderodus sp	------	------	1	------	------	------	------	------	------	------	------
Pelekysgnathus sp	------	------	------	------	1	1	------	------	------	------	------
Pdygnathellus sp	------	------	------	------	------	------	------	1	------	------	------
Polygnathus alatus Ulrich and Bassler	------	------	------	------	2	------	------	------	------	------	------
P. ancyrognathoideus Ziegler?	------	------	------	------	------	------	------	------	------	------	1
P. asymmetricus Bischoff and Ziegler	63	40	1	43	------	------	130	16	------	------	------
a. *asymmetricus* Bischoff and Ziegler	------	------	------	------	------	------	------	------	------	------	45
P. aff. *P. brevilaminatus* Branson and Mehl	------	------	------	------	------	------	------	------	3	------	------
P. brevilanima Branson and Mehl	------	------	------	1	1	------	------	------	------	------	------
P. aff. *P. cristatus* (Hinde)	------	1	------	------	------	------	------	------	7	------	------
P. cf. *P. cristatus* (Hinde)	------	------	------	2	------	------	------	------	------	------	------
P. decorosus Stauffer	------	------	4	------	5	9	------	------	------	------	------
P. dengleri Bischoff and Ziegler	7	6	------	------	------	------	2	------	------	------	4
P. dubius Hinde	37	42	------	50	------	------	14	19	------	------	15
P. foveolatus Philip and Jackson	8	------	------	7	------	------	------	------	------	------	------
P. aff. *P. inornatus* E. R. Branson	------	------	------	------	------	------	------	------	11	------	------
P. lingurformis Hinde	13	2	1	------	------	------	5	7	------	------	4
P. normalis Miller and Youngquist	------	------	------	------	3	------	------	------	------	------	------
P. ordinatus Bryant	------	2	------	------	------	------	------	------	------	------	------
P. pennatus Hinde	1	2	------	2	------	------	------	------	------	------	------
P. varcus Stauffer	3	------	2	3	------	------	------	------	------	------	------
P. cf. *P. varcus* Stauffer	4	------	------	------	------	------	------	------	------	------	50
P. cf. *P. webbi* Stauffer	------	------	------	------	------	7	2	------	------	------	------
P. sp	------	------	------	------	------	------	------	------	------	------	------
Prioniodina dialata (Bryant)	2	2	------	1	------	------	------	4	------	------	------
Schmidtognathus sp	4	------	------	------	------	------	------	------	------	------	------
Synprioniodina prona (huddle)	------	2	------	------	------	------	------	------	------	------	------
S. sp	------	------	6	------	------	------	------	------	3	------	------

TABLE 11.—*Conodonts from transitional assemblage*—Continued

Fossil location	*Age*
L371, boundary between sec. 5 and 8, T. 33 N., R. 51 E.	Probably early Late Devonian *Polygnathus, foveolatus* and *linguiformis* probably reworked from older Devonian
L367, near SE cor. sec. 36, T. 34 N., R. 50 E.	Early Late Devonian in upper *Polygnathus asymmetricus* Zone
L379, NE¼ sec. 8, T. 33 N., R. 51 E.	Late Devonian. Probably *Polygnathus triangularis* Zone. *P. asymmetricus varcus* and *linguiformis* and *Polygnathus pioversa* reworked from older rocks
L368, NE¼ sec. 8, T. 33 N., R. 51 E.	Probably early Late Devonian in *Polygnathus asymmetricus* Zone. *P. foveolatus* and *varcus* probably reworked from older rocks
L366, NW¼ sec. 82, T. 34 N., R. 51 E.	Late Devonian. Probably *Palmatolepsis triangularus* Zone or perhaps in overlying *P. crepida* Zone near Frasnian-Fammenian boundary
L369, NW¼ sec. 4, T. 33 N., R. 51 E.	Late Devonian near boundary of Frasnian and Fammenian in *Palmatolepsis triangularis* Zone
L276, NW¼ sec. 28, T. 34 N., R. 50 E.	Late Devonian. Upper *Polygnathus asymmetricus* Zone
L493, NE¼ sec. 5, T. 33 N., R. 50 E.	Early Late Devonian. *Polygnathus asymmetricus* Zone
L475, SW¼ sec.4, T. 33 N., R. 51 E.	Late Devonian. Probably near Frasnian-Fammenian boundary
L473, NW¼ sec. 4, T. 33 N., R. 51 E.	Early Late Devonian. Probably in lower *Palmatolepsis gigas* Zone. Same fauna in lower part of Sweetland Creek Shale, Iowa
L467, SE¼ sec. 16, T. 34 N., R 50 E.	Late Devonian. Upper *Polygnathus asymmetricus* Zone

are allochthonous above the Roberts Mountains thrust. The sites of deposition of these two assemblages are only roughly known by inference. Based on interpretations of the regional stratigraphy (Roberts and others, 1958), the siliceous and transitional assemblages are inferred to have been deposited west of the carbonate assemblage; the siliceous assemblage was originally west of the transitional assemblage.

The oldest sedimentary rock exposed at the Lynn Window is the autochthonous Hamburg Dolomite of Middle and Late Cambrian age. In the Eureka area, 155 km south of the Lynn Window, the Hamburg Dolomite is succeeded by the Upper Cambrian Dunderberg Shale and Windfall Formation (Nolan and others, 1956, p. 18–22). At the Lynn Window, these two formations are absent, and the Hamburg Dolomite is unconformably overlain by the Pogonip Group. This unconformity apparently does not represent as great a hiatus as the unconformity above the Hamburg Dolomite in the Cortez Mountains 80 km to the south. At Cortez the Pogonip Group is missing and the Hamburg Dolomite is succeeded by Eureka Quartzite (Gilluly and Masursky, 1965, pl. 1).

The Pogonip Group, ranging in age from Early to Middle Ordovician, is divided into four informal units in the Lynn Window. These units contain rock types similar to the formally named units in the Pogonip (Goodwin Limestone, Ninemile Formation, Antelope Valley Limestone), although these formal units could not be definitely identified in the Lynn Window in part owing to alteration of the rock and poor exposures.

The Eureka Quartzite at the Lynn Window overlies the Pogonip Group with a slight angular unconformity, a part of the regional unconformity recognized at the base of the Eureka Quartzite (Nolan and others, 1956, p. 30–31). The quartz-rich upper Middle Ordovician Eureka represents a major change in the sedimentation pattern in the largely carbonate-bearing lower Paleozoic sequence. The most likely source of the sand in the quartzite is in northern Alberta, Canada (Ketner, 1968). The Eureka Quartzite in the Lynn Window and in the Seetoya Mountains, 40 km north of the Lynn Window is two to three times thicker than in other areas of eastern Nevada and western Utah.

The Hanson Creek Formation (late Middle Ordovician to Early Silurian age) in the Lynn Window overlies the Eureka Quartzite with a slight disconformity, a part of the regional unconformity at the base of the Hanson Creek Formation (Nolan and others, 1956, p. 30–31). The uppermost massive dolomite beds of the Hanson Creek contain angular to rounded sand-sized clasts of quartz and chert (37 m max) and local intraformational breccia. The breccia reflects temporary high-energy conditions rather than the quiet-water deposition represented by the rest of the formation. The Hanson Creek Formation is two to six times thicker at the Lynn Window than in the Roberts Mountains, in the Eureka area, at Lone Mountain (Nolan and others, 1956, p. 33), and in the northern Piñon Range (Smith and Ketner, 1975, p. A6).

The siliceous assemblage was being deposited west of the southern Tuscarora Mountains during the Ordovician and Silurian. Some of those strata are equivalent to the Ordovician Vinini Formation. The generally fine to very fine grain sizes and fine laminations in the shale and chert indicate that deposition in quiet water was typical. In places the lithified chert beds were eroded, for associated limestone locally contains angular chert clasts. Intraformational breccia in the siliceous assemblage points to at least local erosion and a somewhat turbulent environment during parts of the Ordovician and Silurian. The depositional sequence of the siliceous assemblage is not clear. Limestone, with Early Ordovician conodonts, occurs in the 1,404-m-thick section west of the Lynn Window. The chert shale and sedimentary breccia beds in that section are steeply dipping and contain no sedimentary textures or structures to indicate the original top of the section. Middle and Late Ordovician graptolites and conodonts occur near the bottom of the 2,472-m-thick section north of the Lynn Window. The lower part of the section, dominantly shale, also contains calcareous sandstone, silty limestone, limy shale, and intraformational limestone breccia. The age of the upper 1,700 m of the section, mostly shale, chert, and quartzite, is not known. It may range into the Silurian, as Silurian strata are known in the siliceous assemblage nearby.

The Roberts Mountains Formation, typically a silty laminated dolomitic limestone, was deposited on the site of the southern Tuscarora Mountains in Middle Silurian to Early Devonian time. A disconformity was reported by Berry and Roen (1963) at the base of the formation, but the disconformity was not seen in this study. The Roberts Mountains Formation appears to be conformable above the Hanson Creek Formation. Beds of limestone breccia increase in number in the thin-bedded limestone toward the top of the formation.

The autochthonous Popovich Formation, ranging from Early to early Late Devonian in age, consists largely of laminated to thin-bedded limestone interbedded with thick-bedded to massive limestone, representing reeflike deposits, and intraformational breccia. This limestone interval was informally subdivided into five units, four of which can be roughly correlated with Devonian formations recognized to the south of the southern Tuscarora Mountains, from oldest to youngest: Windmill Limestone of Johnson (1965), Rabbit

Hill Limestone, McColley Canyon Formation of Johnson (1962), and Denay Limestone. The uppermost 60 m of the Popovich Formation contains abundant clastic debris such as intraformational breccia, quartz sand, and bioclastic material, indicating an increasingly turbulent depositional environment in the Late Devonian.

Contemporaneous with the upper part of the autochthonous Popovich Formation of the carbonate assemblage, the Lower to middle Upper Devonian strata of the transitional assemblage were deposited west of the southern Tuscarora Mountains. The transitional assemblage, chiefly limestone, contains chert and shale beds, much sandy limestone with quartz and chert clasts, and, locally, rounded pebbles and cobbles of chert. The rounded chert clasts indicate erosion of a lithified chert terrain and transport of the clasts for some distance. The erosion may have been related to uplift of the siliceous assemblage in the early stages of the Antler orogeny.

IGNEOUS ROCKS

BASALT

Dark-green, black, gray, and brown sills of aphanitic basalt 6 to 75 m thick intrude the siliceous assemblage south of the Lynn Window. Some of them contain as much as 25 percent phenocrysts, mainly plagioclase and biotite to 2 mm long and conspicuous amygdules of calcite and jarosite. The largest sill, in NE½ sec. 1, T. 33 N., R. 50 E., contains numerous xenoliths of light-gray to white marble, including a layer of bedded marble 3 m long and 0.9 m thick. The groundmass of the basalt is composed of a felted mass of feldspar laths and biotite and magnetite grains to 0.05 mm across. The plagioclase is partly sericitized, the biotite partly chloritized. In some of the sills, the mineral grains are so small that no minerals could be identified with certainty under the petrographic microscope.

A chemical analysis of a sample of one of the dark-green cryptocrystalline dikes given in table 12 shows a silica content consistent with the field designation "basalt" (see analyses in Carmichael and others, 1974, p. 33; Wilkinson, 1967, p. 199). The rock is rather high in Na_2O and low in MgO for a basalt, however, probably altered from its original composition.

