

***Bonnima* sp. (Trilobita; Corynexochida) from the Chambless Limestone (Lower Cambrian) of the Marble Mountains, California: First Dorypygidae in a cratonic region of the southern Cordillera**

JOHN R. FOSTER

Museum of Western Colorado, P.O. Box 20,000, Grand Junction, CO 81502; jfooster@westcomuseum.org

A trilobite pygidium, likely referable to the genus *Bonnima*, is the first evidence of a member of the Corynexochida reported from the Lower Cambrian (Dyeran Stage) Chambless Limestone of the southern Marble Mountains in the Mojave Desert of California. This specimen represents the first occurrence of the family Dorypygidae in the cratonic facies of the Lower Cambrian in the California-western Nevada region, as all of the few previous reports of the family (mostly *Bonnia*) have been from much thicker, more distal open-shelf deposits far to the northwest in the White-Inyo–Esmeralda County region of California and Nevada. Although still relatively rare, the occurrence of Dorypygidae across a range of environments biofacies realms in this area is typical of their distribution in other regions.

INTRODUCTION

The Chambless Limestone is a Lower Cambrian unit exposed in the Marble and Providence mountains in the Mojave Desert of San Bernardino County, California (Hazzard and Crickmay 1933). The formation was named by Hazzard (1954) for outcrops northeast of the town of Chambless along Highway 66, about 10 miles east of Amboy. The Chambless Limestone is well known for containing abundant oncolites and fragments of brachiopods and trilobites in the gray, micritic limestone facies that makes up most of the formation. This unit forms a distinct, steep outcropping of gray limestone throughout the Marble and Providence mountains. Olenellids (*Olenellus*, *Bolbolenellus*, and *Bristolia*) comprise the bulk of the trilobites found in the Chambless Limestone to date, with the ptychopariid *Poulsenia* very rare. In addition, the known non-trilobite fauna from the Chambless Limestone includes several genera of brachiopods, hyoliths, molluscs, and the eocrinoid *Gogia* (Mount 1974, 1976, 1980, Webster et al. 2003, University of California, Riverside, catalog). A recently collected fauna from stratigraphically low in the formation, in interbedded gray shale and orange carbonate, includes the first member of the Corynexochida reported from the formation.

The specimen was found with a fauna consisting of body fossil material and molds of approximately 25 specimens of trilobite fragments, hyoliths, brachiopods, trace fossils, and eocrinoid plates. All were collected from a Chambless Limestone outcrop in the southern Marble Mountains in the west ½, NW ¼, Sec. 12, T5N, R14E, approximately 500 m west-northwest of UCR 7359 (a published site in the overlying Cadiz Formation, Fuller 1980).

Institutional Abbreviations: **MWC**, Museum of Western Colorado, Fruita; **UCR**, University of California, Riverside.

GEOLOGIC SETTING

In the Marble Mountains, the Chambless Limestone consists of 48 m of gray, oncolitic limestone with beds that are

from 5 cm to 1 m thick, and these beds generally decrease in thickness upward in the formation. The Chambless Limestone is also known from the Providence Mountains 30 miles north of the Marble Mountains; the formation is not recognized north of the Providence range, but equivalent units of varying thickness do occur (Palmer and Halley 1979). The abundant oncolites are 2–4 cm in diameter low in the formation and 5 mm to 3 cm in the middle and top sections and are often round or spherical in shape throughout the formation (Unal and Zinsmeister 2007). These oncolites are particularly concentrated in the lower few meters of the formation.

The Chambless Limestone is approximately equivalent to the Gold Ace Limestone and Echo Shale members of the Carrara Formation in the Death Valley region and to the lower Bright Angel Shale in the western Grand Canyon and Las Vegas areas (Stewart 1970, Palmer 1971, Palmer and Halley 1979, Webster 2003). According to Hall (2007), the Chambless Limestone forms part of the Sauk II transgressive sequence, along with the underlying Latham Shale (Gaines and Droser 2002) and the overlying Cadiz (Foster 1994) and Bonanza King formations. Trilobites of the Chambless Limestone are within the *Bonnia-Olenellus* zone (Rasetti 1951) and range from the *Peachella iddingsi* zonule at the base of the Chambless Limestone to the *Bolbolenellus euryparia* zonule for most of the formation (Webster 2003).

