60002237

Mining District File Summary Sheet

DISTRICT	Elko County General
DIST_NO	0050
COUNTY If different from written on document	Elko
TITLE If not obvious	Tectonic Implications of the Presence of the EDNA Mountain Formation in Northern Elko County, Nevada
AUTHOR	Coats, R; Gordon, Jr., M.
DATE OF DOC(S)	1972
MULTI_DIST Y / (N?)	
Additional Dist_Nos:	
QUAD_NAME	Delaware Creek 7½'; Double Mountain 7½'; North Fork 7½'; Wagon Springs 7½'
P_M_C_NAME (mine, claim & company names)	
COMMODITY If not obvious	
NOTES	Geologic report; Geology; geologic map; fossils; U.S. Professional Paper 800C, p C85-C94; Coats donation 10 p.

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	Initials	Date
SS:	DD	12/11/08
DB:	PB	12/01/09
SCANNED:		

Revised: 1/22/08

TECTONIC IMPLICATIONS OF THE PRESENCE OF THE EDNA MOUNTAIN FORMATION IN NORTHERN ELKO COUNTY, NEVADA

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Prepared in cooperation with the Nevada Bureau of Mines

Abstract.—In the Divide Peak area of Elko County, Nevada, about 45 miles north of Elko, an erosional window in Tertiary volcanic rocks exposes Paleozoic rocks of two structural plates, separated by a major thrust that is structurally higher than the Roberts Mountains thrust. In the higher plate, clastic rocks of the Edna Mountain Formation of Permian (Phosphoria) age, that resemble those of the Antler Peak area, rest unconformably on and are involved in imbricate thrust relations with the Valmy Formation (Ordovician) of the western assemblage. In the lower plate, the Phosphoria Formation rests unconformably on the Valmy. Indirect evidence suggests that the thrusting occurred between early late Early Triassic, and the Middle or early Late Jurassic, probably nearer the earlier limit. The differences in sedimentary facies and faunas between the Phosphoria and Edna Mountain Formations of the Divide Peak area are attributed to major overthrusting. Unless autochthonous Edna Mountain Formation, of a facies similar to that of the Divide Peak area, can be found at some place between Antler Peak and Divide Peak, we think that this span of about 96 miles approximates the minimum horizontal dislocation.

In much of northern Nevada, outcrops of Paleozoic rocks were for a long time supposed to be confined mostly to the highlands, which are separated by immense expanses of Tertiary volcanic and sedimentary rocks. Exploration of the volcanic areas, however, has revealed many windows, some of considerable extent, in which the Paleozoic rocks are exposed. In some areas the Paleozoic rocks stand high topographically, as horsts, and many of these may never have been covered by Tertiary rocks, whereas in other areas, post-Tertiary faulting has permitted the stripping of the Tertiary cover and revealed the Paleozoic basement in windows. Information obtained from mapping in these horsts or windows may be vital in interpreting the Paleozoic and Mesozoic tectonic history, but because of the gaps resulting from areally limited and imperfect exposures, much of this interpretation must rest on inference rather than on observation. One window is in the Divide Peak area, 45 miles north of Elko, northern Elko County (fig. 1). The Divide triangulation station is on the south edge, near the southeast corner, of the Wild Horse quadrangle. The Paleozoic rocks that are the principal subject of this paper are exposed both north and southeast of that point, in Tps. 41 and 42 N., R. 55 E. (Mount Diablo base line and meridian). The Paleozoic rocks belong to two sequences, in each of two blocks separated by a major thrust: the early Paleozoic western, or siliceous-volcanic sequence (Roberts and

Figure 1.—Index map of Nevada, showing the locations of the Divide Peak area, Edna Mountain, and Antler Peak.

U.S. GEOL. SURVEY PROF. PAPER 800-C, PAGES C85-C94

others, 1958; Silberling and Roberts, 1962), and the late Paleozoic, or western synorogenic sequence. The early Paleozoic rocks for which paleontologic data are available are part of the Valmy Formation of Ordovician age; others are of doubtful age, but the assignment of all to the western sequence is not in doubt. The late Paleozoic synorogenic rocks of the upper plate belong to the Edna Mountain Formation of Permian age, which lies in both depositional and thrust contact on the early Paleozoic rocks. The early Paleozoic rocks may also be thrust over the Edna Mountain Formation in some places; the thrust plate containing both sequences rests upon Paleozoic rocks of the western assemblage (Roberts and others, 1958; Silberling and Roberts, 1962) and upon the Phosphoria Formation, differing in facies and faunal content from the Edna Mountain Formation, though nearly of the same age.

EARLY PALEOZOIC ROCKS

Valmy Formation

The Valmy Formation in the type area (Roberts, 1951) has been subdivided into two members: the lower mainly of quartzite, dark-gray and greenish chert, gray to black siliceous shale, and some greenstone, the upper mainly of chert interbedded with dark shale and a little greenstone. The age of the Valmy is considered (Roberts and others, 1958, p. 2833; Silberling and Roberts, 1962, p. 12) to span the Ordovician Period.

The rocks of the Divide Peak area that have been identified as Valmy include white to light-tan or gray quartzite, chert, and calcarenite.

The most conspicuous lithic unit of the Valmy Formation is a quartzite which, because of its great resistance to erosion, forms the summit of the high ridge extending northward from Divide triangulation station. Small klippen or windows of the quartzite are found in the midst of exposures of Edna Mountain Formation in the lowlands west of the Divide ridge (fig. 2). The quartzite unit as mapped also includes a small amount of chert, shale, and calcarenite exposed on the southern nose of the ridge mentioned above. To the southeast, areas of low relief are underlain by poorly exposed chert and shale that have been mapped as part of the Valmy, but these have furnished no fossils.

The quartzite is typically gray and has a vitreous appearance on fracture, and in thin section displays a mosaic of quartz grains ranging in size from about 0.07 to 0.7 mm. The grains have simple, not digitate boundaries, and lack any signs of secondary enlargement. In a few places the quartzite is a quartz arenite in which similarly sized quartz grains still retain the high degree of sphericity they had at the time of deposition, and are cemented together by flamboyant quartz. Leaching of this and possibly other cements has left a rather porous arenite.