The exact age of these sills is unknown. They can be no older than the Ordovician rocks they intrude but could have been emplaced during the deposition of the siliceous assemblage rocks in the Ordovician or even intruded later in the Paleozoic. A clue to the age of the sills is an eastward-dipping thrust fault that cuts one of the sills. The thrust may be no younger than Mesozoic and therefore the sills could be no younger than Mesozoic.

TABLE 12—*Analysis of basalt from SW¼SE¼ sec. 5, T. 33 N., R. 51 E., Welches Canyon quadrangle*

[Chemical analyses by rapid rock method; analysts: P. L. D. Elmore, Hezekiah Smith, Gillison Chloe, James Kelsey, and J. L. Glenn. Semiquantitative spectrographic analyses for 30 elements by Chris Heropoulos; gold by atomic absorption, mercury by detector. Looked for but not found, Ag, As, Au, B, Be, Bi, Cd, Cr, Eu, Ge, Hf, In, Li, Mo, Ni, Pb, Pd, Pr, Pt, Re, Sb, Sm, Sn, Ta, Te, Th, Tl, U, W. Zn. Collected by J. G. Evans]

Sample field No. L478			
Chemical analysis (weight percent)		Minor-element composition (parts per million)	
SiO_2	51.9	Ba	500
Al_2O_3	13.2	Ce	150
Fe_2O_3	1.8	Co	15
FeO	5.0	Cu	1.5
MgO	3.1	Ga	20
CaO	7.7	Hg	.24
Na_2O	4.8	La	100
K_2O	.21	Nb	50
H_2O+	3.0	Nd	70
H_2O-	.38	Sc	20
TiO_2	2.8	Sr	100
P_2O_5	.6	V	150
MnO	.1	Y	50
CO_2	5.3	Yb	3
		Zr	200
Total	100		

CRETACEOUS GRANODIORITE

Two small stocks and several dikes of granodiorite[1] (quartz monzonite, IUGS)[2] and granodiorite porphyry intrude the siliceous rocks north of the Lynn Window. Most of the dikes form conspicuous ledges. The stocks, however, are poorly exposed, being covered with gray to brown soil containing numerous subrounded granodiorite pebbles.

The dikes of massive white to dark-gray, fine- to medium-grained, somewhat porphyritic granodiorite are 1 m to 30 m wide and as much as 300 m long. Some of them are dark greenish gray from saussuritization and are speckled with white plagioclase phenocrysts. The granodiorite in the stock at the Gold Strike Claims contains xenoliths of calc-silicate hornfels and quartzite several centimeters to several meters across.

The granodiorite is composed of plagioclase in the range andesine to labradorite (50–60 percent), mafic minerals (pyroxene, hornblende, biotite; 15–25 percent), potassium feldspar (15 percent), and quartz (generally 10 percent; as much as 30 percent in some samples). The plagioclase laths of the stocks are 0.5–1 mm long. Apatite, magnetite, and sphene are interstitial to the plagioclase. Some biotite occurs in rims of pyroxene grains. Partial alteration of the mafic minerals to chlorite is common.

[1]Classification of Bateman (1961).
[2]The rock name in parentheses is from the nomenclature for phaneritic igneousrocks as recommended by the International Union of Geological Sciences (IUGS) Subcommission on the Systemics of Igneous Rocks (Geotimes, 1973).

Chemical and spectrographic analyses were made of four samples of the granodiorite, samples M517, M518, and M523D from the stock exposed at the Gold Strike Claims and sample M393 from the stock east of Little Boulder Basin (table 13), and CIPW norms were determined for three of them. Sample M518 is much higher in CaO and MgO and lower in potassium feldspar than the other three samples. This analysis may reflect the influence of a partially digested carbonate xenolith.

Hausen (1967), using the potassium-argon method, dated biotite from a sample of granodiorite at the Gold Strike Claim at 121±5 m.y., or Early Cretaceous. Only one other intrusive of about this age is known in north-central Nevada, a body in Dawley Canyon, southern Ruby Mountains, about 95 km southeast of the Gold Strike Claim (Willden and Kistler, 1969). It is possible that the age determined on the slightly altered stock at the Gold Strike Claim is not the age of emplacement of the intrusion and that the intrusion is somewhat more than 121 m.y. old.

QUARTZ MONZONITE

A small stock and several dikes of quartz monzonite occur in the southern Lynn Window. The widespread metamorphism of the carbonate rocks and a magnetic anomaly (U.S. Geol. Survey, 1967) in southern Lynn Window suggest that the quartz monzonite intrusives mapped are apophyses of a larger concealed pluton (cross sections C–C′, D–D′, pl. 2). Most of the quartz monzonite weathers to grus.

The buff to light-gray, commonly porphyritic quartz monzonite is composed of the following: quartz, 35–40 percent; oligoclase, 25–35 percent; and potassium feldspar, chiefly perthite, 25–35 percent. Complexly twinned, anhedral, nearly equant plagioclase and quartz grains are 0.1–2 mm across. The potassium feldspar generally occurs in anhedral grains but also forms euhedral phenocrysts to 1 cm long. Biotite, magnetite, muscovite, sphene, and tourmaline are accessory minerals. The biotite is commonly partly chloritized and in some samples is intergrown with muscovite.

The chemical and spectrographic analyses of three samples of the quartz monzonite and the CIPW norm for one of them are given in table 14. Sample L317 is quartz monzonite (granite, IUGS). Samples L7 and L63A are low in Na_2O and CaO, and each contains 700 ppm arsenic; these two samples are probably altered.

Using the potassium-argon method, M. L. Silberman (written commun., 1971) dated biotite from the quartz monzonite stock (sample L317) at 106±2 m.y., or Early Cretaceous. The quartz monzonite has an age close to the ages of several other plutons to the south and

TABLE 13.—*Chemical and spectrographic analyses and C.I.P.W. norms of Cretaceous granodiorite from Rodeo Creek NE quadrangle*

[Chemical analyses by rapid rock method; analysts: P. L. D. Elmore, Hezekiah Smith, Gillison Chloe, James Kelsey, and J. L. Glenn. Semiquantitative spectrographic analyses for 30 elements by Chris Heropoulos; gold by atomic absorption, mercury by detector. Ag, As, Bi, Cd, Li, Pd, Pt, Sb, Te, U, Ge, Hf, In, Re, Sn, Ta, Tl, W, Zn not found. Pr, Sm, Eu, looked for but not found in rocks containing La or Ce. Samples collected by J. G. Evans]

	M517	M518[1]	M523D	M393
Chemical analyses (weight percent)				
SiO_2	58.9	52.5	54.9	57.8
Al_2O_3	17.7	8.2?	16.0	16.7
Fe_2O_3	2.2	2.3	3.6	1.2
FeO	3.8	5.8	3.1	5.5
MgO	3.0	10.7?	4.9	5.0
CaO	5.4	15.0?	6.9	6.4
Na_2O	2.9	1.4	2.5	3.0
K_2O	3.0	.64?	2.0	2.4
H_2O^+	1.3	1.5	2.9	.48
H_2O^-	.12	.27	.84	.12
TiO_2	.86	.77	1.1	1.0
P_2O_5	.19	.0	.32	.24
MnO	.08	.08	.10	.09
CO_2	.25	<.05	.62	<.05
Total	100	99	100	100
CIPW norms				
Q	14.02		13.22	8.40
C	.90		.0	.0
or	17.80		11.95	14.20
ab	24.64		21.38	25.42
an	24.07		26.81	25.05
wo	.0		.71	2.03
en	7.50		12.33	12.47
fs	3.91		1.10	7.64
mt	3.20		5.28	1.74
hm	.0		.0	.0
il	1.64		2.11	1.90
ru	.0		.0	.0
ap	.45		.77	.57
cc	.57		1.43	.11
Total	98.70		97.09	99.53
Semiquantitative spectrographic analyses (parts per million)				
Au	------	------	0.06	------
B	------	------	7	------
Ba	700	200	700	700
Be	2	------	1	1
Ce	150	------	200	100
Co	10	30	20	20
Cr	50	300	150	200
Cu	7	1.5	15	15
Ga	20	10	15	20
Hg	.08	.07	.04	.14
La	70	------	100	70
Mo	------	------	------	15
Nb	15	------	15	10
Nd	------	(2)	70	------
Ni	10	100	50	50
Pb	70	------	10	10
Sc	20	100	20	30
Sr	500	1,500	1,500	1,000
V	100	200	150	150
Y	30	50	30	30
Yb	3	3	3	3
Zr	1,500	70	150	150

[1]Altered.
[2]Not looked for.

M517, Granodiorite from Gold Strike Claims, south side of western apophysis of plug, T. 36 N., R. 50 E.
M518, Granodiorite from Gold Strike Claims, 610 m north sec. 31, T. 36 N., R. 50 E., and 43 m east of west edge of quadrangle
M523D, Granodiorite from Gold Strike Claims, 780 m north of sec. 31, T. 36 N., R. 50 E. and 806 m east of west edge of quadrangle
M393, Diorite from west flank of Tuscarora Mountains, 61 m north of south edge of T. 36 N., R. 50 E., and 550 m west of NE. cor. sec. 2, T. 35 N., R. 50 E.

TABLE 14.—*Chemical and spectrographic analyses and CIPW norm of quartz monzonite from Welches Canyon quadrangle*

[Chemical analyses by rapid rock method; analysts: P. L. D. Elmore, Hezekiah Smith, Gillison Chloe, James Kelsey, and J. L. Glenn. Semiquantitative spectrographic analyses for 30 elements by Chris Heropoulos; gold by atomic absorption, mercury by detector. Ag, Bi, Ce, Cd, Pd, Pt, Sb, Te, U, Ge, Hf, In, La, Li, Mo, Re, Sn, Ta, Th, Tl, W, Zn not found; n.a. = not analyzed. Samples collected by J. G. Evans]

	L317	L7	L63A
Chemical analysis (weight percent)			
SiO_2	76.2	76.0	75.1
Al_2O_3	13.1	13.8	14.3
Fe_2O_3	.38	.21	.87
FeO	.56	.32	.48
MgO	.20	.08	.42
CaO	.93	.17	.62
Na_2O	3.2	.23	.53
K_2O	4.5	5.6	4.7
H_2O^+	.74	2.9	1.5
H_2O^-	.09	.24	.70
TiO_2	.05	.09	.13
P_2O_5	.0	.0	.16
MnO	.0	.0	.17
CO_2	<.05	<.05	.15
Total	100	100	100
CIPW norm			
Q	37.96	------	------
C	1.39	------	------
or	26.62	------	------
ab	27.10	------	------
an	4.30	------	------
en	.49	------	------
fs	.63	------	------
mt	.55	------	------
il	.09	------	------
ap	.0	------	------
cc	.11	------	------
Total	99.24		
Semiquantitative spectrographic analyses (parts per million)			
Au	------	n.a.	0.1
As	------	700	700
B	------	7	10
Ba	70	150	700
Be	5	2	7
Co	------	15	7
Cr	------	1	7
Cu	2	20	5
Ga	15	20	30
Hg	.04	n.a.	.07
Nb	20	50	20
Nd	(1)	(1)	(1)
Ni	---	------	1.5
Pb	20	15	30
Sc	------	------	3
Sr	70	20	70
V	7	15	15
Y	------	15	20
Yb	1.5	3	2
Zr	30	100	100

[1]Not looked for.

