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PRECAMBRIAN AND CAMBRIAN ROCKS OF SOUTH-CENTRAL ESMERALDA COUNTY, NEVADA

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ABSTRACT. More than 13,000 feet of Precambrian and Cambrian sedimentary rocks occur in south-central Esmeralda County, Nevada. The succession contains Upper Precambrian to Upper Cambrian strata in conformable sequence and appears to be unconformably overlain by the Middle Ordovician Palmetto Formation. The Cambrian rocks are considered to include the oldest Cambrian strata in North America because of the presence of the olenellid trilobite *Fallotaspis*.

Approximately two-thirds of the Precambrian and Lower Cambrian sedimentary rocks are quartzose detrital deposits, similar in thickness and lithologic character to strata of equivalent age in the Inyo Mountains, California. Carbonate rocks dominate the Middle and Upper Cambrian.

INTRODUCTION

A thick sequence of Precambrian and Cambrian sediments, made classic by Walcott's study of the Waucoba Springs section, is well known from the Inyo Mountains, the Nopah-Resting Springs Mountains and other areas in the California-Nevada region. Similar rocks were noted in Esmeralda County, Nevada by Turner and Walcott around the turn of the century, but no further study was made of the stratigraphy of this area until 1958, when McKee mapped a small area comprised mostly of Lower Cambrian strata in the Last Chance Range, California.

When mapping was extended into Esmeralda County in 1959-1961, more Lower Cambrian sediments were noted, as well as underlying Precambrian and overlying Middle and Upper Cambrian sediments. Similar rocks in central Esmeralda County were mapped in 1960-1961 by J. P. Albers and J. H. Stewart of the U. S. Geological Survey and by Moiola (see fig. 1, index map). Although the structure of the area is complex, enough partial sections of the poorly known Middle and Upper Cambrian sequence were found to make possible the compilation of a tentative composite section. This section has been combined with the Precambrian-Lower Cambrian section exposed in the Last Chance Range, California, and in the south-central part of Esmeralda County (fig. 2).

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STRATIGRAPHY

General

More than 13,000 feet of Precambrian-Cambrian strata are present in south-central Esmeralda County, Nevada, and the entire sequence appears to

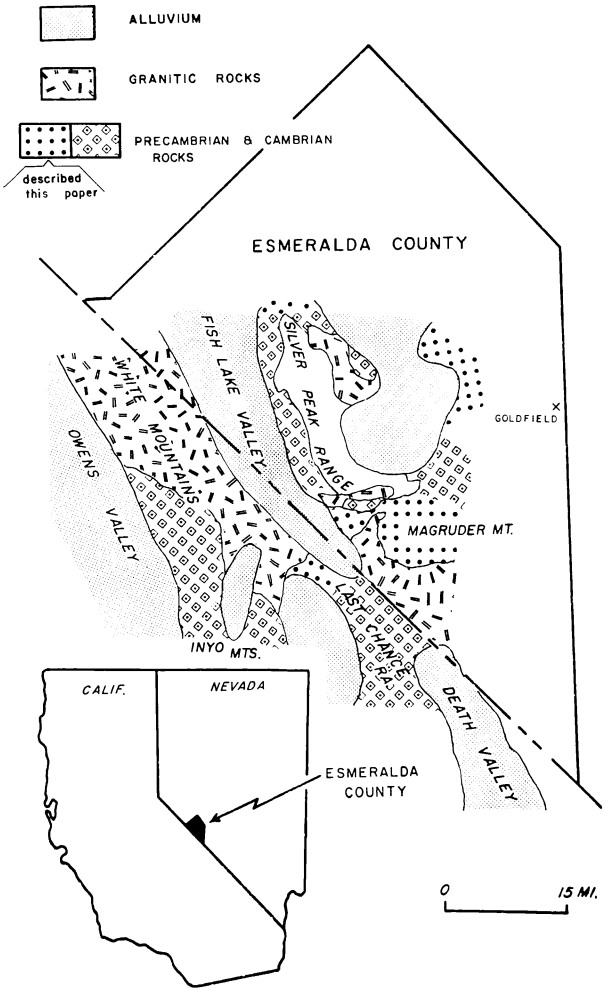

Fig. 1. Index map showing areas of Precambrian and Cambrian rocks described in this paper and rocks of adjacent areas.