The fossils collected for this study were found in an approximately 5-m-thick unit of interbedded light brown fissile shale and gray-green to brown and orange, silty limestone or dolomite with beds 0.5–15.0 cm thick; this unit is stratigraphically low in the formation with m-scale beds of gray, oncolitic limestone, typical of the formation, above and below (Fig.1). The fossils were found in ~6–20 mm, thin weathered plates of orange to brown limestone or dolomite stratigraphically low in this unit. The thicker ~15–20 mm carbonate layers in this interval have small, cm-scale crossbeds and preserve, on some bedding surfaces, apparent interference (ladder-back) ripples.

SYSTEMATIC PALEONTOLOGY

TRILOBITA

CORYNEXOCHIDA Kobayashi 1935

DORYPYGIDAE Kobayashi 1935

BONNIMA SEMIDISCOIDEA Fritz 1991

Bonnima sp. indet.

Referred Specimen—MWC 6961, pygidium preserved in internal/ventral view; from approximately 2 m up into the ~5-m-thick shaly zone in the stratigraphically lower part of the Chambless Limestone, southern Marble Mountains, San Bernardino County, California; *Bonnia-Olenellus* zone (*Bolbolenellus euryparia* zonule), Dyeran Stage.

Description—The pygidium is 8.24 mm long and 9.18 mm wide, with an axial lobe 2.84 mm wide at the anterior end; the axial lobe tapers slightly posteriorly (Fig. 2A). Preserved height of the pygidium is approximately 3 mm. There are seven pygidial axial rings and six pygidial pleural ribs (Fig. 2B). The structure of the pygidium is fairly clear; however, the pygidial pleural furrows become progressively fainter posteriorly so the exact number of axial rings and pleural ribs is difficult to ascertain and the size of the terminal axial piece hard to confirm. There is no evidence of anterolateral spines on the pygidium, nor of a distinct pygidial border. MWC 6961 is preserved in internal/ventral view and most of the element is intact, so the nature of the external/dorsal surface of the pygidium cannot be described, but the impression of the pygidium, as preserved at the margins in the surrounding sediment, suggests the outer surface was smooth.

Discussion—Fritz's (1991) diagnosis of *Bonnima* notes its overall similarity to *Bonnia* but lists several features that distinguish it from the latter genus: (1) smoother external surfaces of the cranium and pygidium with very low relief and indistinct furrows; (2) occipital ring much narrower; (3) pygidial border furrow absent on dorsal surface and very shallow (or absent) on internal surface; and (4) a "semidetached" anterior pleural segment on the pygidium. Although the external surface of the pygidium may be nearly smooth in *Bonnima*, the internal surface shows the form of the furrows much more clearly.

MWC 6961 is similar to the pygidium of *Bonnima semidiscoidea* Fritz 1991 in the number of pleural ribs and axial rings, length-to-width proportions, lack of a pygidial border, lack of anterolateral spines, and smooth outer edge of the pygidium. The "semidetached" anterior pleural segment characteristic of *Bonnima* (Fritz 1991) appears to be mostly broken off anteriorly with only the posterior edge remaining and with a deep pleural furrow between it and the rest of the pygidium. Part of the left anterior pleural segment may be present just anterior to the rest of the pygidium.

The specimen is distinct from *Bonnia* in having a higher (more nearly 1:1) length-to-width ratio than most species of that genus, in lacking a defined pygidial border, in having less distinct axial rings and pleural furrows, a more tapered axial lobe, and a greater number of pleural ribs and axial rings (when compared with *Bonnia* as illustrated in Rasetti 1948,