The calcarenite mentioned above has furnished the only fossil collections from the early Paleozoic rocks of this area. Two collections have been made: in 1964 (USGS 5455-CO), and in 1970 (USGS 7104-CO). Both collections yielded only conodonts, determined by John Huddle; the taxa determined in the smaller collection are also present, with others, in the larger subsequent collection. The Nevada (E. zone) coordinates of the site are E. 447,450, N. 2,457,400, scaled from the Wells 2° quadrangle. This point is about 800 feet S. 45° W. of Divide triangulation station on the south edge of the Wild Horse quadrangle. The fauna reported by Huddle is as follows:

	Number of specimens
Drepanodus robustus Hadding	
drepanodiform element	7
oistodiform element	7
Periodon aculeatus Hadding	
ozarkodiniform element	13
ligonodiform element	15
cordylodiform element	8
falodiform element	5
trichonodelliform element?	1
"*Oistodus*" *multicorrugatus* Harris	6
Scolopodus sp.	1

"This fauna is Middle Ordovician in age."

Greenstone and chert

In the southeastern part of the Divide Peak area, two fault slivers of rocks of different type, both lacking in fossils, are attributed to the western, or siliceous-volcanic assemblage. One of the slivers is a now chloritized and epidotized greenstone unit that locally is a calcareous peperitic breccia. This suggests that the breccia, probably of andesitic composition originally, was erupted into marine waters in which calcareous muds were accumulating. This unit is considered to be of Paleozoic age.

The other unit consists predominantly of black chert but includes minor amounts of pale-purplish and pale-greenish-gray shale. Its weathering yields few outcrops, and the surface is littered with a carpet of sharply angular inch-sized fragments of lustrous black chert, many with reentrant angles. The age of the chert is unknown. James Gilluly (oral commun., 1965) suggested that it might be correlatable with the Slaven Chert, of Devonian age, the type locality of which is in the northern Shoshone Range. The characteristics of the Slaven Chert, as described (Gilluly and Gates, 1965, p. 37), resemble closely those of the chert in this area, but the interbedded shale in the type area is described as dark colored, rather than varicolored. In nearby ranges, similar cherts have been found in fossiliferous Ordovician rocks of the western assemblage (Evans and Ketner, 1971).

PERMIAN ROCKS

Permian rocks of the Divide Peak area are referred to two formations, the Edna Mountain Formation and the Phosphoria Formation. These are approximately of the same age, but the lithologic facies differ, and the fossil assemblages also differ considerably. The Edna Mountain Formation rests in thrust contact on the Phosphoria Formation in the southeastern part of the area.

Edna Mountain Formation

The type locality of the Edna Mountain Formation is in the Golconda quadrangle on the west slope of Edna Mountain, about 100 miles west-southwest of the Divide Peak area (Roberts, 1951; Ferguson and others, 1952). Lithologies in the study area generally resemble those in the type area. In the study area the rocks include minor well-indurated chert-quartz conglomerate and gray, buff-weathering sandstone and siltstone that contain a mold fauna. Some of the siltstone in the study area weathers to a highly characteristic pale-purplish red (5*RP* 6/2).

Almost all collections in our area are of a mold fauna in a buff-weathering sandstone or siltstone. Much of the sandstone is so massive that attitudes cannot be measured. The typical sandstone is a chert-quartz arenite, made up of angular fragments, that grades to a granule conglomerate. In some places as much as 5 percent of the fragments may be phyllite. Almost all the fragments are of rocks that are known to occur in the Valmy Formation. At station 1645 (E. 451,700, N. 2,447,500) the Edna Mountain rests unconformably on the Valmy. At this point the Edna Mountain is a poorly sorted granule to pebble sharpstone conglomerate of subangular fragments of brown-weathering porous quartzite. The quartzite consists of well-rounded quartz grains, partly cemented together by flamboyant quartz, leaving angular interstices now vacant, but apparently once filled with some iron-bearing mineral. The unconformable contact here dips 20° S. 15° E.

Phosphoria Formation

The rocks of the Divide Peak area that are attributed to the Phosphoria Formation of Permian age are almost entirely fine buff-weathering siltstones and massive light-gray limestone; a few beds are as much as 8 feet thick. The typical chert and phosphatic shale lithologies of the Phosphoria, which are present but a few miles to the north and south of the Divide Peak area, have not been recognized here, perhaps because of the restricted area of outcrop of the Phosphoria.

PERMIAN FAUNAS

The fossils of the Edna Mountain Formation are shown as the *Spiriferella* assemblage in table 1. This invertebrate fauna is made up predominantly of individuals of a spiriferoid brachiopod, *Spiriferella* sp. A, together with other less common brachiopods and a few mollusks. The fauna was recognized in 10 collections from eight stations and is typical of most of the Permian outcrops in this area. *Spiriferella* sp. A is also the dominant species in the type Edna Mountain Formation, where it is associated with *Hustedia* cf. *H. phosphoriensis* Branson. Some of the typical fossils of this assemblage are illustrated in figure 3.

The relatively close relationship of this assemblage to the predominantly molluscan fauna of the autochthonous *Cyrtorosta* assemblage, here referred to the Phosphoria Formation, is also indicated in table 1. Four species of brachiopods are common to the two assemblages: *Phrenophoria* sp. A, *Leiorhynchoidea*? sp., *Composita* cf. *C. mira* Girty, and *Hustedia* cf. *H. phosphoriensis* Branson.