be conformable. The base is not exposed, but in the Inyo Mountains, 20 miles to the west, the lowermost unit of the sequence, a phyllitic siltstone, sandstone, and limestone is more than 1000 feet thick. No more than 500 feet of this unit crop out in Esmeralda County. The uppermost unit appears to be overlain by shale of the Middle Ordovician Palmetto formation. If this relationship is valid, an unconformity separates the Upper Cambrian from the Ordovician in this region. The Cambrian rocks are considered to include the oldest Cambrian rocks in North America because of the presence of the olenellid trilobite *Fallotaspis*.

The problem of the Precambrian-Cambrian boundary recurs in this sequence as it does in most of the thick Cambrian-Precambrian sections of west-

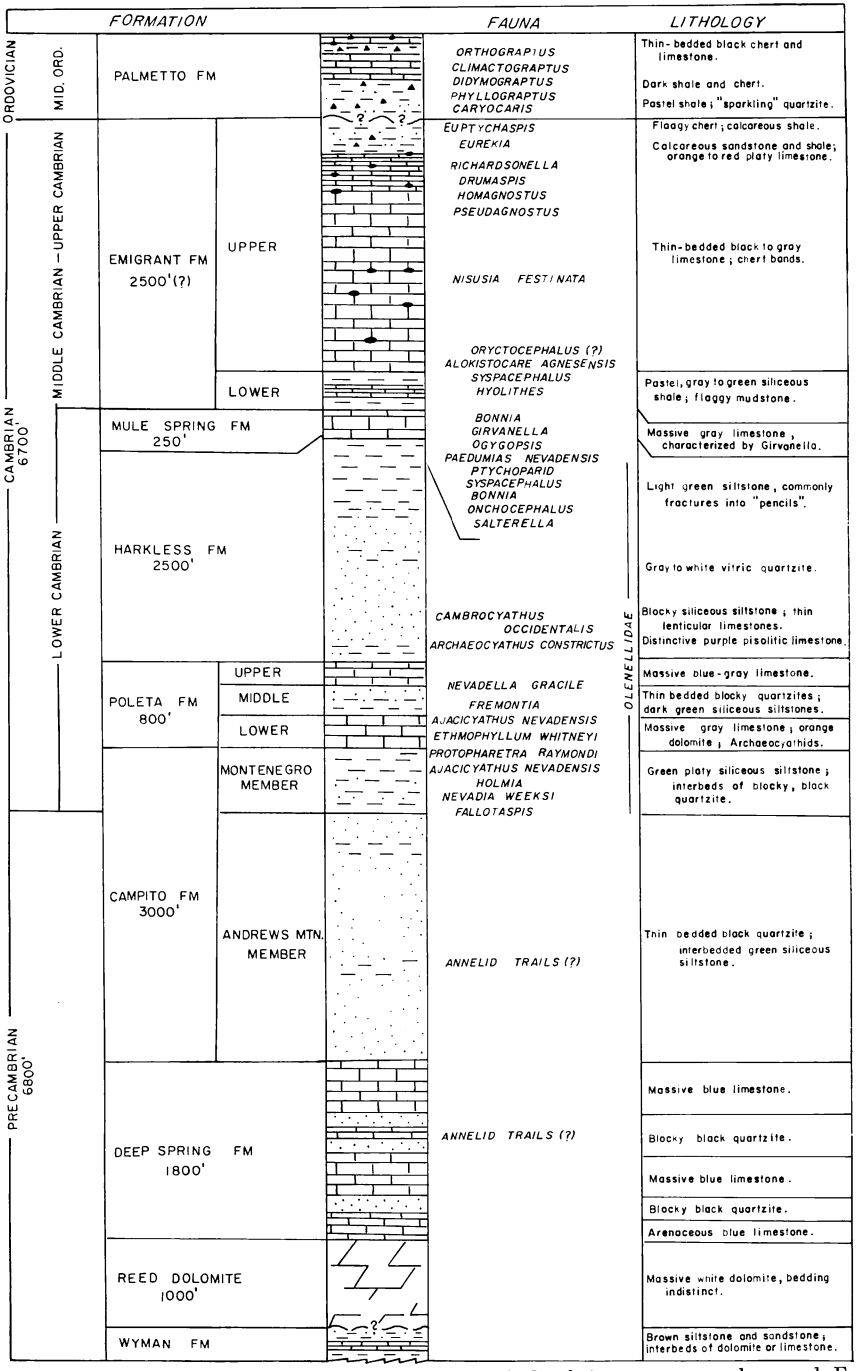

Fig. 2. Composite section of Precambrian and Cambrian strata, south-central Esmeralda County, Nevada.

ern Nevada and eastern California. The writers choose to follow Wheeler (1947) in placing the base of the Cambrian at the lowest occurrence of olenellid trilobites. These trilobites occur throughout most of the Montenegro member of the Campito formation, and the Cambrian-Precambrian boundary is drawn at the base of this member.

Formational names for the 6800 feet of Precambrian strata are derived from the sequence described by Kirk (in Knopf, 1918) in the Inyo Mountains. Names applied to the 4500 feet of Lower Cambrian strata are those used by Nelson (1962) for similar rocks in the Inyo Range. They replace the vaguely defined Silver Peak formation of Turner (1902) and Walcott (1908). Middle and Upper Cambrian rocks are referred to the Emigrant formation, the name proposed by Turner (1902) for Upper Cambrian rocks in the Silver Peak Range, Esmeralda County, Nevada. The Emigrant formation is the least known unit in the sequence and subsequent renaming may be necessary.

Wyman Formation

The oldest rocks in the area are referred to the Wyman formation, a name proposed by Maxson (1934) for phyllites and interbedded dolomite below the Reed dolomite in the White Mountains, California. About 500 feet of this formation crop out conformably below the Reed dolomite in Esmeralda County. Where not metamorphosed, it consists of silt and sandstone with interbeds of limestone or dolomite. The detrital rocks have a distinctive brownish cast in contrast to the predominate green-to-black color of the overlying Precambrian and Lower Cambrian detrital rocks, whereas the carbonate rocks resemble the overlying Reed dolomite.