L317, quartz monzonite from Richmond district, NW¼SW¼ sec. 2, T. 34 N., R. 50 E.
L7, quartz monzonite from Richmond district, 550 m north SW. cor. sec. 2, T. 34 N., R. 50 E.
L63A, quartz monzonite from SE¼SW¼ sec. 36, T. 35 N., R. 50 E.

west of the southern Tuscarora Mountains (Roberts and others, 1971): northern Shoshone Range, 99 m.y.; Ruby Hill, near Eureka, 100 m.y.; southeast Humboldt County, 87–105 m.y..

RHYODACITE

Rhyodacite flows cap the peaks along the southern edge of the Welches Canyon quadrangle (terminology of Peterson, 1961, for volcanic rocks). These well-exposed rocks form bold jagged outcrops and crags. The flows lie directly on the rocks of the Paleozoic siliceous assemblage. In places, as much as 15 m of unconsolidated subrounded volcanic boulder conglomerate in which most of the boulders exceed 30 cm in diameter is present at the base of the flows. These boulders are black, glassy, vuggy, and are extremely hard volcanic rock. Above the basal conglomerate, the volcanic rocks are black, gray, and maroon speckled with white plagioclase phenocrysts; they commonly have flow banding parallel to which prominent partings are developed. The section of flows along the south edge of the Welches Canyon quadrangle is about 275 m thick and becomes thicker to the south.

Phenocrysts, mostly zoned and twinned subhedral laths of plagioclase (andesine and labradorite) to 2 mm long, make up 20 to 50 percent of rhyodacite. Hornblende with brown and green pleochroism, pyroxene, biotite, and quartz are less abundant phenocrysts and are usually less than 1 mm long. The phenocrysts occur singly and are glomeroporphyritic. Both plagioclase and hornblende grains are embayed by the groundmass, which consists of equant grains of potassium feldspar, quartz, plagioclase, and magnetite a few hundredths of a millimeter across. The plagioclase is partly altered to sericite, and the mafic minerals are partly altered to hematite and magnetite.

The chemical and spectrographic analyses and CIPW norms of four samples of the flows are given in table 15: samples L374, L388, and L383 from the interval 18–24 m above the base of the rhyodacite, and sample L394 from a site approximately 122 m above the base of the volcanic rock. Although the compositions of the rhyodacite flows and the Tertiary granodiorite dikes are roughly similar, no field evidence was found to indicate a connection between the flows and the dikes.

A radiometric date was not obtained for the rhyodacite owing to the difficulty in obtaining samples with fresh potassium-bearing minerals. Regnier (1960, p. 1193) cites the occurrence of freshwater brachiopods west of the town of Carlin in a thin bed of clay and angular volcanic gravel interbedded with volcanics similar to the rhyodacite. Van Houten (in Regnier, 1960) identified these brachiopods as being of Cretaceous or early Tertiary age. The rhyodacite may therefore be Cretaceous or early Tertiary.

ANDESITE

Andesite dikes intrude the siliceous assemblage north of the Lynn Window in sec. 13 T. 35 N., R. 50 E., and in the SW cor., T. 36 N., R. 50

TABLE 15.—*Chemical and spectrographic analyses and CIPW norms of rhyodacite, from Welches Canyon quadrangle*

[Chemical analyses by rapid rock method; analysts: P. L. D. Elmore, Hezekiah Smith, Gillison Chloe, James Kelsey, and J. L. Glenn. Semiquantitative spectrographic analyses for 30 elements by Chris Heropoulos; gold by atomic absorption, mercury by detector. Ag, As, Au, B, Bi, Cd, Ge, Hf, In, Li, Re, Sb, Sn, Ta, Te, Th, Tl, U, W, Zn not found Pr, Sm, Eu looked for but not found in rocks containing La or Ce. Gd, Tb, Dy, Ho, Er, Tm, Lu looked for but not found in L394, n.a. = not analyzed. Samples collected by J. G. Evans]

	L394	L374	L388	L383
Chemical analyses (weight percent)				
SiO_2	59.6	63.4	63.8	59.8
Al_2O_3	17.5	16.4	16.2	16.7
Fe_2O_3	3.1	4.5	3.9	3.9
FeO	3.1	1.0	.76	2.6
MgO	2.3	.85	1.3	2.2
CaO	5.3	4.2	4.0	5.0
Na_2O	2.9	3.3	3.3	3.2
K_2O	2.8	3.1	3.3	2.7
H_2O^+	1.3	1.6	1.5	1.9
H_2O^-	.52	.81	1.0	.81
TiO_2	1.1	.73	.63	.80
P_2O_5	.32	.10	.24	.34
MnO	.09	.05	.06	.10
CO_2	<.05	<.05	<.05	<.05
Total	100	100	100	100
CIPW norms				
Q	17.69	22.66	22.49	17.89
C	.95	.34	.62	.36
or	16.64	18.45	19.69	16.07
ab	24.67	28.13	28.19	27.27
an	24.02	20.01	18.13	22.43
en	5.76	2.13	3.27	5.52
fs	1.49	.0	.0	.42
mt	4.52	1.28	.83	5.69
hm	.0	3.65	3.37	.0
il	2.10	1.39	1.21	1.53
ap	.76	.24	.57	.81
cc	.11	.12	.12	.12
Total	98.71	98.40	98.49	98.11
Semiquantitative spectrographic analyses (parts per million)				
Ba	1,500	1,500	1,500	1,500
Be	------	2	1.5	------
Ce	100	100	70	100
Co	15	10	7	15
Cr	15	5	15	3
Cu	10	10	10	20
Ga	20	20	20	30
Hg	.07	.05	.05	n.a.
La	100	70	50	70
Mo	------	------	------	3
Nb	15	7	10	10
Nd	------	------	------	70
Ni	5	------	5	1.5
Pb	15	20	30	20
Sc	15	15	10	15
Sr	700	1,000	700	1,000
V	100	100	70	150
Y	30	20	15	20
Yb	3	2	2	2
Zr	150	150	150	150

L394, Rhyodacite from SW¼N⅜¼ sec. 9, T. 33 N., R. 50 E.
L374, Rhyodacite from summit 6887, SW¼ sec. 1, T. 33 N., R. 50 E.
L388, Rhyodacite from summit 6572, S½SW¼ sec. 3, T. 33 N., R. 50 E.
L383, Rhyodacite from NW¼NW¼ sec. 11, T. 33 N., R. 50 E.

E., unsurveyed. The dikes are dark gray to dark greenish gray speckled with white plagioclase phenocrysts and black hornblende phenocrysts to 1 mm long and with irregular-shaped calcite amygdules a few millimeters in diameter. Weathered surfaces have a brownish cast and are pitted where the calcite has been dissolved. The groundmass consists chiefly of plagioclase laths and hornblende less than 0.3 mm long. Quartz and potassium feldspar, both minor constituents of the groundmass, occur interstitial to the plagioclase. The rock has been saussuritized and the mafic minerals partly altered to chlorite. In some dikes, the chloritization of mafic minerals is complete, and the outlines of relict grains suggest that pyroxene and hornblende were originally abundant in the rock.

The age of the andesite is not known. The dikes may postdate the Antler orogeny and may be as young as Tertiary.

TERTIARY GRANODIORITE

Granodiorite dikes intrude the siliceous rocks south of the Lynn Window. The dikes are generally deeply weathered to brown soil with angular dark-brown-stained granodiorite pebbles. On fresh surfaces, the diorite is creamy white to gray, reflecting the variation in mafic mineral content of the rock.

The rock consists of labradorite (50–70 percent), quartz (5–40 percent), potassium feldspar (5–20 percent), and mafic minerals (biotite and hornblende, to 10 percent). Grains of labradorite, biotite, and hornblende are 0.5–1 mm long. The biotite is poikilitic with inclusions of plagioclase and magnetite. Grains of quartz and potassium feldspar are small (less than 0.05 mm), are mostly interstitial, and occupy thin veins in labradorite. The labradorite is partly sericitized; the hornblende is partly altered to chlorite, hematite, and magnetite and partly replaced by talc and calcite. Garnet, pyroxene, and sphene are accessory minerals.

The chemical and spectrographic analyses of three samples of the granodiorite and the CIPW norms of two of them are given in table 16. Samples L404 and L340 are from typical gray granodiorite with about 10 percent mafic minerals. Sample L357 is a creamy-white quartz-rich granodiorite poor in mafic minerals. This sample is high in silica, low in iron, magnesia, and potassium, contains 700 ppm arsenic, and is probably altered.

Biotite from the granodiorite (sample L340) was dated by M. L. Silberman (written commun., 1971), using the potassium-argon method, at 37±0.8 m.y., or approximately at the boundary between the Eocene and Oligocene. The granodiorite is about the same age as other small intrusions ranging in age from 34 to 39 m.y. at Battle Mountain, the northern Shoshone Range, the Cortez Mountains, the southern Independence Mountains, and other parts of north-central Nevada (Roberts and others, 1971, p. 18–19).

TABLE 16.—*Chemical and spectrographic analyses and CIPW norms of Tertiary granodiorite from Welches Canyon quadrangle*

[Chemical analyses by rapid rock method; analysts: P. L. D. Elmore, Hezekiah Smith, Gillison Chloe, James Kelsey, and J. L. Glenn. Semiquantitative spectrographic analyses for 30 elements by Chris Heropoulos; gold by atomic absorption, mercury by detector. Ag, Au, Bi, Cd, Ge, Hf, In, Li, Pd, Pt, Re, Sb, Sn, Ta, Te, Th, Tl, U, W, Zn not found. Pr, Sm, Eu looked for but not found in samples containing La or Ce. Samples collected by J. G. Evans]

	L404	L357	L340
Chemical analyses (weight percent)			
SiO_2	61.9	72.6	62.1
Al_2O_3	16.9	15.9	16.3
Fe_2O_3	1.1	.17	3.0
FeO	4.2	.28	2.8
MgO	1.9	.25	2.0
CaO	5.0	5.2	4.4
Na_2O	3.1	3.4	3.2
K_2O	2.6	.83	2.7
H_2O^+	1.6	.83	1.3
H_2O_2	.30	.17	.69
TiO_2	.79	.54	.67
P_2O_5	.28	.08	.31
MnO	.12	.0	.05
CO_2	<.05	<.05	.36
Total	100	100	100
CIPW norms			
Q	18.78	......	22.03
C	.69	.....	1.70
or	15.44	.....	16.09
ab	26.35	......	27.29
an	22.76	....	17.67
en	4.75	......	5.02
fs	5.75	....	1.66
mt	1.60	....	4.39
hm	.0	......	.0
il	1.51	....	1.28
ru	.0	......	.0
ap	.67	...	.74
cc	.11	....	.83
Total	98.41	..	98.70
Semiquantitative spectrographic analyses (parts per million)			
As		700	....
B		7	.....
Ba	1,000	700	1,000
Be	.	3	1
Ce	100	..	100
Co	10		10
Cr	1	3	3
Cu	7	10	10
Ga	20	20	15
Hg	.35	.03	.13
La	50		50
Mo	3		..
Nb	7	15	10
Nd	70		....
Ni		2	
Pb	20	15	20
Sc	15	5	10
Sr	700	500	500
V	100	20	70
Y	20	10	20
Yb	2	1	2
Zr	150	100	100

L404, Granodiorite dike from N½N½ sec. 26, T. 34 N., R. 50 E.
L357, Granodiorite dike from NE¼SE¼ same section, same township
L340, Granodiorite dike from Welches Canyon, NE¼SW¼ sec. 27, same township.