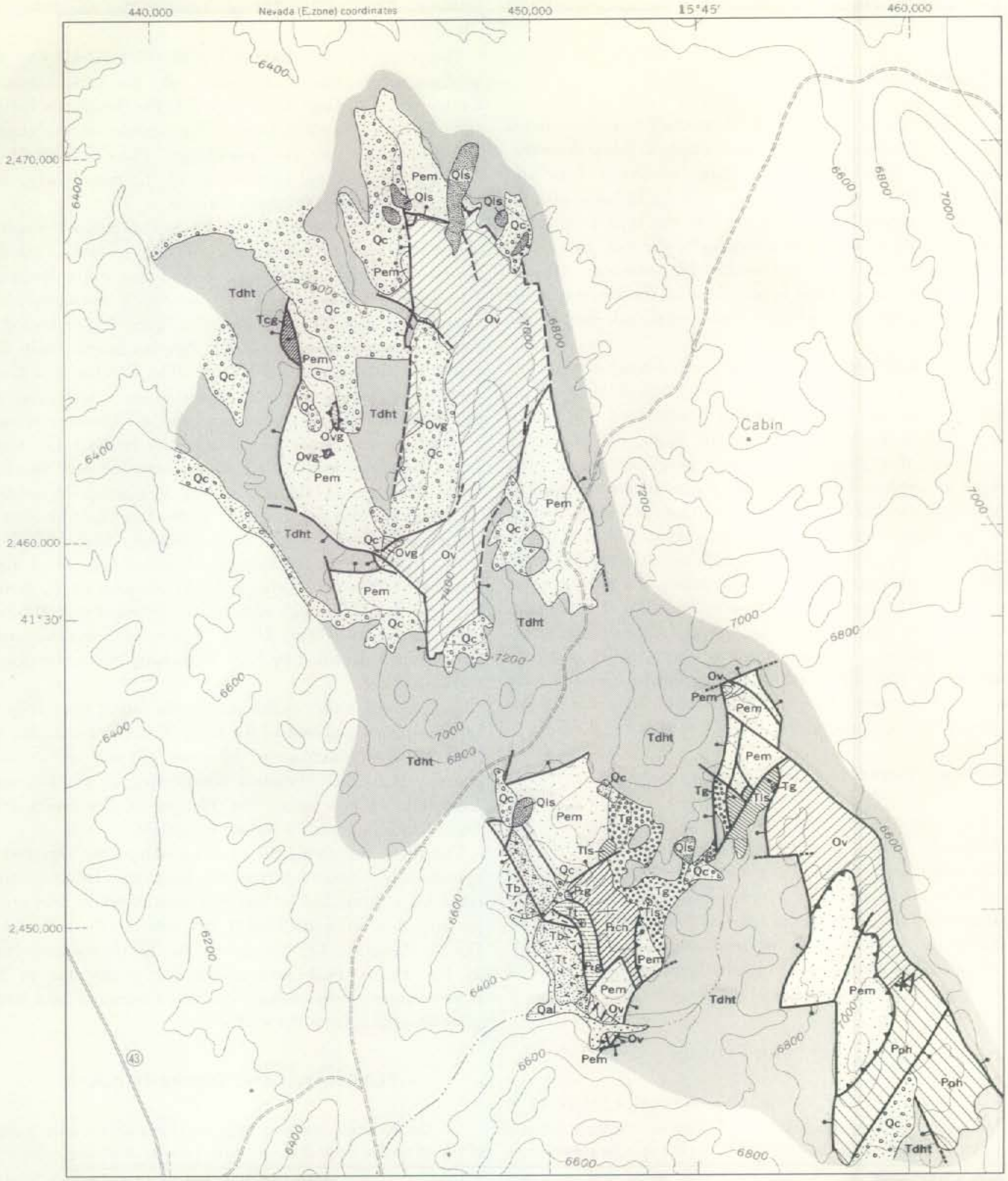
The fossils from rocks referred to the Phosphoria Formation are shown as the *Cyrtorostra* assemblage in table 1. Occurrences of species common to it and the Edna Mountain Formation are listed under the *Spiriferella* assemblage. The *Cyrtorostra* assemblage, illustrated in figure 4, is restricted to the southeasternmost part of the Permian outcrop belt. The collection localities are listed in table 2. This is a fauna predominantly of mollusks associated with less abundant brachiopods. The most common species, *Cyrtorostra varicostata* Branson, is common also locally in the Franson and Ervay Members of the Park City Formation and the Tosi Chert Member of the Phosphoria Formation in western Wyoming and also occurs locally in the Rex Chert Member of the Phosphoria Formation in southeastern Idaho (Ciriacks, 1963, p. 58). The brachiopods identified here as cf. *Cancrinella phosphatica* (Girty) and *Rhynchopora* cf. *R. taylori* Girty have close affinities with species described from the Park City Formation (Girty, 1910). A pleurotomariacean snail, *Eirlysia* sp., (identified by E. L. Yochelson) is also common in this assemblage.

As discussed earlier in this article, the faunal assemblage of the Phosphoria and that of the Edna Mountain Formation are regarded as approximately the same age but are in fault contact, the Edna Mountain constituting an allochthonous formation in this area. The Phosphoria Formation rests unconformably upon the Valmy Formation.

The rocks containing the two assemblages are regarded as approximately contemporaneous. They are, however, separated by a thrust fault at the only locality where they are in juxtaposition, on a small hill 3 to 4 miles north-northwest of Double Mountain. The presence of the *Spiriferella* assemblage in the Divide Peak area is believed to be due to the incorporation of the Edna Mountain Formation in a thrust plate brought in from the west.

TERTIARY(?) AND TERTIARY ROCKS

On the extreme western edge of the mapped area, a small sliver of rocks, bounded on both sides by high-angle faults, is attributed to the Tertiary(?). These rocks are well-indurated, deeply iron stained roundstone conglomerates made up of clasts derived chiefly from the Valmy Formation. No fossils were found in them; they resemble the rocks described by Van Houten (1956, p. 2806) as eastern conglomerates, that rest on the Paleozoic rocks. Van Houten (1956, p. 2807) suggests that



Base from U.S. Geological Survey Wells, Nevada; Utah; Idaho 1:250,000, 1955 and Wildhorse 1:62,500, 1956

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Geology by R. R. Coats, 1962, 1964, and 1967

Figure 2.—Geologic map of the Divide Peak area, Elko County, Nev.