The Wyman formation of south-central Esmeralda County is considered Precambrian in age and is correlative with the type of the White Mountains. This correlation is based on lithologic similarity and position in the stratigraphic column.

Reed Dolomite

The Reed dolomite was named by Kirk (in Knopf, 1918) for exposures of massive white dolomite in the White Mountains, California.

In south-central Esmeralda County the Reed dolomite rests conformably on the Wyman formation. An unconformity at this stratigraphic horizon as reported by Maxson (1934) from the White Mountains in California is not seen in Esmeralda County, although locally there is evidence of erosion at the top of the Wyman formation. The Reed dolomite is conformable with the overlying Deep Spring formation.

The Reed dolomite is a massive white dolomite that weathers to a cream color and commonly develops a coarsely "wrinkled" surface. It is fine to medium grained and "sugary" in appearance. Pisolitic or oölitic texture occurs locally. At least 1000 feet of this dolomite are exposed in south-central Esmeralda County.

The Reed dolomite is considered to be Precambrian in age because it lies several thousand feet below the lowest known olenellid fauna. It can be readily correlated with the Reed dolomite of the Inyo Mountains, and the lithologic and stratigraphic similarity between the Reed dolomite and the Noonday

dolomite, as described by Hazzard (1937) from the Nopah Range of the Death Valley region, makes correlation between these units most probable.

Deep Spring Formation

Conformably above the Reed dolomite are 1800 feet of limestone and quartzite of the Deep Spring formation. This formation was named by Kirk (in Knopf. 1918) for exposures along the west side of Deep Spring Valley. in the Inyo Range. At Magruder Mountain in Esmeralda County, Nevada, five distinctive divisions, three carbonate units and two classic units. can be mapped within this formation.

The carbonate units are massive to thin-bedded, blue to gray limestones, which are arenaceous in places. Their combined thickness is 1200 feet. Clastic units are dark quartzites interbedded with siliceous shales. The clastic rocks are 600 feet thick.