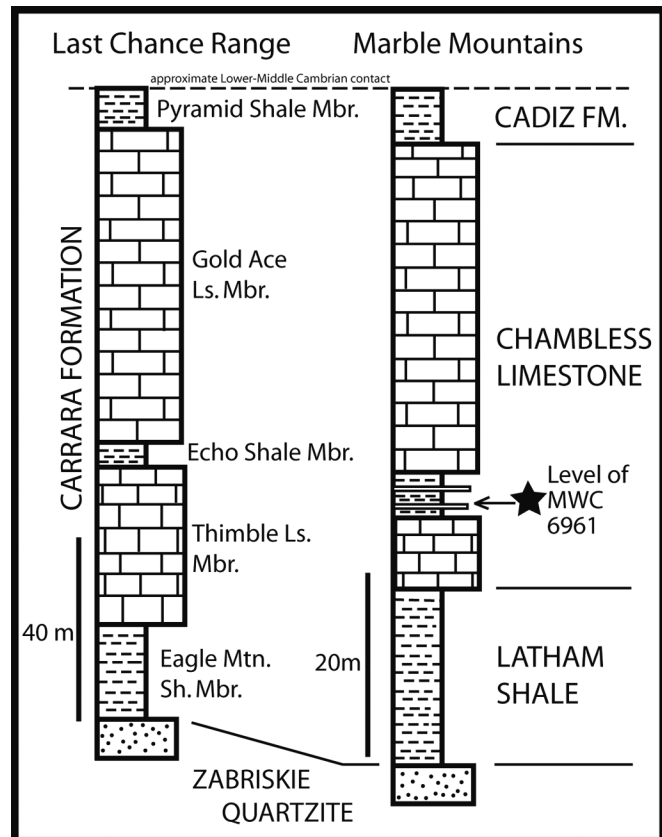


Figure 1. Stratigraphic section showing the level of the *Bonnima* sp. indet. specimen (MWC 6961) within the Chambless Limestone in the Marble Mountains. Associated fauna is from same level. Bottom and top boundaries of section shown are the top of the Zabriskie Quartzite and the Lower-Middle Cambrian contact within the Cadiz Formation. Shown for comparison (on left) is a section of the Carrara Formation in same interval from the southern Last Chance Range, California. Note different scales and the cratonic Marble Mountains section is approximately half the thickness of Last Chance Range section. Marble Mountains section measured by the author; Last Chance Range section from data in Palmer and Halley (1979).

Palmer 1964, and Fritz 1991). The pygidium of Palmer's (1964) *Bonnia caperata*, for example, is distinctly wider than long, has a clear border, distinct furrows, and only three pleural ribs.

MWC 6961 differs from *Bonniella desiderata* in lacking the long pygidial spines and expanded pygidial flanges of *B. desiderata* (Walcott 1890, Resser 1937) and differs from Resser's (1938) various additional species of *Bonniella* (= *Bonnia*) in lacking spines, a pygidial border area, and in having less distinct furrows. *Bonniopsis virginica* also appears to possess border spines (Palmer 1964), which distinguishes that species from MWC 6961 as well.

The preservation of the internal/ventral view of the pygidium and lack of access to the dorsal surface prevents confirmation of the smooth dorsal surface of the pygidium characteristic of *Bonnima*. However, the internal definition