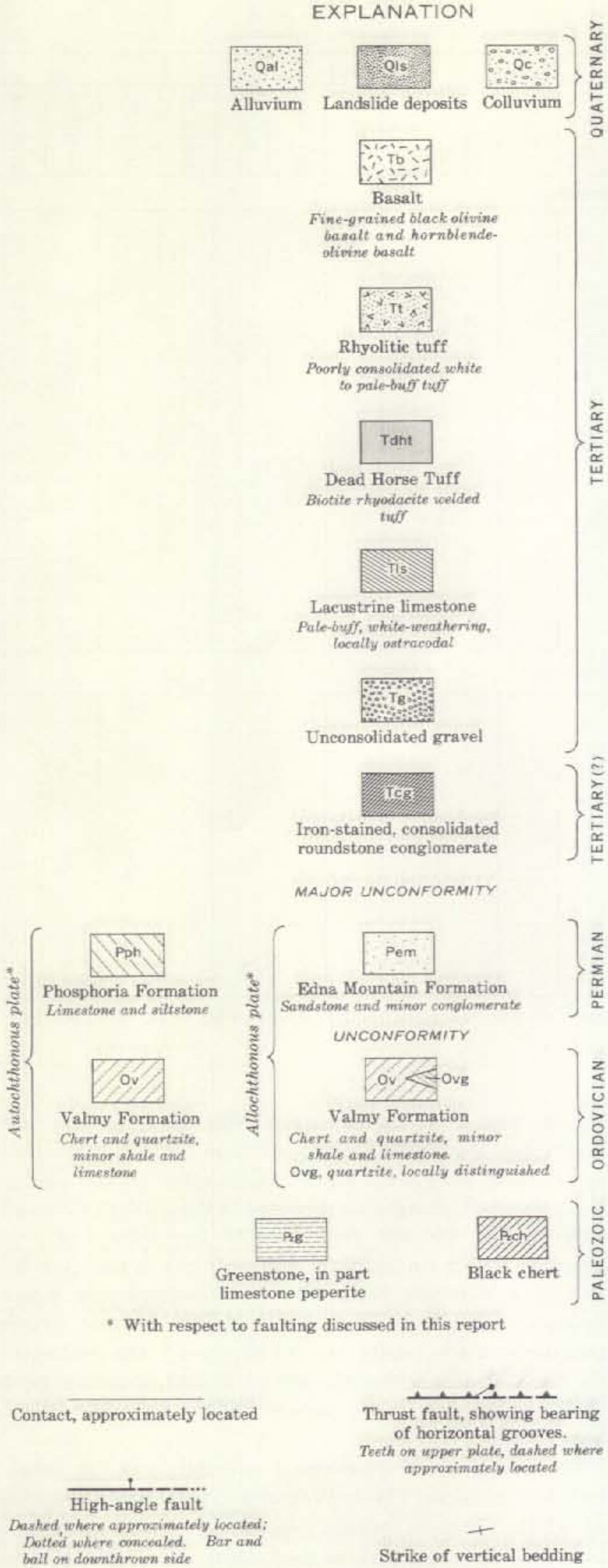

Figure 2.

these conglomerates in northwestern Utah and east-central Nevada may be equivalent to conglomerates in the Paleocene or lower Eocene Wasatch Formation of north-central Utah.

Near the middle of the mapped area, the Paleozoic rocks are obscured by a mantle of unconsolidated, poorly sorted angular gravel of fragments derived from the Paleozoic rocks. The thickness is uncertain because lack of outcrops prevents determination of the attitude, but it is probably less than 100 feet. In a few places the gravel is overlain by buff, white-weathering fine-grained ostracodal limestone, which may range in thickness from 2 feet to perhaps as much as 20 feet. The ostracodes are not of determinable age.

The most widespread of the Tertiary formations is a biotite rhyolite welded tuff which, at least locally, has scattered small grains of yellow andradite. Near the west margin of the area mapped, this tuff unit appears to interfinger with white lacustrine rhyolitic tuffs, now opalized in part, containing fragmentary leaves of grass and sedge. This unit is believed to be correlative with the Dead Horse Tuff (Coats, 1964, p. M7), for which a K-Ar age of 39.9 million years was determined (Axelrod, 1966, p. 500). Numerous high-angle faults, mostly north trending, cut the Dead Horse in this area, and the strata in many of the fault blocks display moderately steep dips.

On the southern flank of the area, the Dead Horse Tuff is overlapped by soft, poorly consolidated rhyolitic tuffs overlain by dense, black olivine basalt and hornblende-olivine basalt. The age of these rocks is unknown.

TECTONIC RELATIONS

The Valmy Formation and the undifferentiated western-assemblage Paleozoic rocks are allochthonous, wherever their relations have been determined in this region. The Edna Mountain Formation, as indicated above, is in depositional contact with the Valmy Formation; in most places, the contact is not well exposed, but at coordinates E. 451,700, N. 2,447,500 (Nevada, E. zone) the thin gently dipping basal conglomerate of the Edna Mountain rests with angular unconformity on the Valmy. In many places, however, the contact is a tectonic one; at E. 452,500, N. 2,499,700, the Edna Mountain rests on a fault surface on the undifferentiated Paleozoic chert. Here there is a well-developed horizontal mullion structure trending N. 55° E. Elsewhere the relations are equivocal. The ridge to the north of Divide triangulation station is capped by a plate of gray Valmy quartzite, apparently not more than 50 feet thick. The considerable horizontal extent of this plate suggests that it is nearly flat lying, but to the southwest of the triangulation station, fossiliferous Ordovician rocks trend nearly north and dip steeply, leading to the inference that the quartzite plate is thrust over the fossiliferous rocks. To the west of the high ridge of Divide Peak, in secs. 21 and 28, two isolated masses of Valmy are shown as windows. Both of these are quartzite, and numerous slickensided surfaces of diverse trend are present in