QUARTZ LATITE

Quartz latite dikes occur throughout the Rodeo Creek NE and Welches Canyon quadrangles but are most abundant south and west of the Lynn Window. The creamy-white, light-gray, and light-brown dikes are generally well exposed. Some of them form prominent ledges that can be traced for about 30 to several hundred meters. The largest dike crossing Welches Canyon is covered by regolith except at its margins. Most of the dikes range in thickness from a meter to as much as 90 m. The largest one is as much as 520 m thick.

The quartz latite contains 20 to 35 percent phenocrysts consisting chiefly of euhedral and angular anhedral grains of twinned plagioclase (mostly oligoclase, but also albite) 0.1–2 mm long. Phenocrysts of euhedral biotite, hornblende, pyroxene, and rounded quartz are minor constituents. Many of the phenocrysts are embayed by the groundmass, mostly of potassium feldspar and quartz in approximately equal proportions. Microcline was tentatively identified by X-ray diffraction study of the groundmass of one sample. In another sample, the groundmass consisted of 50 percent dark-green glass. Biotite, hornblende, and magnetite are minor constituents of the groundmass. Spherulites of potassium feldspar 0.1 mm across occur in some dikes. In places, the argillic alteration of the plagioclase and the chloritization of the mafic minerals is complete, but the outlines of the original grains are preserved.

The chemical and spectrographic analyses and CIPW norms of four samples of quartz latite are given in table 17. Sample L335, though indistinguishable in hand specimen from the other samples, differs by containing more silica and less alumina, iron, magnesia, and lime. The spectrographic analysis of the sample shows that the rock is poorer than the others in barium and richer in lithium and lead. Sample L335, therefore, may be altered quartz latite. Sample L356, containing a little silver, may also be somewhat altered.

Biotite from the large quartz latitie dike in Welches Canyon (sample L344) was dated at 36.6±0.7 m.y., which is early Oligocene (McKee and others, 1971, p. 41; potassium-argon method), and is the same age, within analytical uncertainties, as the Tertiary granodiorite in Welches Canyon.

INTRUSIVE BRECCIA

Intrusive breccia dikes and sills ranging in thickness from a meter to 183 m are present within 1.6 km of the southern end of Lynn Window. Other unmapped sills about a meter thick occur in the thin-bedded chert and shale near the southeast corner of the Welches Canyon quadrangle (NE¼ sec. 1, T. 33 N., R. 50 E., NW¼ sec. 8, T. 33 N., R. 51 E.).

The intrusive breccia consists of angular fragments of marble, recrystallized chert, creamy-white felsite, brecciated basalt, and basalt

TABLE 17. —*Chemical and spectrographic analyses of quartz latite and CIPW norms of quartz latite from Welches Canyon quadrangle*

[Chemical analyses by rapid rock method; analysts: P. L. D. Elmore, Hezekiah Smith, Gillison Chloe, James Kelsey, and J. L. Glenn. Semiquantitative spectrographic analyses for 30 elements by Chris Heropoulos; gold by atomic absorption, mercury by detector. As, Au, Cd, Ge, Hf, In, Pd, Pt, Re, Sb, Sn, Ta, Te, Th, Tl, U, W, Zn not found. Pr, Sm, Eu looked for but not found in rocks containing La or Ce. Samples collected by J. G. Evans]

	L344	L335	L343	L356
Chemical analyses (weight percent)				
SiO_2	69.0	75.2	67.3	69.8
Al_2O_3	14.2	13.2	14.3	15.2
Fe_2O_3	1.1	.32	1.5	.90
FeO	1.1	.20	.76	.36
MgO	1.5	.20	1.1	.72
CaO	1.8	.85	2.3	2.4
Na_2O	2.2	3.4	2.0	3.0
K_2O	4.1	4.6	4.3	4.3
H_2O^+	2.0	1.1	3.1	1.5
H_2O^-	2.3	.55	1.7	.37
TiO_2	.25	.0	.25	.34
P_2O_5	.11	.0	.08	.13
MnO	.05	.0	.03	.0
CO_2	.20	<.05	<.05	<.05
Total	100	100	99	100
CIPW norms				
Q	35.77	36.11	34.20	30.43
C	3.69	1.21	2.55	2.19
or	24.82	27.42	26.09	25.62
ab	19.07	29.03	17.38	25.59
an	7.12	3.94	10.86	10.83
en	3.83	.50	2.81	1.81
fs	.81	.10	.0	.0
mt	1.63	.47	1.87	.18
hm	.0	.0	.25	.79
il	.49	.0	.48	.65
ap	.27	.0	.19	.31
cc	.47	.12	.12	.12
Total	97.97	98.90	96.80	98.52
Semiquantitative spectrographic analyses (parts per million)				
Ag	----	------	------	<0.07
B	----	10	------	------
Ba	1,500	70	5,000	2,000
Be	2	5	2	2
Ce	70	------	------	70
Co	2	------	3	------
Cr	5	7	15	3
Cu	3	2	1.5	50
Ga	20	30	15	30
Hg	.06	.18	.04	.06
La	30	------	------	30
Li	----	200	------	------
Mo	----	------	------	7
Nb	15	30	10	10
Nd	----	([1])	([1])	------
Ni	----	5	2	------
Pb	50	100	50	20
Sc	5	3	7	5
Sr	200	50	1,000	700
V	30	7	50	50
Y	15	15	15	20
Yb	1.5	2	1	1.5
Zr	100	50	70	150

[1]Not looked for.

L344, Quartz latite from Welches Canyon, NW¼NW¼ sec. 26, T. 34 N., R. 50 E.
L335, Quartz latite from summit 6029, SE¼ sec. 22, T. 34 N., R. 50 E., Welches Canyon quadrangle.
L343, Quartz latite from Welches Canyon, NW¼NW¼ sec. 26, T. 34 N., R. 50 E.
L356, Quartz latite from E½E½ sec. 26, T. 34 N., R. 50 E., Welches Canyon quadrangle.

cemented by a gray to black aphanitic material (fig. 15). The proportions of the different kinds of fragments vary from dike to dike and

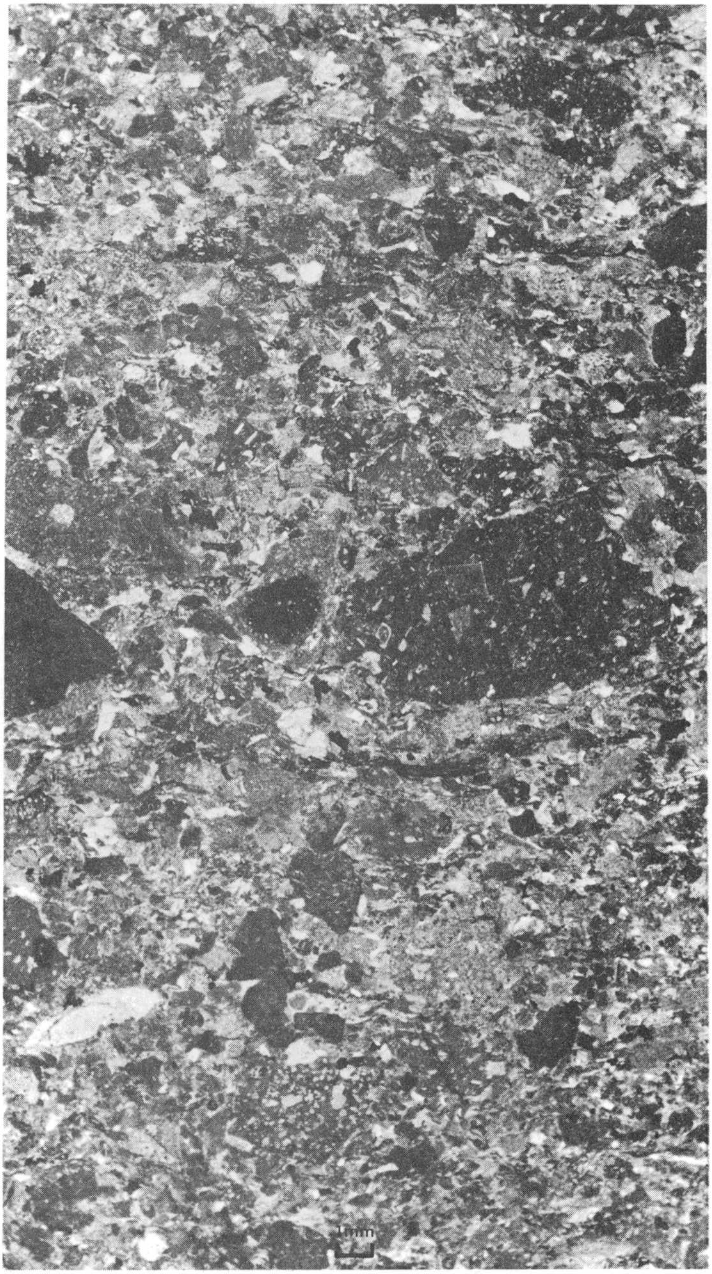


FIGURE 15.—Photomicrograph under cross nicols of intrusive breccia. Dark- and medium-gray fragments are biotite- and magnetite-rich andesite. Lighter fragments are fine-grained potassic rhyolite, some containing biotite, and angular plagioclase fragments. ×4. Sample from N¼ sec. 16, T. 34 N., R. 50 E., Welches Canyon quadrangle.

within a single dike. In the field, ledges of the breccia look like sedimentary chert breccia. The clasts are typically less than about 10 cm long, but some of the marble and chert fragments are about a meter long. A crude layering is developed by the long dimensions of the angular and roughly augen shaped clasts. Calcite, some of it intensely twinned, cements the siliceous breccia locally, forms spherical or ovoid amygdules to several millimeters across, and replaces some of the chert and andesite breccia clasts. The basalt clasts resemble the basalt of Paleozoic or early Mesozoic age. The felsite fragments contain potassium feldspar and could be phenocryst-free fragments of quartz latite. If the felsite in the breccia is genetically related to the quartz latite dikes, the breccia dikes are probably early Oligocene in age or younger.

PYROCLASTIC ROCKS

The maroon, dark-brown, and black rhyolitic welded tuff exposed along the west side of the Tuscarora Mountains is part of a more extensive volcanic assemblage that underlies some of the low hills between the Tuscarora Mountains and the Sheep Creek Range to the west. Slopes underlain by the welded tuff typically are covered with angular slabs. Prominent outcrops and bluffs of the rock are common along the east margin of the unit and along Sheep Creek.