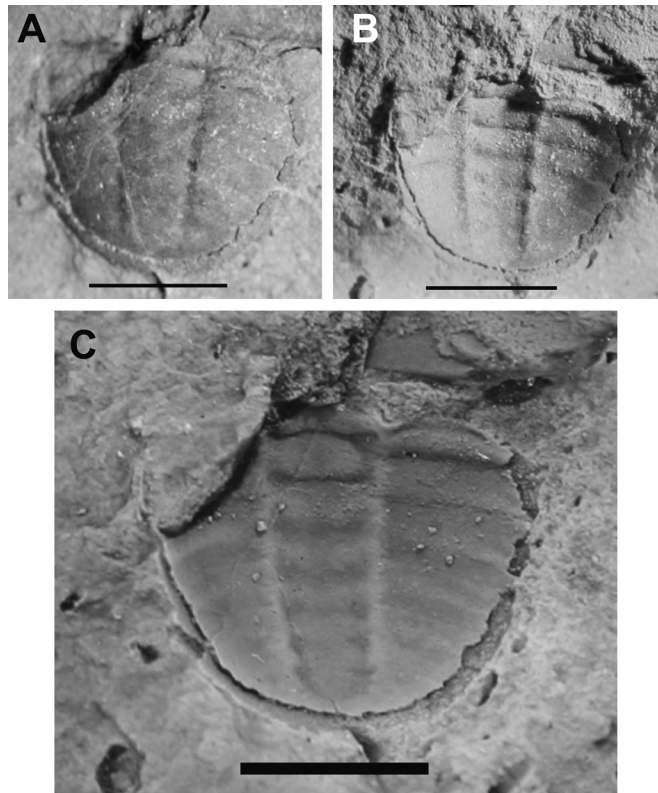


Figure 2. *Bonnima* sp. indet. from the Chambless Limestone of the Marble Mountains, California. MWC 6961, pygidium. **A.** Internal/ventral view in high-angle lighting from left, showing overall proportions and preservation. No coating. **B.** Internal/ventral view in low-angle lighting from right showing internal texture. No coating. **C.** Internal/ventral view of slightly whitened specimen in high-angle lighting showing internal texture of pleural furrows and axial rings. Scale bars = 5 mm.

of pygidial features is more subtle than in *Bonninia*, and the impression of the external pygidial surface along the rim of the fossil, where the edge of the pygidium is broken off, appears to be smooth. Thus, the fossil appears to better match *Bonnima* than either *Bonninia*, *Bonniopsis*, or *Bonniella*.

DISCUSSION

This is the first evidence of a corynexochid in the Chambless Limestone and if the identification is correct, the first occurrence of *Bonnima* in the southwestern United States. More importantly, it is the first occurrence of the Dorypygidae in one of the few thin, cratonic Lower Cambrian sections in the southern Cordilleran region. All previously reported occurrences of Dorypygidae in the region (mostly *Bonninia*) have been found in miogeoclinal strata (Fig. 3). The designation of the cratonic-miogeoclinal boundary in Figure 3 is based on Stewart (1970) and Nelson (1978), which are in close agreement on the placement of the transition and what it represents. In cratonic sections Cambrian strata are often comparatively thin and rest on Precambrian granitics and metamorphics, whereas miogeoclinal strata thicken dramati-

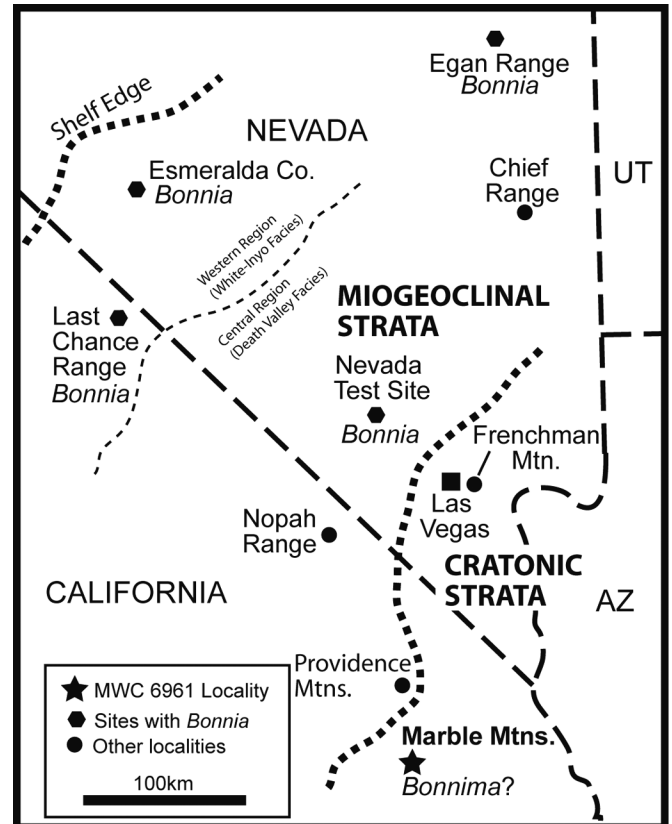


Figure 3. Occurrence of *Bonnima* (MWC 6961) in Chambless Limestone of Marble Mountains relative to other sites with trilobites of similar age, sites with other Dorypygidae, and cratonic-miogeoclinal strata boundary (thick dashed line to southeast). Also shown are approximate shelf edge and beginning of deep-water deposits (thick dashed line to northwest) and, within miogeoclinal, open-shelf region, the approximate transition from central to western regions (of Stewart 1970) and Death Valley to White-Inyo facies (of Nelson 1978).

cally toward the northwest and often lie on thick sequences of Proterozoic strata (Stewart 1970). Cratonic sections probably represent shallow-shelf deposits closest to the shoreline. The most distal sites with *Bonninia* specimens (the Last Chance Range, California, and sites in Esmeralda County, Nevada) are close to what are probably the deep-water deposits of the shelf edge as exposed near Miller Mountain, Nevada (Stevens and Greene 1999). In between the two would have been the open-shelf environments of the miogeoclinal strata.