Table 1.—*Permian fossils from the Divide Peak area, Elko County, Nev.*

Fossils	Collection[1]													
	21583-PC	21584-PC	21585-PC	21593-PC	21594-PC	22820-PC	23216-PC	23778-PC	23779-PC	23780-PC	24513-PC	24514-PC	64NC133	64NC134
***Spiriferella* assemblage**														
Corals:														
Horn coral, gen. and sp. indet.	...	...	×	...	×	×	...	...	...	...	...	...	...	...
Brachiopods:														
Orbiculoidea sp.	...	...	×	...	...	...	×	...	...	...	...	...	...	...
Sulcataria? sp. indet.	...	...	...	...	...	...	...	...	×	...	...	...	...	...
Strophalosia sp.	?	...	×	...	×	×	×	...	...	...	...	...	...	...
Productoid, gen. and sp. indet.	...	...	...	...	...	×	...	...	×	...	...	...	...	...
Phrenophoria sp. A.	×	×	×	×	×	×	...	...	...	×	×	×	...	...
Leiorhynchoidea? sp.	×	×	...	?	×	...	...	...	...	...	×	...	...	...
Rhynchopora? sp.	...	...	...	...	...	...	...	×	...	?	...	...	...	...
Cleiothyridina sp. indet.	...	...	×	...	×	...	×	...	...	...	...	...	...	...
Composita cf. *C. mira* Girty	...	×	...	×	...	×	×	...	×	...	...	...	...	...
Spiriferella sp. A	...	...	×	?	×	×	×	×	×	×	×	×	×	×
Xestotrema sp. indet.	...	...	...	...	...	...	...	×	...	...	...	...	...	...
Hustedia cf. *H. phosphoriensis* Branson	×	×	×	×	×	×	×	×	...	...	×	×	...	...
Beecheria sp. B.	...	...	...	...	...	...	...	×	...	×	...	...	...	...
Mollusks:														
Phestia sp. indet.	...	...	...	...	...	×	...	...	...	×	...	...	...	...
Parallelodon sp.	...	...	...	...	...	...	×	...	...	...	...	...	...	...
Aviculopinna? sp. indet.	...	...	...	...	...	...	...	...	...	×	...	...	...	...
Conocardium sp. indet.	...	...	...	...	...	...	...	...	...	×	...	...	...	...
Pleuronautilus (*Huanghoceras*) sp.	...	...	...	...	...	...	...	...	...	×	...	...	...	...
***Cyrtorostra* assemblage**														
Bryozoans:														
Trepostome, small ramose form.	×	×	...	×	...	...	...	...	...	...	...	...	...	...
Echinoderms:														
Crinoid columnals	×	...	...	...	...	...	...	...	...	...	...	...	...	...
Brachiopods:														
cf. *Cancrinella phosphatica* (Girty)	×	×	...	×	...	...	...	...	...	...	...	...	...	...
Grandaurispina sp.	...	×	...	×	...	...	...	...	...	...	...	...	...	...
Rhynchopora cf. *R. taylori* (Girty)	...	×	...	×	...	...	...	...	...	...	...	×	...	...
Spiriferella? sp. B	×	×	...	×	...	...	...	...	...	...	...	...	...	...
Beecheria sp. A.	×	...	...	×	...	...	...	...	...	...	...	?	...	...
Mollusks:														
Nuculopsis sp. indet.	...	...	...	...	...	...	...	...	...	...	...	×	...	...
Streblochondria? cf. *S.*? *montpelierensis* (Girty).	×	×	...	×	...	...	...	...	...	...	...	...	...	...
Cyrtorostra varicostata Branson	×	×	...	×	...	...	...	...	...	...	...	...	...	...
Eirlysia sp.	×	×	...	×	...	...	...	...	...	?	...	×	...	...

[1]Five-figure numbers followed by "PC" are U.S. Geological Survey Upper Paleozoic collection numbers; numbers beginning 64NC are field specimen numbers assigned by R. R. Coats.

them; in the northern and larger window (if that is what it is) a continuous slickensided fault surface forms the upper surface of the quartzite over a considerable area. This fault surface is subcylindrical, the axis trends about N. 32° W., and the mullion structure on the surface plunges, on the southwest about 5° SW. and on the northeast, about 20° NE., passing through the horizontal on the crest of the convex-upward fault surface. Many minor, low-dipping slickensided fault surfaces are exposed in both Valmy and the Edna Mountain. The striations or mullions on these surfaces range in trend from N. 80° E. to S. 65° E. In addition to these low-angle faults, many steep faults with generally northerly trend cut the Valmy quartzite; although well-developed slickensides, with striations nearly down the dip, are observable in many of these, few of them can be traced far, and displacements are probably small.

Near the north end of the exposure of Valmy Formation, in the SW. cor. sec. 21, T. 42 N., R. 55 E., the Valmy is shown, on the map, as in thrust contact with the Edna Mountain Formation. This relation is inferred from the relative position and the map trend of the contact, as the actual contact surface is not exposed. Along a hill slope just to the north of the fossil locality at E. 450,450, N. 2,450,800, large blocks of pink quartzite are strewn upon the surface which is underlain by the Edna Mountain Formation. No topographically higher outcrop of the Valmy can now be found, but the former presence of a now totally removed klippe of Valmy, resting on the Edna Mountain near the top of the hill, seems the most likely explanation for the presence of the Valmy fragments here.

The Phosphoria Formation is autochthonous or parautochthonous in the Divide Peak area. The Valmy Formation on which it rests, in seeming depositional contact, must then be part of the upper plate of the Roberts Mountains thrust, or some other pre-Phosphoria thrust of regional extent.