The Deep Spring formation is considered to be Precambrian in age. As described in Esmeralda County, it can be correlated with the Deep Spring formation in the Inyo Mountains. Regional stratigraphic considerations as well as lithologic similarity indicate that the Deep Spring formation of Esmeralda County is correlative with the Johnnie formation, described by Nolan (1929).

Campito Formation

A thick sequence of dark quartzitic sandstones conformably overlies the Deep Spring formation. This unit, named the Campito sandstone by Kirk (in Knopf, 1918), is approximately 3500 feet thick. The upper 600 feet of the Campito formation consist of thin-bedded siliceous shales named the Montenegro member by Nelson (1962), and the lower 2900 feet consist of blocky quartzite called the Andrews Mountain member.

Olenellid trilobites (*Fallotaspis*, *Holmia*, and others) are found throughout the Montenegro member, but no fossils have been found where quartzite dominates the lithology. For this reason, the Montenegro member of the Campito formation is considered to be Lower Cambrian in age, and the underlying sandstone is assigned to the Precambrian.

The Andrews Mountain member of the Campito formation is correlated with the Campito sandstone of the Inyo Mountains and probably with the Stirling quartzite and lower Wood Canyon formation described by Hazzard from the Nopah Range (1937). The fossil-bearing shales of the Montenegro member are equivalent to the Montenegro member of the Inyo Mountains and may be equivalent to units 4D and 4E of the Wood Canyon formation described by Hazzard (1937).

Poleta Formation

Conformably overlying the siliceous shales and siltstones of the Montenegro member of the Campito formation are rocks of the Poleta formation. This formation derives its name from exposures in the White Mountains, which have been studied in detail by Nelson (1962). It is divided into three members, a lower carbonate member, a middle shale and quartzite member, and an upper limestone member.

The lower carbonate member is a massive blue and orange, mottled limestone characterized by abundant archaeocyathids. At Magruder Mountain this member is 400 feet thick but it varies by as much as 100 feet in nearby areas.

Thin-bedded, dark green siliceous siltstone and quartzite comprise most of the middle member. However, near the top clastic rocks give way to occasional beds of limestone. Trilobites are relatively abundant in the shaly portions of this member, the most common species being *Nevadella gracile* Walcott. Three hundred feet of strata from the middle member have been measured at Magruder Mountain but the unit thins to 200 feet in the Last Chance Range.

The upper carbonate member, a massive blue-gray limestone, is lithologically similar to thin limestone beds in the upper part of the middle member but much thicker (150 feet thick). Absence or scarcity of archaeocyathids distinguishes the upper from the lower carbonate member.

A Lower Cambrian age is assigned to the Poleta formation because it contains olenellid trilobites. It is correlated with the Poleta formation of the Inyo Mountains. In the Death Valley region unit 4F of the Wood Canyon formation described by Hazzard (1937) probably corresponds to the Poleta formation.

Harkless Formation

A return to predominantly clastic deposition is indicated by the Harkless formation, named by Nelson (1962) for exposures in the Waucoba Mountain quadrangle, Inyo Mountains, but is also recognizable eastward in Esmeralda County.

The lower 400 feet of the formation are predominantly siliceous siltstone and quartzite similar in appearance to the middle Poleta clastic member. The formation can be distinguished from the Poleta shales, however, by the presence of a thin pisolitic limestone containing large (0.5-1.0 inch) purple pisolites and by the presence of lenticular "reefs" of large archaeocyathids (*Cambrocyathus occidentalis, Archaeocyathus constrictus*). Quartzites become prevalent near the top of this 400-foot interval and dominate the lithology for the next 1500 feet. The Harkless quartzite is similar in appearance to the Campito sandstone but generally contains less chloritic material and is more vitreous. Above the quartzite lie approximately 1000 to 2000 feet of light green siltstone that characteristically breaks into blocks or "pencils".

Fossils are sparse throughout the entire formation except near the top of the upper siltstones. *Salterella* (?), olenellid trilobites, and the non-olenellid form *Ogygopsis* are found in this horizon.