The base of the welded tuff rests directly on Paleozoic rocks in most places. The base of the tuff is usually a black vitrophyre. Locally sandstone to 6 m thick occurs between the Paleozoic rocks and the tuff. The angular sand-sized clasts of the poorly indurated sandstone are mostly clear and brown translucent glass with minor quartz, feldspar, hornblende, and hematite. The welded tuff that constitutes most of the unit is layered and contains numerous small vugs to 5 mm across, some filled with zeolites and chalcedony. The welded tuff is chiefly cryptocrystalline material, probably quartz, feldspar, and hematite (fig. 16). It contains to 15 percent angular fragments, as much as 2 mm long, of oligoclase, sanidine, hornblende, pyroxene and biotite, and rounded quartz grains. Many of the grains are embayed by the cryptocrystalline material. Some samples of the tuff contain sanidine spherulites to 1 mm across. Others have lenses of oligoclase, quartz, and magnetite elongate parallel to the layering. Mafic minerals in the rock are partly altered to hematite and magnetite.

Chemical and spectrographic analyses and CIPW norms are shown in table 18 for four samples of the welded tuff taken from widely separated localities to obtain a representative sample and from different levels within the unit. Sample M466 was taken at the base of the tuff; sample L140, from at least 45 m above the base; sample

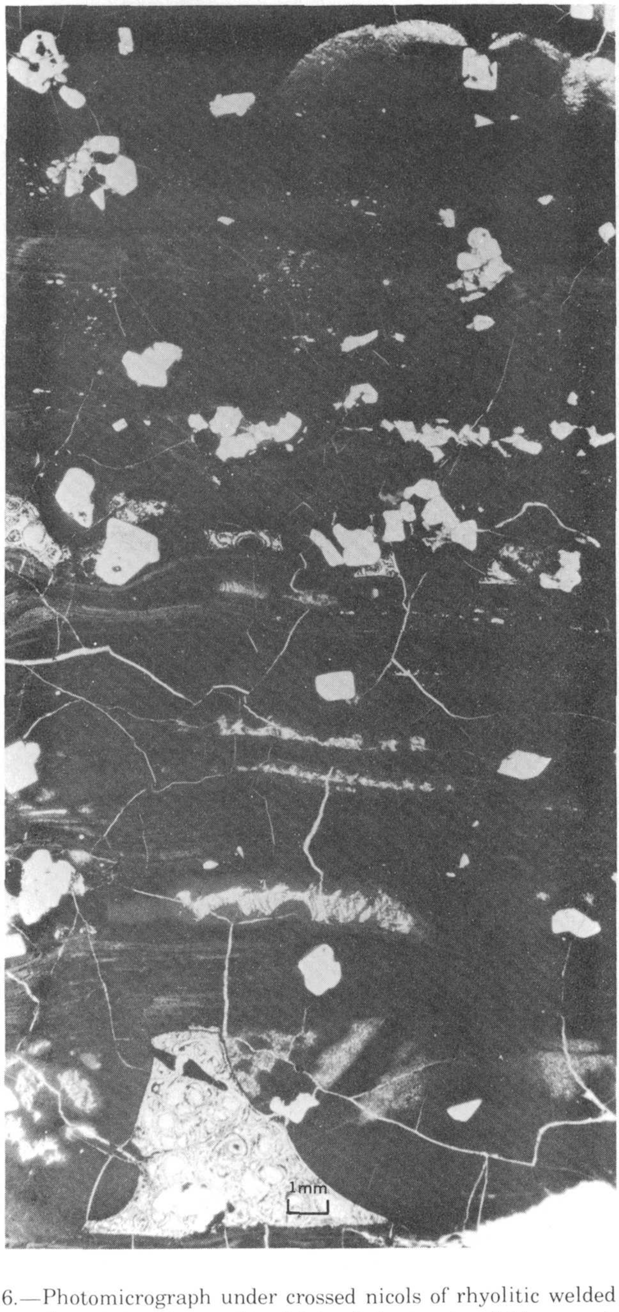


FIGURE 16.—Photomicrograph under crossed nicols of rhyolitic welded tuff. Most of rock is very fine grained iron-oxide-rich landed potassium feldspar and quartz. White angular and subangular spots are sanidine and oligoclase phenocrysts. Black spots are magnetite. Light areas with colliform structure are clear glass; hematite outlines the oval shapes. ×4. Sample from NW¼ sec. 21, T. 35 N., R. 50 E., Rodeo Creek NE quadrangle.

TABLE 18.—*Chemical and spectrographic analyses and CIPW norms of rhyolitic welded tuff*

[Chemical analyses by rapid rock method; analysts: P. L. D. Elmore, Hezekiah Smith, Gillison Chloe, James Kelsey, and J. L. Glenn. Semiquantitative spectrographic analyses for 30 elements by Chris Heropoulos; gold by atomic absorption, mercury by detector. Ag, As, Au, B, Bi, Cd, Co, Cr, Ge, Hf, In, Li, Ni, Pd, Pt, Re, Sb, Sc, Ta, Te, Th, Tl, U, W, Zn not found. Pr, Sm, Eu looked for but not found in rocks containing La or Ce. Gd, Tb, Dy, Ho, Er, Tm, Lu looked for but not found in M394, L140, M441, and M466, n.a. = not analyzed. Sample collected by J. G. Evans]

	M394	L140	M441	M466
Chemical analyses (weight percent)				
SiO_2	73.9	73.2	72.8	72.0
Al_2O_3	13.0	12.7	12.5	12.9
Fe_2O_3	2.5	2.9	2.4	.91
FeO	.12	.12	.59	1.9
MgO	.03	.12	.13	.02
CaO	.42	.79	.83	.92
Na_2O	3.4	3.4	3.0	3.4
K_2O	5.4	5.5	5.4	5.4
H_2O^+	.59	.62	1.3	2.2
H_2O^-	.27	.22	.41	.14
TiO_2	.22	.19	.22	.20
P_2O_5	.07	.05	.02	.0
MnO	.03	.03	.21	.04
CO_2	<.05	<.05	<.05	<.05
Total	100	100	100	100
CIPW norms				
Q	32.94	30.86	33.09	28.64
C	1.09	.0	.38	.0
or	31.99	32.59	32.09	31.93
ab	28.85	28.86	25.53	28.79
an	1.31	3.16	3.69	3.99
wo	.0	.02	.0	.11
en	.0	.38	.33	.05
fs	.0	.0	.0	2.48
mt	.0	.0	1.96	1.32
hm	2.51	2.91	1.06	.0
il	.32	.32	.42	.38
tn	.0	.06	.0	.0
ru	.05	.0	.0	.0
ap	.17	.12	.05	.0
cc	.11	.11	.11	.11
Total	99.34	99.39	98.71	97.80
Semiquantitative spectrographic analyses (parts per million)				
Ba	700	300	200	150
Be	5	7	5	5
Ce	300	200	300	200
Cu	2	7	7	2
Ga	20	30	30	30
Hg	.08	n.a.	.08	.04
La	200	150	150	150
Mo	10	10	5	10
Nb	50	50	30	30
Nd	100	100	100	100
Pb	50	50	50	70
Sn		10	10	
Sr	30	30	150	15
V	15	15		
Y	70	100	100	100
Yb	7	10	10	10
Zr	700	700	700	500

M394, Quartz latite from vicinity of ruin along Sheep Creek, NE¼NW¼ sec. 21, T. 35 N., R. 50 E., Rodeo Creek NE quad.
L140, Quartz latite from SW¼SW¼ sec. 5, T. 34 N., R. 50 E., Welches Canyon quad.
M441, Quartz latite from locality 610 m east of southwest corner of Rodeo Creek NE quad.
M466, Quartz latite from SW¼NW¼ sec. 16, T. 35 N., R. 50 E., Rodeo Creek NE quad.

M441, from 55 m above the base; sample M394, about 76 m above the base. The most striking feature of the analyses is the similarity of the samples in composition.

The tuff unit is 214 m thick in the Rodeo Creek NE, and Welches Canyon quadrangles and thickens to the west.

Sanidine from the rhyolitic welded tuff (sample M394) was dated at 14.2±3 m.y. (McKee and others, 1971, p. 41; potassium-argon method), or middle Miocene. The tuff is approximately the same age as rhyolite in Palisades Canyon, west of Carlin (Armstrong, 1970, p. 212–213), and as the intertonging rhyolites and basalts in the Sheep Creek Range, 13 km west of the Tuscarora Mountains (McKee and Silberman, 1970).

TERTIARY AND QUATERNARY SEDIMENTARY ROCKS AND DEPOSITS

CARLIN FORMATION

Tertiary and Quaternary sedimentary rocks and deposits include the Carlin Formation of Regnier (1960), largely conglomerates, siltstone, and sandstone; siltstone on the west side of the Tuscarora Mountains; chert pebble-and-cobble fanglomerate on the east side of the range; and alluvium underlying streams and valleys in and near the range, chiefly of chert and siliceous siltstone.

The Carlin Formation occurs along parts of Indian and Cottonwood Creeks near the northeast corner of the Rodeo Creek NE quadrangle and in the northeast quarter of the Welches Canyon quadrangle. In general, the formation is poorly exposed. The few good exposures occur in streambanks, in bulldozer cuts, and along a few steep slopes.

Rocks of the Carlin Formation include a wide range of rock types: brown, poorly indurated, rounded chert-cobble conglomerate; light-brown angular chert-pebble conglomerate with white siliceous cement; buff pebbly sandstone; creamy white welded tuff; buff to white, massive silty sandstone. Distinctive lithologic units are not well enough exposed to permit subdivision of the formation. Coarse-grained clastic rocks seem to occur in parts of the formation close to the Paleozoic formations, whereas finer grained rocks occur farther from the Paleozoic rocks and presumably nearer the center of the depositional basin.

The minimum stratigraphic thickness of the Carlin Formation along the east side of the Tuscarora Mountains is estimated at 214 m, based on the greatest topographic relief in the formation in the Welches Canyon quadrangle. Regnier (1960, p. 1198) estimated a minimum thickness of 191 m for the Carlin Formation.

Vertebrate fossils found in the Carlin Formation northeast and west of the town of Carlin are middle Miocene to early Pliocene (Hemphillian and Clarendonian, Regnier, 1960, p. 1199). Presumably, the Carlin Formation along the east flank of the Tuscarora

Mountains is the same age. Part of the Carlin may be the same age as the rhyolitic welded tuff on the west side of the Tuscarora Mountains.

SILTSTONE

Poorly consolidated to well-indurated sedimentary rocks, largely siltstone, occur on the west side of the Tuscarora Mountains in the northwest corner of the Rodeo Creek NE quadrangle and near the southwest corner of the Welches Canyon quadrangle. These deposits underlie low hills nearly devoid of outcrops.

In the Roedo Creek NE quadrangle, the rocks are massive and thin-bedded tuffaceous siltstone. In the Welches Canyon quadrangle, the rocks include sedimentary breccia composed of pebbles and slabs of laminated siliceous siltstone to 10 cm across in a tuffaceous siltstone matrix, buff to creamy white siltstone, and creamy white tuffaceous siltstone with subangular pumice fragments to 1.5 cm long and as much as 2 percent fresh black mafic minerals, including biotite.

The most extensive deposit in the northwest corner of the Rodeo Creek NE quadrangle is estimated to be at least 110 m thick. This thickness is derived from the maximum relief in the area underlain by the unit.