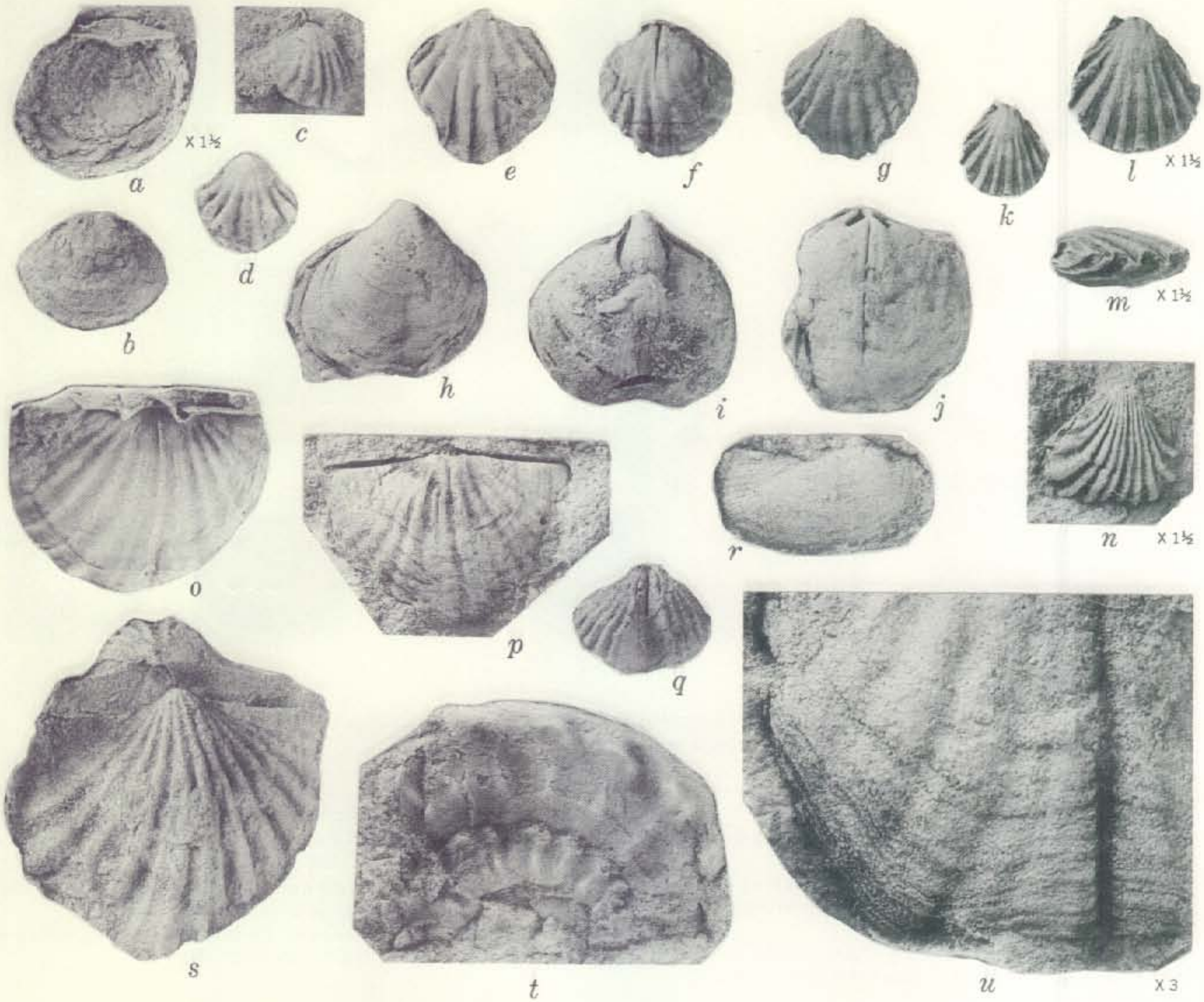

Figure 3.—Fossils of the *Spiriferella* assemblage from the Edna Mountain Formation in the Divide Peak area. Photographs natural size unless otherwise indicated.

a, b. Strophalosia sp. Enlarged brachial view of latex cast from USGS colln. 21594-PC and internal mold of pedicle valve from USGS colln. 24367-PC.

c, d. Phrenophoria sp. A. Slightly oblique view of brachial valve associated with *Strophalosia* of fig. *b*, and latex cast of pedicle valve from USGS colln. 22820-PC.

e–g. Leiorhynchoidea sp. Internal mold of pedicle valve from USGS colln. 24367-PC, and brachial and pedicle views of internal mold from same locality.

h–j. Composita cf. *C. mira* Girty. Pedicle view of latex cast, internal mold of pedicle valve, and incomplete internal mold of brachial valve; all from USGS colln. 22820-PC.

k–n. Hustedia cf. *H. phosphoriensis* Branson. Brachial view and enlarged brachial and side view of internal mold, also pedicle view of latex cast; both specimens from USGS colln. 22820-PC.

o, p, s, u. Spiriferella sp. A. Three brachial valves (*o, p, u*) from USGS colln. 22820-PC including interior view of latex cast, internal mold, and enlarged view of latex cast to show surface pustules; brachial view (*s*) of latex cast from USGS colln. 21585-PC.

q. Xestotrema sp. Internal mold of pedicle valve from USGS colln. 23778-PC.

r. Parallelodon sp. Latex cast of right valve from USGS colln. 23216-PC.

t. Pleuronautilus (*Huanghoceras*) sp. Latex cast of impression from USGS colln. 23780-PC.