The only other reported occurrences of the Dorypygidae in this region are from much more distal environments to the northwest, away from the cratonic setting of the Marble Mountains. Palmer and Halley (1979) identified two cranidia of *Bonninia* sp. in the Mule Spring Limestone from the Cucomungo Canyon section of the northern Last Chance Range in California and from a Nevada Test Site locality. Palmer and Halley (1979) originally recorded the Cucomungo Canyon occurrences as Gold Ace Limestone Member of the Carrara Formation, but they reported no

other corynexochids from the Lower Cambrian of the Carrara Formation; the Eagle Mountain, Thimble Limestone, Echo Shale, and lower Pyramid Shale members all appear to be devoid of these trilobites. About a half dozen specimens of *Bonnia caperata* have been reported in the lower Saline Valley Formation at a level approximately equivalent to the lower Carrara Formation (Palmer 1964), and the genus has also been identified from several sites in the Harkless Formation and Mule Spring Limestone (Albers and Stewart 1972, J.S. Hollingsworth, *personal communication* 2010). These fossils from the Saline Valley, Harkless, and Mule Spring, are all from Esmeralda County, Nevada, approximately the same distance from the Lower Cambrian craton as the Last Chance Range occurrence from Palmer and Halley (1979). Although each of these occurrences consists of just a few specimens, Fritz (1968) recorded more than 150 *Bonnia copia* specimens in the Pioche Formation in the Egan Range north of Ely, Nevada. Lochman (1952) also reported eight specimens of *Bonnia sonora* from the Buelna Formation near Caborca in northern Mexico; the Buelna is also part of a miogeoclinal section (Stewart et al. 2002).

Bonnia has been found in eastern and western Canada (Fritz 1972, Bohach 1997), Virginia, the Death Valley area, and numerous other regions (Resser 1938, Palmer and Halley 1979, Fritz 1991). *Bonniella* is known from the Lower Cambrian of sites mostly in eastern North America, including Vermont, Pennsylvania, and Virginia (Resser 1937, 1938, Resser and Howell 1938, Shaw 1955), but has been reassigned to *Bonnia* (Bohach 1997). *Bonnima* was first described by Fritz (1991) from the upper Illtyd Formation (Dyeran) in the Yukon Territory and was also identified by Fritz (1991) in eastern Canada. I have been unable to find reference to its previous occurrence in the Lower Cambrian of the Great Basin or Mojave Desert, making the Chambless Limestone specimen possibly the first of that genus in this region. Except at the Pioche Formation locality in the Egan Range of Nevada, Dorypygidae in general do not appear to be abundant in the Lower Cambrian of the Southwest, and where they do occur they appear to be in most cases distal facies, possibly deeper-water species. But the Chambless Limestone occurrence of MWC 6961 demonstrates that in the southern Cordillera they could range well into the cratonic biofacies realm as defined by Lochman-Balk and Wilson (1958) and supported by Rowell et al. (1973). The cratonic biofacies probably represents a shallow, restricted shelf setting (Palmer 1977), and although lateral equivalents of the Chambless Limestone out as far as the Nopah and Last Chance ranges suggest similar environmental settings existed across the miogeoclinal shelf, slightly deeper water might be expected in these areas. *Bonnia* and other dorypygids commonly range across several environments and biofacies realms in younger sections and in other regions (Lochman-Balk and Wilson 1958).

The shale interval in the Chambless Limestone that yielded MWC 6961 and the associated fauna may represent a brief

flooding event bringing outer, open-shelf forms such as *Bonnima* onto the craton; alternatively, it could represent a temporary shift in the carbonate shoal environments of the area with little change in depth, one that simply brought in more terrigenous influence for a period of time. The presence of apparent interference ripples in the carbonate layers containing the fossils in this sample may support the latter scenario. If the shale and thin carbonate interval does not represent a flooding event, then the apparent environmental range of Dorypygidae along the shelf, from the proximal Chambless Limestone occurrence to the distal localities with *Bonnia* specimens (Palmer 1964, Fritz 1968, Albers and Stewart 1972, Palmer and Halley 1979), would be consistent with the family's apparent broad tolerance of variable environmental conditions in other regions (Lochman-Balk and Wilson 1958). If the shale and carbonate interval does represent a flooding event, then the *Bonnima* specimen provides evidence for a temporary expansion of the ranges of typically open-shelf species onto the craton.