The siltstone unit differs sufficiently from the rocks of the Carlin Formation for it to be considered as a separate unit until a more definite correlation with the Carlin Formation can be established. The relation of the siltstone to the 14-m.y.-old rhyolitic welded tuff is not known because the two units are not in contact in the map area, but a late Tertiary age seems probable.

FANGLOMERATE

Fanglomerate occurs on the east side of the Tuscarora Mountains north of the Carlin gold mine road in Simon Creek Canyon. The deposit consists of unconsolidated angular and subangular chert pebbles and cobbles in a matrix of brown sand, silt, and clay derived chiefly from the rocks of the siliceous assemblage. No bedding was observed. Along the west edge of the deposit, the fanglomerate overlies the Carlin Formation and Paleozoic rocks. Although the deposit is dissected, the shape of the original fan is crudely preserved. The fanglomerate forms the southwest edge of a group of coalescing alluvial fans extending for several kilometers northwest along the east side of the Tuscarora Mountains. Its thickness in the Rodeo Creek NE quadrangle could be as much as 244 m, an estimated thickness deduced from the maximum topographic relief in the area underlain. If low hills of Carlin Formation are buried beneath the deposit, the actual thickness may be much less. A Quaternary age for the deposit is suggested by the recognizable fan morphology and the unconsolidated nature of the sediment.

LANDSLIDE DEPOSITS

Landslide deposits occur chiefly near the lower contact of the Eureka Quartzite with the Pogonip Group in south-central Rodeo Creek NE quadrangle and in north-central Welches Canyon quadrangle. The deposits are mainly angular boulders and slabs of Eureka Quartzite; some of the clasts are more than 60 cm long. The upper surfaces of the deposits exhibit the hummocky topography typical of landslides. A small landslide deposit in S½ sec. 15, T. 35 N., R. 50 E., consists of a block of Upper Devonian limestone that has slid over Roberts Mountains Formation.

ALLUVIUM

Unconsolidated alluvium underlies the stream channels and the valleys adjacent to and within the mountain range. In general, the alluvium is made up of angular sand- and pebble-sized clasts, chiefly of chert and siliceous siltstone, in a powdery brown silt and clay matrix. The largest clasts, locally to 30 cm are found near the mountains. In streamcuts through terraces or older valley fill, thin crossbedded pebbly and cobbly sandstones and stream channel conglomerates are exposed. The thickness of the alluvium is variable, but local relief in the alluvium suggests thicknesses of at least 15 to 30 m.

STRUCTURAL GEOLOGY

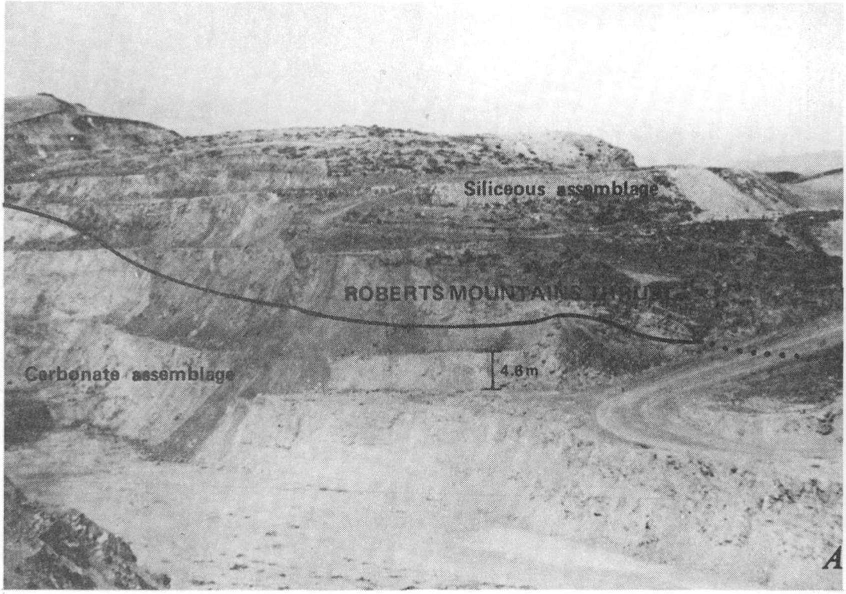
The Antler orogeny in Late Devonian-Early Mississippian time is the earliest deformation recorded in the southern Tuscarora Mountains. Prior to that time, rocks deposited on the site of the range were predominantly fine grained carbonates. The allochthonous limestone of the transitional assemblage with its angular grit and rounded cobbles of chert points to the beginning of the Antler orogeny somewhere west of the Tuscarora Mountains by Late Devonian time. During the Antler orogeny, the lower to middle Paleozoic rocks of the siliceous assemblage and the transitional assemblage were thrust eastward along the Roberts Mountains thrust over the carbonate assemblage rocks of the same age. The Lower Mississippian (Kinderhookian) Webb Formation described by Smith and Ketner (1968) unconformably overlies the allochthonous Ordovician and Devonian rocks in the northern Piñon Range, thereby giving an upper age limit to the Antler orogeny in northeast Nevada.

At the Lynn Window, the thrust contact between the siliceous and carbonate assemblages is commonly referred to as the Roberts Mountains thrust. This structure is younger than early Late Devonian and probably older than Cretaceous. As shown for the Carlin-Piñon Range area to the south by Smith and Ketner (1977), at least four tectonic episodes occurred between the Antler orogeny and the Tertiary that could have affected the southern Tuscarora Mountains. Two of these episodes, one of Pennsylvanian and another of Late Jurassic to Early Cretaceous age, involved thrusting. Post-earliest Mississippian thrusting was recognized at Swales Mountain, 24 km east of the Lynn Window (Evans and Ketner, 1971; Ketner, 1970b). The major thrust between the siliceous and carbonate rocks at the Lynn Window could therefore be either a segment of the Roberts Mountains thrust that may have been affected by later tectonism or another thrust that postdates the Antler orogeny. Because the siliceous assemblage was brought into the area of the northern Piñon Range during the Antler orogeny (Smith and Ketner, 1968), the major thrust contact at the Lynn Window is referred to in this paper as the Roberts Mountains thrust.

The Roberts Mountains thrust is exposed at few places in the Lynn Window. In the best exposures at the Carlin gold mine (fig. 17), the thrust is a zone of gouge and breccia separating the Popovich Formation (carbonate assemblage) from the overlying chert and shale (siliceous assemblage). Angular fragments of limy siltstone, quartzite, chert, and cherty shale, ranging in length from less than 2.5 cm to 3 m, are loosely cemented by gouge and clay along the fault. In places, the thrust zone contains imbricate slivers of silicified limestone, limestone, and chert. In the southern part of the Lynn Window, the imbricate thrust zone is as much as 600 m thick.

Within the carbonate assemblage, the Eureka Quartzite is thrust over the Pogonip Group, the Roberts Mountains Formation, and the Popovich Formation along the Richmond Mountain thrust (fig. 18). Other thrusts in the Pogonip Group may have stratigraphic separations of 300 m or more. The vertical South Richmond fault, which is truncated by the Richmond Mountain thrust, separates two very different parts of the carbonate assemblage. On the southwest side, the rocks are Hanson Creek Formation and Roberts Mountains Formation; on the northeast side, the Hamburg Dolomite.

Faulting throughout the rocks of the siliceous assemblage is indicated by fracturing of chert and shale in outcrop and fragments of chert breccia in the regolith. Some of the faulting probably dates from the Antler orogeny. South of the Lynn Window, the limestone of the transitional assemblage provides marker horizons that indicate much imbricate thrusting in the allochthon. North of the Lynn Window,



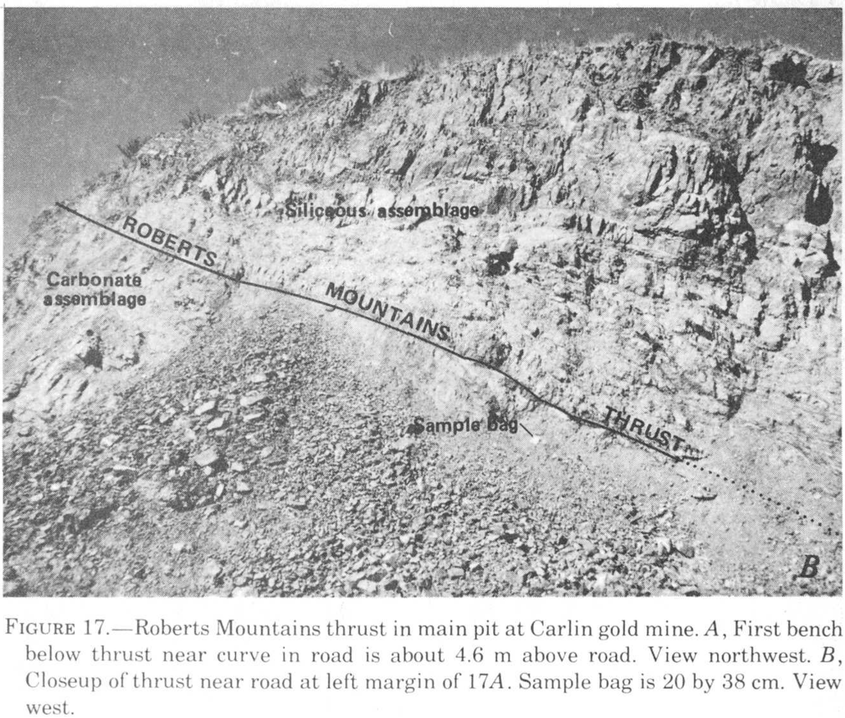


FIGURE 17.—Roberts Mountains thrust in main pit at Carlin gold mine. *A*, First bench below thrust near curve in road is about 4.6 m above road. View northwest. *B*, Closeup of thrust near road at left margin of 17*A*. Sample bag is 20 by 38 cm. View west.

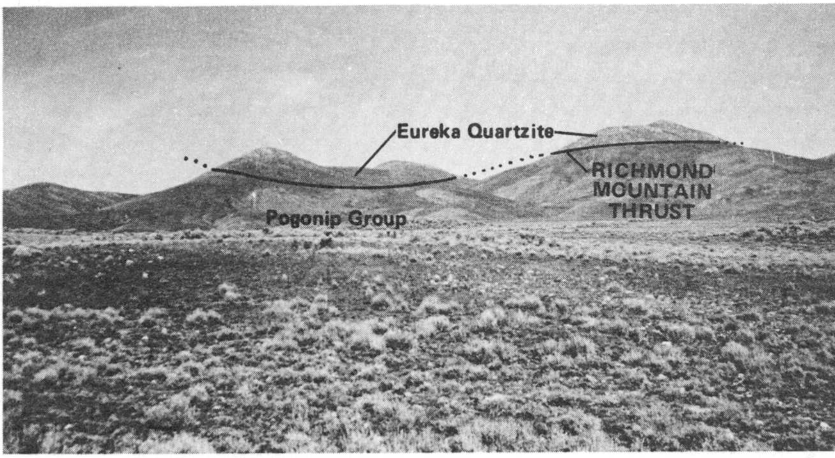


FIGURE 18.—Richmond Mountain thrust (dotted where missing) is the contact between Eureka Quartzite and Pogonip Group. View of east flank of Tuscarora Mountains looking westward. South (left) of view, thrust overrides Roberts Mountains and Popovich Formations.