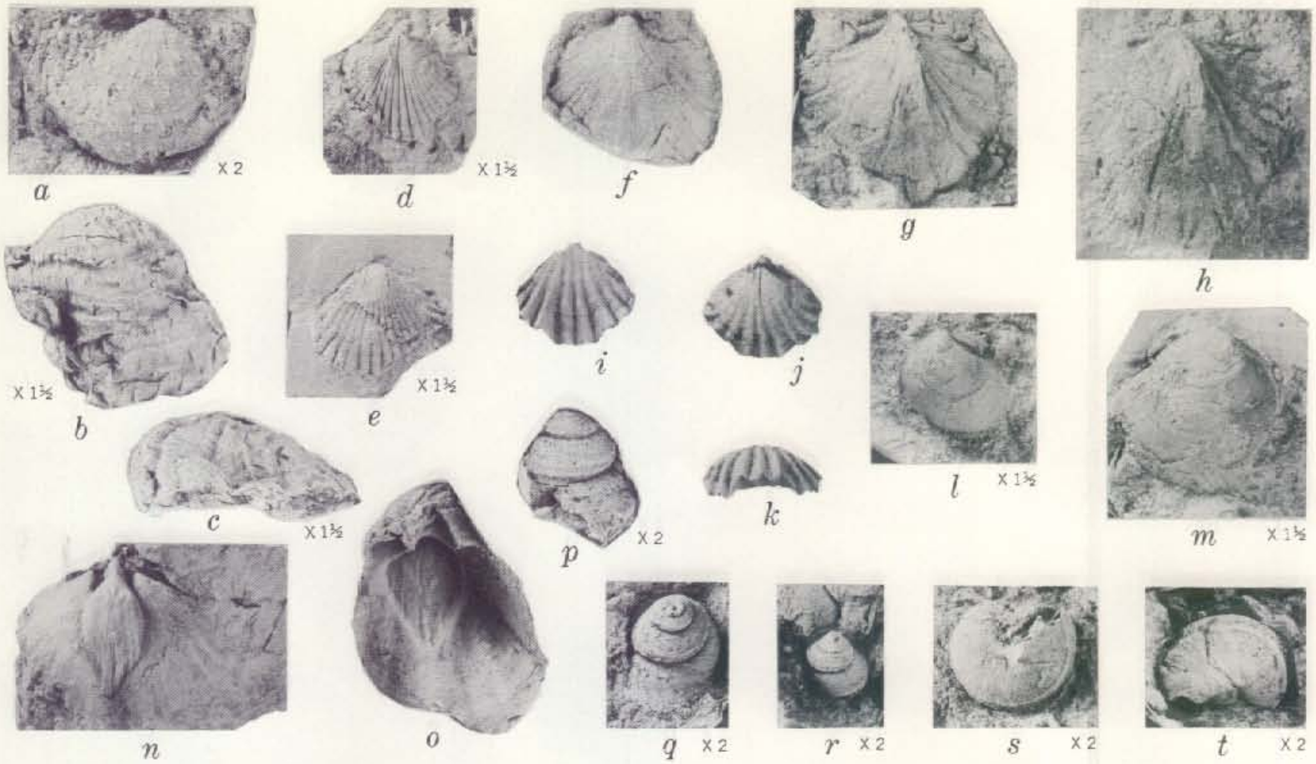

Figure 4.—Fossils of the *Cyrtorostra* assemblage from the Phosphoria Formation in the Divide Peak area. Photographs natural size unless otherwise indicated.

a. Grandaurispina sp. Enlarged view of latex cast of pedicle valve from USGS colln. 21584-PC.

b, c. cf. *Cancrinella phosphatica* Girty. Enlarged ventral and side views of pedicle valve from USGS colln. 21583-PC.

d, e. Rhynchopora cf. *R. taylori* Girty. Enlarged views of internal molds of brachial valve and pedicle valve, both from USGS colln. 21593-PC.

f–h. Cyrtorostra varicostata Branson. Latex cast of right valve and internal molds of two left valves from USGS colln. 21584-PC.

i–k. Phrenophoria sp. A. Ventral, dorsal, and anterior view of well-preserved internal mold from USGS colln. 21593-PC.

l, m. Streblochondria? cf. *S.*? *montpelierensis* Girty. Enlarged views of right and left valves from USGS colln. 21593-PC.

n, o. Spiriferella sp. B. Internal mold of pedicle valve and view of latex cast of pedicle valve, both from USGS colln. 21593-PC.

p–t. Eirlysia sp. Enlarged views of five latex casts showing surface of this little snail, all from USGS colln. 21593-PC.

The high-angle faults that cut both the Tertiary and Paleozoic rocks, and separate these units from one another, fall into two principal sets, one predominantly north trending, the other with a northwesterly trend. Both sets cut the older Tertiary rocks, but the faults that bound the younger tuffs and the basalt seem to be predominantly the northwest-trending set.

TECTONIC INFERENCES

The exposed and inferred structural relations of the Edna Mountain and Phosphoria Formations with the Valmy and other western assemblage Paleozoic rocks imply an imbricate relation for the western assemblage and the Permian rocks. Two possible explanations may be considered: either the Permian formations are nearly autochthonous in the Divide Peak region, and the imbricate thrusting has displaced them but little from their sites of deposition, or the Edna Mountain and the Valmy and other western assemblage Paleozoic rocks are all allochthonous, and make up part of a thrust sheet, resting on a plate containing the Valmy and Phosphoria. We favor the latter explanation for two reasons, both based on inferences from the facies relationships of the Edna Mountain of this area with other rocks of similar age. The lithology of the Edna Mountain differs markedly from that of the Phosphoria in the Divide Peak area as well as at sites a few miles to the north and south where the Phosphoria is dominantly dark shales, cherts, and limestones, phosphatic in part. On the other hand, the lithology of the Edna Mountain in the Divide Peak area differs significantly from that of the Edna Mountain on Edna Mountain, about 96 miles west-southwest. The type Edna Mountain Formation on Edna Mountain, in the Golconda quadrangle (Ferguson and others, 1952) is somewhat micaceous, whereas the sandstone of Edna

Table 2.—*Register of Permian fossil collection localities in the Divide Peak area*[1]

USGS colln. 21583-PC. Station 346. Projected position in SE¼ sec. 2, T. 41 N., R. 55 E. In a roadcut, 0.4 miles south from an obscure road junction. Coordinates E. 460,100, N. 2,447,600. Collected by R. R. Coats and Domingo Malicdem, 1961.

USGS colln. 21584-PC. Station 396. Coordinates E. 460,400, N. 2,446,700. About 300 feet east of road, at a point 2,000 feet south of obscure road junction. NW¼NW¼ sec. 12, T. 41 N., R. 55 E. Collected by R. R. Coats, Keith Howard, and Ralph Roberts, 1962.

USGS colln. 21585-PC. Station 397. Coordinates E. 450,550, N. 2,459,000. 100 feet west of road, just south of small gully, 3,000 feet northeast of Divide triangulation station, Wild Horse quadrangle. NE¼SW¼ sec. 27, T. 42 N., R. 55 E. Collected by R. R. Coats, Keith Howard, and Ralph Roberts, 1962.

USGS colln. 21593-PC. Station 346. See colln. 21583-PC above. Collected by R. R. Coats and Keith Howard, 1962.

USGS colln. 21594-PC. Station 368. Coordinates E. 457,400, N. 2,449,400. Collected by R. R. Coats, 1962.

USGS colln. 22820-PC. Station 397. See colln. 21585-PC above. Collected by R. R. Coats and Mackenzie Gordon, Jr., 1964.

USGS colln. 23216-PC. Station 1644. Coordinates E. 450,350, N. 2,450,800. Just south of mouth of shallow southeastward-trending gully, and near point where larger gully changes trend from west to south. NW¼NE¼ sec. 4, T. 41 N., R. 55 E.