ACKNOWLEDGEMENTS

Thanks to the Museum of Western Colorado crews that helped with this exploratory survey of Chambless Limestone and Cadiz outcrops in the Marbles and, over the years, with the work in the Latham Shale. Thanks also to M. Kooser for compiling and sending data from the UCR catalog regarding the Chambless Limestone, and to F. Sundberg and J. S. Hollingsworth for reviews of the manuscript. Field work for this project was conducted under Bureau of Land Management permit CA-08-00-002P.

LITERATURE CITED

- Albers, J.P., and Stewart, J.H. 1972. Geology and mineral deposits of Esmeralda County, Nevada. *Nevada Bureau of Mines and Geology Bulletin* 78:1-80.
- Bohach, L.L. 1997. Systematics and biostratigraphy of Lower Cambrian trilobites of western Laurentia. Ph.D. dissertation, University of Victoria. 492 pp.
- Foster, J.R. 1994. A note on depositional environments of the Lower-Middle Cambrian Cadiz Formation, Marble Mountains, California. *The Mountain Geologist* 31:29-36.
- Fritz, W.H. 1968. Lower and early Middle Cambrian trilobites from the Pioche Shale, east-central Nevada, U.S.A. *Palaeontology* 11:183-235.
- Fritz, W.H. 1972. Lower Cambrian trilobites from the Sekwi Formation type section, Mackenzie Mountains, northwestern Canada. *Geological Survey of Canada Bulletin* 212. 90 pp.
- Fritz, W.H. 1991. Lower Cambrian trilobites from the Illtyd Formation, Wernecke Mountains, Yukon Territory. *Geological Survey of Canada Bulletin* 409. 77 pp.
- Fuller, J.E. 1980. A Middle Cambrian fossil locality in the Cadiz Formation, Marble Mountains, California. *Southern California Paleontological Society Special Publication* 2:30-33.
- Gaines, R.R., and Droser, M.L. 2002. Depositional environments, ichnology, and rare soft-bodied preservation in the Lower Cam-