Silurian and Ordovician graptolites in the chert and shale are juxtaposed or in reverse stratigraphic order, suggesting the presence of faults with large separations in the allochthon.

Large north-northeast- and north-trending folds (see pls. 1 and 2) are better developed in the siliceous allochthon south of the Lynn Window. Minor folds with similar orientations occur locally in the thin-bedded chert (fig. 19). In general, the folds are concentric with steeply dipping and vertical axial planes. A detailed study of the minor structures by Evans and Theodore (1978) indicates that most of the minor folding visible is in the chert. The structures in the chert do not accurately reflect the total strain of the allochthon. Masses of chert, after early ductile folding, behaved in a brittle manner in the more ductile shale and argillite matrix, which thereafter took up much of the strain. The minor folds in the chert indicate an apparent horizontal component of tectonic shortening of the allochthon along a direction N. 70°–75° W., consistent with the eastward movement accepted for the Roberts Mountains allochthon. Minor folds with west-northwest trends may have formed in the direction of tectonic transport during this orogeny.

The carbonate strata in the Lynn Window form a broad asymmetric anticline plunging 20° N. 15° W. (fig. 20). Beds on the southwest limb of the fold are steeply dipping and overturned. On the east limb the beds have low to moderately steep dips. Smaller folds parallel to the

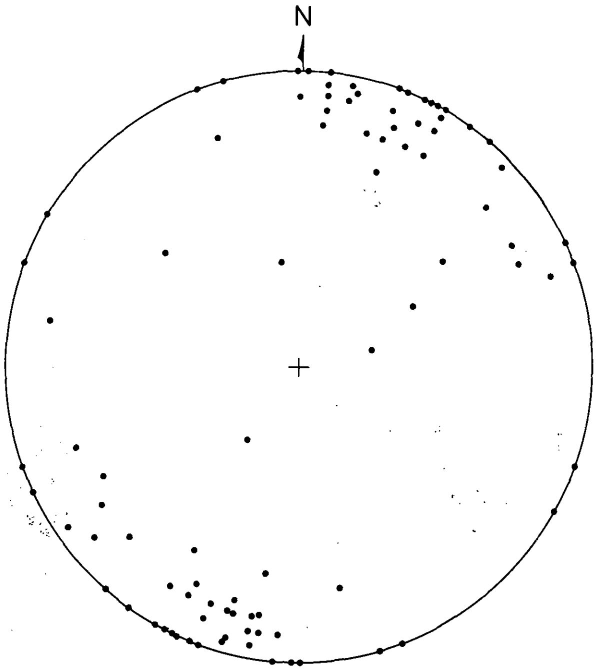


FIGURE 19.—Seventy-three fold axes (•) from the siliceous assemblage. Data plotted on lower hemisphere of equal-area projection. N, geographic north direction; vertical downward direction is marked by a cross.

major fold axis occur in the Roberts Mountains and Popovich Formations in northwest Lynn Window. The large anticline trends at an angle of approximately 30° across the general north-northeast trend of the Antler orogenic belt and is therefore likely to be younger than the Antler orogeny.

The southwest limb of the major anticline contains several north- and northwest-trending thrusts that dip east and northeast. The longest of these faults, the West Lynn thrust (fig. 21), contains carbonate rocks in the upper plate and siliceous rocks in the lower plate. Interpretation of the West Lynn thrust as an overturned segment of the Roberts Mountains thrust may be valid. Yet the gentle east dip of the West Lynn thrust and the composition of its upper and lower plates are clearly inconsistent with the structural relations generally exhibited by the Roberts Mountains thrust. More likely, the West Lynn thrust is younger than the Antler orogeny.

The large anticline and the West Lynn thrust may have formed in response to the emplacement of the Cretaceous quartz monzonite pluton inferred to lie beneath the carbonate assemblage (see cross sec-

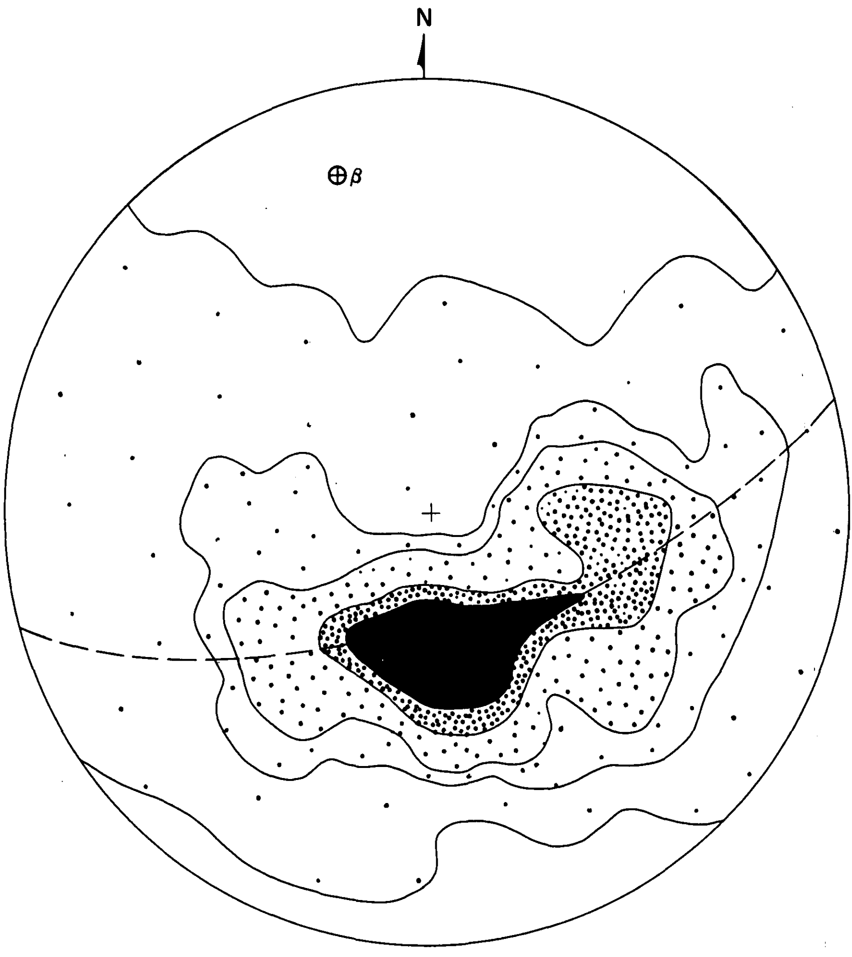


FIGURE 20.—Contour diagram of poles to bedding (300 points) in carbonate assemblage rocks on Richmond Mountain. Data were plotted on lowerhemisphere of equal-area projection. Contours in sigmas (2, 4, 8 and 12) and pole-free area (method of Kamb, 1959). Stippling pattern reflects density of data points. Dashed line is great circle. Circle with cross is beta axis defining orientation of main anticline in carbonate assemblage. N, geographic north direction; vertical downward direction is marked by a cross.

tion *A–A*, *C–C*, *D–D*, pl. 2). Alternatively, the anticline and the West Lynn thrust may have formed during the late Paleozoic or early Mesozoic episode of thrusting that affected the Adobe Range, 55 km northeast of the Lynn Window (Ketner, 1970a), and the Carlin-Piñon Range area (Smith and Ketner, 1977).

Some of the steep north-northeast- and northwest-trending faults cut the Roberts Mountains thrust and the intrusions and must partly postdate the Antler orogeny. These and other relatively minor

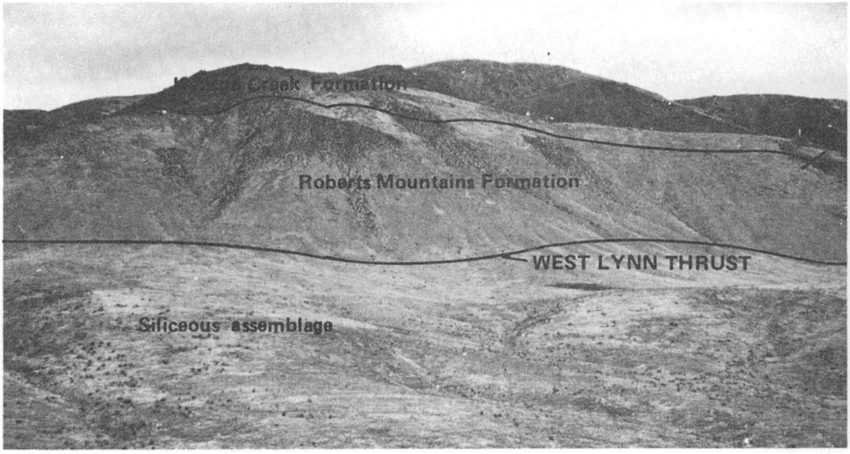


FIGURE 21.—West Lynn thrust. Carbonate assemblage is interpreted as thrust over siliceous assemblage in foreground. Contact between Roberts Mountains Formation and Hanson Creek Formation is overturned and steeply dipping to east. View of west flank of Tuscarora Mountains looking east.

episodes of faulting occurred throughout the Mesozoic and Tertiary. The largest normal fault in the area, the Tuscarora fault, lies along the east flank of the Tuscarora Mountains from Marys Mountain in the Schroeder Mountain quadrangle (Evans and Cress, 1972) to some point north of the map area of this report. The Carlin Formation of middle Miocene to early Pliocene age is juxtaposed with the Paleozoic rocks of the siliceous assemblage along the Tuscarora fault in the northeast corner of the Rodeo Creek NE quadrangle, where bedding in the Carlin dips steeply westward. The Tuscarora fault now lies along much of the west edge of the Tertiary basin that formed between the Tuscarora Mountains and the Independence Mountains. It may have been a boundary fault critical to the forming of that sedimentary basin and could have been active as long ago as middle Miocene. Two steep northwest-trending faults cut the Tuscarora fault at Indian Creek in the northeast corner of the Rodeo Creek NE quadrangle. These two faults, apparently the latest ones in this part of the Tuscarora Mountains, do not offset the Quaternary fanglomerate or the alluvium.

REFERENCES CITED

Akright, R. L., Radtke, A. S., and Grimes, D. J., 1969, Minor elements as guides to gold in the Roberts Mountains Formation, Carlin gold mine, Eureka County, Nevada: Colorado School Mines Quart., v. 64, no. 1, p. 49–66.

Armstrong, R. L., 1970, Geochronology of Tertiary igneous rocks, eastern Basin and Range province, western Utah, eastern Nevada and vicinity, U.S.A.: Geochim. et Cosmochim. Acta, v. 34, p. 203–232.

Bateman, P. C., 1961, Granitic formations in the east-central Sierra Nevada near Bishop, California: Geol. Soc. America Bull., v. 72, p. 1521–1538.

Berry, W. B. N., and Roen, J. B., 1963, Early Wenlock graptolites from Roberts Mountains Formation, Tuscarora Mountains, Nevada: Jour. Paleontology, v. 37, p. 1123–1126.

Carlisle, Donald, Murphy, M. A., Nelson, C. A., and Winterer, E. L., 1957, Devonian stratigraphy of Sulphur Springs and Piñon Ranges, Nevada: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 10, p. 2175–2191.

Carmichael, I. S. E., Turner, F. J., and Verhoogen, John, 1974, Igneous petrology: New York, McGraw-Hill, 739 p.