USGS colln. 23778-PC. Station 951. Coordinates E. 444,050, N. 2,464,000, Wild Horse quadrangle. SW¼ sec. 21, T. 42 N., R. 55 E. Near prominent ledge of conglomerate, on brow of slope southwest of sharp bend in gulch. Collected by R. R. Coats, 1964.

USGS colln. 23779-PC. Station 962. Wells 2° sheet. Coordinates E. 449,900, N. 2,452,000. Near and on south side of ridge trending southwestward, 50 feet southeast of and below prominent ledge on brow of hill. Collected by R. R. Coats, 1964.

USGS colln. 23780-PC. Station 968. Coordinates E. 452,600, N. 2,449,800. Near center sec. 3, T. 41 N., R. 55 E.; top of 20-foot-high hill between two higher hills. Collected by R. R. Coats, 1964.

USGS colln. 24513-PC. Field No. 62NC12. Station 367. Coordinates E. 457,900, N. 2,450,300. Collected by R. R. Coats, 1962.

USGS colln. 24514-PC. Station H-2. Coordinates E. 460,450, N. 2,445,700. Crest of ridge, about 2,500 feet south of obscure road junction, and 900 feet east of roads NW¼ sec. 12, T. 41 N., R. 55 E. Collected by Keith Howard, 1962.

Field No. 64NC-133. Station 953. Coordinates E. 444,200, N. 2,462,750. Wild Horse quadrangle. NW¼NW¼ sec. 28, T. 42 N., R. 55 E. Collected by R. R. Coats, 1964.

Field No. 64NC134. Station 954. Wild Horse quadrangle. Coordinates E. 445,600, N. 2,458,200. SW¼SE¼ sec. 28, T. 42 N., R. 55 E., about ½ mile west of Divide triangulation station. Collected by R. R. Coats, 1964.

USGS colln. 24367-PC. West of where road traverses saddle, halfway between road and hilltop. NE¼ sec. 11, T. 41 N., R. 55 E. Five miles air line north-northeast of Double Mountain. Edna Mountain Formation. Collected by K. B. Ketner, 1969. (Not included in table 1.)

[1] Where possible, descriptions of the positions of fossil localities with respect to local features are included, but most geographic features in the study area are not named. Further locality information is given by use of the Nevada (E. zone) coordinate system, the positions given in feet. For the northwestern part of the map, positions have been plotted on the 1956 U.S. Geological Survey 1:62,500-scale map of the Wild Horse, Nev., quadrangle (southeast corner at 41°30′N., 115°45′ W.) from the aerial photographs on which the mapping was done. Coordinates in this part of figure 2 are thus scaled from a relatively good topographic map. In the southern and eastern parts of figure 2, which are derived from the 1955 1:250,000-scale map of the Wells quadrangle, precision of plotting of the collection localities is poorer. The coordinates of the collection localities given in this report are scaled with reference to the coordinate ticks appearing on figure 2; different coordinates may be assigned to the same localities when larger scale maps of this area are available and positions of the collection localities are replotted.

Mountain Formation in the Antler Peak quadrangle, about 20 miles farther southeast, consists predominantly of chert and quartz fragments, like the Edna Mountain Formation in the Divide Peak area. We therefore believe that the Edna Mountain Formation of the Divide Peak area is part of a single thrust plate of major extent with a horizontal displacement of at least 96 miles. The time of thrusting must be post-Edna Mountain. Some indirect evidence for the maximum age in this area is available. Clark (1957, p. 2205) has described an area of lower Triassic rocks in the vicinity of Coal Canyon, in the River Range, in T. 38 N., R. 56 E. Keith Ketner (written commun., 1967) collected from this area fossils placed by Norman Silberling (written commun., 1967) in the early, but not earliest, late Early Triassic. These rocks are characterized by limestone and shale with almost no conglomerate. It is arguable that the presence of a major thrust plate a short distance to the north at the time of deposition would have resulted in a much increased percentage of conglomerate.

The oldest pluton in the immediate area is the Gold Creek stock, at the northern edge of the Mount Velma quadrangle, about 18 miles to the north. McKee (written commun., 1970) determined an age of 152 m.y., by K-Ar methods, on biotite from this stock, which, because of lack of visible deformation, is thought to be postorogenic. This date, which corresponds to Middle or early Late Jurassic (Howarth, 1964), represents the extreme lower limit of the age of thrusting, but we prefer a Triassic age for the orogeny here described.

The thrusting here documented could be attributed to either of two orogenies, evidence for which has been recognized in this part of Nevada, or possibly even to a third, hitherto unrecognized orogeny, though we tend to reject this last alternative. The two orogenies previously recognized are the Sonoma orogeny (Silberling and Roberts, 1962, p. 36) and the Lewis orogeny (Gilluly and Gates, 1965, p. 123–125).

The Sonoma orogeny and its most conspicuous manifestation, the Golconda thrust, were considered by Silberling and Roberts (1962, p. 36) as of Late Permian, pre-Koipato age.

R. C. Speed has recently (Speed, 1971) traced the Golconda thrust southward for a distance of 270 miles. He believes that the Golconda thrust is no older than early Early Triassic and no younger than Early Triassic. This age assignment is compatible with the assignment of the thrusting in the Divide Peak area to the Sonoma orogeny.

It is possible also that the orogeny that has brought the Edna Mountain and associated rocks into this area correlates with the Lewis orogeny of Gilluly and Gates (1965, p. 123–125). They are unwilling to infer so great a distance of travel of the allochthonous upper Paleozoic rocks in the Shoshone Range as we have deduced in the Divide Peak area, preferring, apparently, the hypothesis of minor additional transport of rocks that had already been moved some distance by the Golconda thrust. The maximum age of the Lewis orogeny can be inferred in part from the youngest formation involved in it, the China Mountain(?) Formation, according to Gilluly and Gates. Nichols (1971, p. 171) has recently reported that the China Mountain(?) Formation of the Shoshone Range is more properly attributable to the Middle Triassic Panther Canyon Formation (largely Ladinian in age, according to Nichols), and accordingly, the Lewis orogeny must be post-Ladinian.

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