- brian Latham Shale, east Mojave. Pp. 153–164 in F.A. Corsetti (ed.), Proterozoic-Cambrian of the Great Basin and Beyond. SEPM Pacific Section Book 93.
- Hall, C.A. 2007. Introduction to the geology of Southern California and its native plants. University of California Press, Berkeley. 493 pp.
- Hazzard, J.C. 1954. Rocks and structure of the northern Providence Mountains, San Bernardino County, California. *California Division of Mines and Geology Bulletin* 170:27–35.
- Hazzard, J.C., and Crickmay, C.H. 1933. Notes on the Cambrian rocks of the eastern Mohave Desert, California. *University of California Publications in Geological Sciences* 23:57–70.
- Kobayashi, T. 1935. The Cambro-Ordovician formations and faunas of South Chosen, Palaeontology, Part III, Cambrian faunas of South Chosen with special study on the Cambrian trilobite genera and families. *Journal of the Faculty of Science, Imperial University of Tokyo* 4(2):49–344.
- Lochman, C. 1952. Trilobites. Pp. 60–161 in G.A. Cooper, A.R.V. Arellano, J.H. Johnson, V.J. Okulitch, A. Stoyanow, and C. Lochman (eds.), Cambrian Stratigraphy and Paleontology near Caborca, Northwestern Sonora, Mexico. *Smithsonian Miscellaneous Collections* 119.
- Lochman-Balk, C., and Wilson, J.L. 1958. Cambrian biostratigraphy in North America. *Journal of Paleontology* 32:312–350.
- Mount, J.D. 1974. Early Cambrian faunas from the Marble and Providence mountains, San Bernardino County, California. *Bulletin of the Southern California Paleontological Society* 6(1):1–5.
- Mount, J.D. 1976. Early Cambrian faunas from eastern San Bernardino County, California. *Bulletin of the Southern California Paleontological Society* 8(12):173–182.
- Mount, J.D. 1980. Characteristics of Early Cambrian faunas from eastern San Bernardino County, California. *Southern California Paleontological Society Special Publication* 2:19–29.
- Nelson, C.A. 1978. Late Precambrian-Early Cambrian stratigraphic and faunal succession of eastern California and the Precambrian-Cambrian boundary. *Geological Magazine* 115:121–126.
- Palmer, A.R. 1964. An unusual Lower Cambrian trilobite fauna from Nevada. *United States Geological Survey Professional Paper* 483-F.
- Palmer, A.R. 1971. The Cambrian of the Great Basin and adjacent areas, western United States. Pp. 1–77 in C.H. Holland (ed.), Lower Palaeozoic rocks of the world, volume 1, The Cambrian of the New World. Wiley-Interscience, New York.
- Palmer, A.R. 1977. Biostratigraphy of the Cambrian System—a progress report. *Annual Review of Earth and Planetary Sciences* 5:13–33.
- Palmer, A.R., and Halley, R.B. 1979. Physical stratigraphy and trilobite biostratigraphy of the Carrara Formation (Lower and Middle Cambrian) in the southern Great Basin. *United States Geological Survey Professional Paper* 1047. 131 pp.
- Rasetti, F. 1948. Lower Cambrian trilobites from the conglomerates of Quebec (exclusive of the Ptychopariidea). *Journal of Paleontology* 22:1–24.
- Rasetti, F. 1951. Middle Cambrian stratigraphy and faunas of the Canadian Rocky Mountains. *Smithsonian Miscellaneous Collections* 116(5):1–277.
- Resser, C.E. 1937. Third contribution to nomenclature of the Cambrian trilobites. *Smithsonian Miscellaneous Collections* 95(22):1–29.
- Resser, C.E. 1938. Cambrian system (restricted) of the southern Appalachians. *Geological Society of America Special Paper* 15. 140 pp.
- Resser, C.E., and Howell, B.F. 1938. Lower Cambrian *Olenellus* Zone of the Appalachians. *Bulletin of the Geological Society of America* 49:195–246.
- Rowell, A.J., McBride, D.J., and Palmer, A.R. 1973. Quantitative study of Trempealeauian (Latest Cambrian) trilobite distribution in North America. *Geological Society of America Bulletin* 84:3429–3442.
- Shaw, A.B. 1955. Paleontology of northwestern Vermont. V. The Lower Cambrian fauna. *Journal of Paleontology* 29:775–805.
- Stevens, C.H., and Greene, D.C. 1999. Stratigraphy, depositional history, and tectonic evolution of Paleozoic continental-margin rocks in roof pendants of the eastern Sierra Nevada, California. *Geological Society of America Bulletin* 111:919–933.
- Stewart, J.H. 1970. Upper Precambrian and Lower Cambrian strata in the southern Great Basin California and Nevada. *United States Geological Survey Professional Paper* 620. 206 pp.
- Stewart, J.H., Amaya-Martínez, R., and Palmer, A.R. 2002. Neoproterozoic and Cambrian strata of Sonora, Mexico: Rodinian supercontinent to Laurentian Cordilleran margin. *Geological Society of America Special Paper* 365:5–48.
- Unal, E., and Zinsmeister, W.J. 2007. Oncoid growth strategies in response to fluctuating depositional environments during the late Early Cambrian of eastern California. *Geological Society of America Abstracts with Programs* 39(6):397.
- Walcott, C.D. 1890. The fauna of the Lower Cambrian or *Olenellus* Zone. *United States Geological Survey, Tenth Annual Report for 1888–89*, part 1. Pp. 515–717.
- Webster, M. 2003. Olenelloid trilobites of the southern Great Basin, U.S.A., and a refinement of uppermost Dyeran biostratigraphy. *Geological Society of America Abstracts with Programs* 35(6):166.
- Webster, M., Sadler, P.M., Kooser, M.A., and Fowler, E. 2003. Combining stratigraphic sections and museum collections to increase biostratigraphic resolution: application to Lower Cambrian trilobites from southern California. Pp. 95–128 in P.J. Harries (ed.), Approaches in High-Resolution Stratigraphic Paleontology. *Topics in Geobiology* 21.