The Harkless formation is assigned a Lower Cambrian age on the basis of the olenellid trilobites found in it; however, the upper siltstones are probably near the Middle-Lower Cambrian boundary. *Ogygopsis*, a trilobite typical of the Middle Cambrian, is found with olenellid trilobites, indicating a lower range for *Ogygopsis* than is usually assumed (Nelson, 1960).

The Harkless formation in Esmeralda County is correlated with the Harkless formation and overlying Saline Valley formation described by Nelson (1962) from the Waucoba Mountain quadrangle in the Inyo Mountains. In the Death Valley region it probably corresponds to the Upper Wood Canyon formation, units 4G through 4M described by Hazzard (1937). The Zabriskie

quartzite member of the Wood Canyon formation (unit 4H) is probably equivalent to the middle Harkless quartzites.

Mule Spring Formation

Siltstones from the upper part of the Harkless formation pass gradationally into the predominantly carbonate Mule Spring formation, the base of which consists of thin-bedded, platy limestone that becomes more massive in the upper three-fourths of the formation. These massive beds are medium- to thick-bedded, gray arenaceous limestone characterized by the algal form "*Girvanella*". The formation is approximately 200 feet thick.

The presence of the olenellid trilobite *Fremontia* and the non-olenellid form *Bonnia* in the lower platy limestones indicates that these beds are of Lower Cambrian age. No fossils have been found in the overlying massive limestones, but Middle Cambrian forms are present in the Emigrant formation, which lies conformably on the Mule Spring formation. The Lower-Middle Cambrian boundary is therefore drawn at the top of the Mule Spring formation.

The Mule Spring formation of Esmeralda County is correlated with the type Mule Spring formation in the Inyo Mountains. It also probably correlates with the upper Lower Cambrian algal limestone (unit 4N) of the Wood Canyon formation described by Hazzard (1937) from the Nopah Range.

Emigrant Formation

General.—The name Emigrant formation was proposed by Turner (1902) for a sequence of rocks exposed south of Emigrant Pass in the northern part of the Silver Peak Range, Esmeralda County, Nevada. According to him, the Emigrant formation consists of thin-bedded limestones and reddish slates with some interbedded layers of black chert. Turner also stated that the formation lies unconformably on the Lower Cambrian, or Silver Peak formation, and conformably underlies the Palmetto formation of Ordovician age. Fossils which he collected were examined by Walcott, who regarded the assemblage as indicating an Upper Cambrian age.

Recent work in the Silver Peak-Goldfield area by the authors and by Albers and Stewart of the U. S. Geological Survey has shown that the Emigrant formation as defined by Turner corresponds approximately to the upper member of a sequence of Middle and Upper Cambrian rocks to which the authors have extended the name "Emigrant formation".

Thus, as used in this paper, the name "Emigrant formation" refers to a series of Middle and Upper Cambrian rocks that lie conformably on the Lower Cambrian strata of the area.

A twofold subdivision of the Emigrant formation has been established tentatively by the authors: a lower member of shale and mudstone, and an upper member of thin-bedded limestone with clastic beds near the top. The true thickness of the formation is unknown at present, but from composite sections and from regional considerations it is possible to postulate a thickness of 2500+ feet.

Lower member.—The lower member of the formation lies conformably on the Mule Spring formation of uppermost Lower Cambrian age. Pastel, gray-to-green siliceous shales and very thin-bedded, flaggy mudstones are characteristic of the member, which also contains interbeds of very thin-bedded, flaggy chert and laminated, platy limestone. It is approximately 500 feet thick.

Upper member.—The upper member of the Emigrant formation is composed predominantly of thin-bedded, blue-to-gray limestones alternating with 0.5- to 2.0-inch, buff-to-black bands of chert or iron-stained limestone. Distinctive beds of intraformational limestone breccia, 1 to 10 feet thick, occur locally and are typical of the unit. The limestones become platy near the top of the interval and pass into orange to reddish gray calcareous shales, very thin-bedded calcareous sandstones, and very thin-bedded cherts. The upper member is approximately 2000 feet thick.