Dunham, J. B., 1977, Depositional environments and paleogeography of the Upper Ordovician, Lower Silurian carbonate platform of central Nevada *in* Stewart, J. H., Stevens, C. H., and Fritsche, A. E., eds., Paleozoic paleogeography of the western United States: Soc. Econ. Paleontologists and Mineralogists, Pacific Sec., Pacific Coast Paleogeography Symposium 1, p. 157–164.

Emmons, W. H., 1910, A reconnaissance of some mining camps in Elko, Lander, and Eureka County, Nevada: U.S. Geol. Survey Bull. 408, 130 p.

Evans, J. G., 1974a, Geologic map of the Rodeo Creek NE quadrangle Eureka County, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ–1116, scale 1:24,000.

———1974b, Geologic map of the Welches Canyon quadrangle, Eureka County, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ–1117, scale 1:24,000.

Evans, J. G., and Cress, L. D., 1972, Geologic map of the Schroeder Mountain quadrangle, Eureka and Elko Counties, Nevada: U.S. Geol. Survey Misc. Field Studies Map MF–324, scale 1:24,000.

Evans, J. G., and Ketner, K. B., 1971, Geologic map of the Swales Mountain quadrangle and part of the Adobe Summit quadrangle, Elko County, Nevada: U.S. Geol. Survey Misc. Geol. Inv. Map I–667, scale 1:24,000.

Evans, J. G., and Mullens, T. E., 1976, Bootstrap Window, Elko and Eureka Counties, Nevada: U.S. Geol. Survey Jour. Research, v. 4, no. 1, p. 119–125.

Evans, J. G., and Theodore, T. G., 1978, Deformation of the Roberts Mountains allochthon in north-central Nevada: U.S. Geol. Survey Prof. Paper. 1060, 18 p.

Geotimes, 1973, Plutonic rocks—classification and nomenclature recommended by the IUGS Subcommission on the systematics of igneous rocks: Geotimes, v. 18, no. 10, p. 26–30.

Gilluly, James, and Gates, Olcott, 1965, Tectonic and igneous geology of the northern Shoshone Range, Nevada: U.S. Geol. Survey Prof. Paper 465, 153 p.

Gilluly, James, and Masursky, Harold, 1965, Geology of the Cortez quadrangle, Nevada: U.S. Geol. Survey Bull. 1175, 117 p.

Hague, Arnold, 1883, Geology of the Eureka district, Nevada: U.S. Geol. Survey 3d Ann. Rept., p. 237–290.

———1892, Geology of the Eureka district, Nevada: U.S. Geol. Survey Mon. 20 (with atlas), 419 p.

Hardie, B. S., 1966, Carlin gold mine, Lynn district, Nevada: Nevada Bur. Mines Rept. 13, p. 73–83.

Hausen, D. M., 1967, Fine gold occurrence at Carlin, Nevada: Columbia Univ., New York, Ph.D. thesis.

Hausen, D. M., and Kerr, P. F., 1968, Fine gold occurrence at Carlin, Nevada, *in* Ridge, J. D., ed., Ore deposits of the United States, 1933–1967 (Graton-Sales Volume), V. 1: New York, Am Inst. Mining, Metall., and Petroleum Engineers, p. 908–9400.

Johnson, J. G., 1962, Lower Devonian-Middle Devonian boundary in central Nevada: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 4, p. 542–546.

———1965, Lower Devonian stratigraphy and correlation, northern Simpson Park Range, Nevada: Canadian Petroleum Geology Bull., v. 13, p. 365–381.

———1966, Middle Devonian brachiopods from the Roberts Mountains, central Nevada: Paleontology, v. 9, p. 152–181.

———1970, Great Basin Lower Devonian brachiopoda: Geol. Soc. America Mem. 121, 421 p.

———1973, Placer gold deposits of Nevada: U.S. Geol. Survey Bull. 1356, 118 p.

Kamb, W. B., 1959, Ice petrofabric observations from Blue Glacier, Washington, in relation to theory and experiment: Jour. Geophys. Research, v. 64, p. 1891–1909.

Ketner, K. B., 1968, Origin of Ordovician quartzite in the Cordilleran miogeosyncline, *in* Geological Survey research 1968: U.S. Geol. Survey Prof. Paper 600–B, p. B169–B117.

———1970a, Geology and mineral potential of the Adobe Range, Elko Hills and adjacent areas, Alko County, Nevada, *in* Geological Survey research 1970: U.S. Geol. Survey Prof. Paper 700–B, p. B105–B108.

———1970b, Limestone turbidite of Kinderhook age and its tectonic significance, Elko County, Nevada, *in* Geological Survey research 1970: U.S. Geol. Survey Prof. Paper 700–D, p. D18–D22.

King, Clarence, 1878, Systematic geology: U.S. Geol Explor. 40th Parallel (King), v. 1, 803 p.

Kirk, Edwin, 1933, The Eureka Quartzite of the Great Basin region: Am. Jour. Sci., 5th ser., v. 26, p. 27–44.

Lehner, R. E., Tagg, K. M., Bell, M. M., and Roberts, R. J., 1961, Preliminary geologic map of Eureka County, Nevada: U.S. Geol. Survey Misc. Field Studies Map MF–178, scale 1:200,000.

McKee, E. H., and Silberman, M. L., 1970, Geochronology of Tertiary igneous rocks in central Nevada: Geol. Soc. America Bull., v. 81, p. 2317–2328.

McKee, E. H., Silberman, M. L., Marvin, R. E., and Obradovich, J. D., 1971, A summary of radiometric ages of Tertiary volcanic rocks in Nevada and eastern California—pt. 1, central Nevada: Isochron/West, no. 2, p. 21–42.

McQuisten, F. W., Jr., and Hernlund, R. W., 1965, Newmont's Carlin gold project: Mining Cong. Jour., v. 51, no. 11, p. 26–39.

Matti, J. C., Murphy, M. A., and Finney, S. C., 1975, Silurian and Lower Devonian basin and basin-slope limestones, Copenhagen Canyon, Nevada: Geol. Soc. America Spec. Paper 159, 48 p.

Merriam, C. W., 1940, Devonian stratigraphy and paleontology of the Roberts Mountains region, Nevada: Geol. Soc. America Spec. Paper 25, 114 p.

———1963, Paleozoic rocks of Antelope Valley, Eureka and Nye Counties, Nevada: U.S. Geol. Survey Prof. Paper 423, 67 p.

Merriam, C. W, and Anderson, C. A., 1942, Reconnaissance survey of the Roberts Mountains, Nevada: Geol. Soc. America Bull., v. 53, p. 1675–1728.

Moore, R. C., and Jeffords, R. M., 1968, Classification and nomenclature of fossil crinoids based on studies of dissociated parts of their columns: Kansas Univ. Paleont. Contr., art. 9, 86 p.

Mullens, T. E., and Poole, F. G., 1972, Quartz-sand-bearing zone and Early Silurian age of upper part of the Hanson Creek Formation in Eureka County, Nevada, *in* Geological Survey research 1972: U.S. Geol. Survey Prof. Paper 800–B, p. B21–B24.

Nolan, T. B., Merriam, C. W., and Williams, J. S., 1956, The stratigraphic section in the vicinity of Eureka, Nevada: U.S. Geol. Survey Prof. Paper 276, 77 p.

Peterson, D. W., 1961, Description modal classification of igneous rocks, AGI data sheet 23: Geotimes, v. 5, no. 6, p. 30–36.

Radtke, A. S., 1973, Preliminary geologic map of the Carlin gold mine, Eureka County, Nevada: U.S. Geol. Survey Misc. Field Studies Map MF–537, scale 1:3,636.

——— 1974, Preliminary geologic map of the area of the Carlin and Blue-Star gold deposits, Eureka County, Nevada: U.S. Geol. Survey Misc. Field Studies Map MF–552, scale 1:12,000.

——— 1980, Geology of the Carlin gold deposits, Nevada: U.S. Geol. Survey Prof. Paper (in press).

Radtke, A. S., and Scheiner, B. J., 1970, Studies of hydrothermal gold deposition (I)—Carlin gold deposit, Nevada—the role of carbonaceous materials in gold deposition: Econ. Geology, v. 65, p. 87–102.

Regnier, Jerome, 1960, Cenozoic geology in the vicinity of Carlin, Nevada: Geol. Soc. America Bull., v. 71, p. 1189–1210.

Roberts, R. J., 1964, Stratigraphy and structure of the Antler Peak quadrangle, Humboldt and Lander Counties, Nevada: U.S. Geol. Survey Prof. Paper 459–A, 93 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, no. 12, p. 2813–2857.

Roberts, R. J., Montgomery, K. M., and Lehner, R. E., 1967, Geology and mineral resources of Eureka County, Nevada: Nevada Bur. Mines Bull. 64, 152 p.

Roberts, R. J., Radtke, A. S., and Coats, R. R., 1971, Gold-bearing deposits in north-central Nevada and southwestern Idaho: Econ. Geology, v. 66, p. 14–33.

Roen, J. B., 1961, Geology of the Lynn Window, Tuscarora Mountains, Eureka County, Nevada: California Univ., Los Angeles, M.S. thesis, 99 p.

Ross, R. J., Jr., 1970, Ordovician brachipods, trilobites, and stratigraphy in eastern and central Nevada: U.S. Geol. Survey Prof. Paper 639, 103 p.

Smith, J. F., Jr., and Ketner, K. B., 1968, Devonian and Mississippian rocks and the date of the Roberts Mountains thrust in the Carlin-Piñon Range area, Nevada: U.S. Geol. Survey Bull. 1251–I, 18 p.

——— 1975, Stratigraphy of Paleozoic rocks in the Carlin-Piñon range area, Nevada: U.S. Geol. Survey Prof. Paper 867–A, 87 p.

——— 1977, Tectonic events since early Paleozoic in the Carlin-Piñon area, Nevada: U.S. Geol. Survey Prof. Paper 867–C, 18 p.

U.S. Geological Survey, 1967, Aeromagnetic map of the Palisades 1 and Palisades 2 quadrangles, Eureka and Elko Counties, Nevada, Sheet 9 *of* Aeromagnetic maps in north-central Nevada: U.S. Geol. Survey Open-File Rept.

Vanderburg, W. O., 1936, Placer mining in Nevada: Nevada Univ. Bull., v. 30, no. 4, 180 p.

——— 1938, Reconnaissance of mining districts in Eureka County, Nevada: U.S. Bur. Mines Inf. Circ. 7022.

Westgate, L. G., and Knopf, Adolf, 1932, Geology and ore deposits of the Pioche district, Nevada: U.S. Geol. Survey Prof. Paper 171, 79 p.

Wheeler, H. E., and Lmmon, D. M., 1939, Cambrian formations of the Eureka and Pioche district, Nevada: Nevada Univ. Bull., v. 33, no. 3, Geology and Mining ser. 31, 60 p.

Wilkinson, J. F. G., 1967, The petrography of basaltic rocks *in* Hess, H. H., and Poldervaart, Arie, eds., Basalt—the Poldervaart treatise on rocks of basaltic composition, V. 1: New York and London, Interscience Pubs., p. 163–214.

Willden, Ronald, and Kistler, R. W., 1969, Geologic map of the Jiggs quadrangle, Elko County, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ–859, scale 1:62,500.