Overlying the upper member of the formation with apparent unconformity is the Palmetto formation of Middle Ordovician age. Graptolites identified from the Palmetto formation are typical Middle Ordovician forms (*Climacograptus, Dichograptus, Orthograptus*, W. B. N. Berry, oral communication, 1961), which would indicate a break in sedimentation between the end of the Cambrian and Middle Ordovician times. However, because of the prevalent fault relationship between the Palmetto and Emigrant formation, there is the possibility that the Palmetto formation may represent an allochthonous sequence.

Age.—Turner's collection of fossils from the Emigrant formation was examined by Walcott and regarded as indicating an Upper Cambrian age for the formation. In the areas studied by the writers the formation is sparsely fossiliferous; however, fossils collected by Albers and Stewart and identified by A. R. Palmer of the U. S. Geological Survey have been tied into the sequence. On the basis of Palmer's identifications, the Emigrant formation is assigned a Middle and Upper Cambrian age.

The lower age limit of the formation is established by the presence of trilobites (*Oryctocephalus* (?), *Alokistocare* cf., *A. agnesensis, Syspacephalus*) of the *Wenchemnia-Stephenaspis* fauna, the oldest Middle Cambrian fauna, in the lower member of the formation. Middle Cambrian fossils also occur in the lower part of the upper member.

Trilobites collected from the upper member of the formation include *Richardsonella, Drumaspis, Homagnostus, Idahoia* (?), and *Pseudagnostus*, assignable to the *Ptychaspis-Prosaukia* zone of the upper Cambrian (mid-Upper Cambrian), and the Trempealeauan forms *Euptychaspis* and *Eurekia* (?).

Correlation.—On the basis of current data, correlation of the Emigrant formation with other Middle and Upper Cambrian units in southern Nevada and eastern California is tenuous.

References

Hazzard, J. C., 1937, Paleozoic section in the Nopah and Resting Springs Mountains, Inyo County, California: California Jour. Mines and Geology, v. 33, p. 273-339.

Hazzard, J. C., and Mason, J. F., 1936, Middle Cambrian formations of the Providence and Marble Mountains, California: Geol. Soc. America Bull., v. 47, p. 229-240.

Knopf, Adolph, 1918, A geologic reconnaissance of the Inyo Range and the eastern slope of the southern Sierra Nevada, California; with a section on the stratigraphy of the Inyo Range, by Edwin Kirk: U. S. Geol. Survey Prof. Paper 110, 130 p.

Maxson, J. H., 1934, Pre-Cambric stratigraphy of the Inyo Range [abs.]: Geol. Soc. America Proc. 1934, p. 314.

McKee, E. D., and Weir, G. W., 1953, Terminology for stratification and cross stratification in sedimentary rocks: Geol. Soc. America Bull., v. 64, p. 381-390.

Nelson, C. A., 1957, Waucoban stratigraphy, Inyo Mountains, California [abs.]: Geol. Soc. America Bull., v. 68, p. 1838.

———— 1960, Stratigraphic range of Ogygopsis [abs.]: Geol. Soc. America Bull., v. 71, p. 2070-2071.

———— 1961, Age of the Johnnie formation [abs.]: Geol. Soc. America Spec. Paper 68, p. 45-46.

———— 1962, Lower Cambrian-Precambrian succession, White-Inyo Mountains, California: Geol. Soc. America Bull., v. 73, p. 139-144.

Nolan, T. B., 1929, Notes on the stratigraphy and structure of the northwest portion of the Spring Mountains, Nevada: Am. Jour. Sci., 5th ser., v. 17, p. 461-472.

Turner, H. W., 1902, A sketch of the historical geology of Esmeralda County, Nevada: Am. Geologist, v. 29, p. 261-272.

———— 1909, Contribution to the geology of the Silver Peak quadrangle, Nevada: Geol. Soc. America Bull., v. 20, p. 228-264.

Walcott, C. D., 1908, Cambrian sections of the Cordilleran area: Smithsonian Misc. Colln., v. 53, p. 167-230.

Wheeler, H. E., 1947, Base of the Cambrian system: Jour. Geology, v. 55, p. 153-159.

———— 1948, Late pre-Cambrian-Cambrian stratigraphic cross section through southern Nevada: Nevada Univ. Bull., Geol. and Min. Ser. 47, 58 p.