Physical Stratigraphy and Trilobite Biostratigraphy of the Carrara Formation (Lower and Middle Cambrian) in the Southern Great Basin

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GEOLOGICAL SURVEY PROFESSIONAL PAPER 1047

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March 3, 1849

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By ALLISON R. PALMER *and* ROBERT B. HALLEY

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Nine members are described; a model for Grand Cycle sedimentation is proposed; nine trilobite zonules are defined; and 95 species representing 38 genera are described

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METRIC-ENGLISH EQUIVALENTS

[SI, International System of Units, a modernized metric system of measurement]

Length

SI unit		U.S. customary equivalent	
millimeter (mm)	=	0.039 37	inch (in)
meter (m)	=	3.281	feet (ft)
	=	1.094	yards (yd)
kilometer (km)	=	0.621 4	mile (mi)
	=	0.540 0	mile, nautical (nmi)

Area

SI unit		U.S. customary equivalent	
centimeter^2 (cm^2)	=	0.155 0	inch^2 (in^2)
meter^2 (m^2)	=	10.76	feet^2 (ft^2)
	=	1.196	yards^2 (yd^2)
	=	0.000 247 1	acre
hectometer^2 (hm^2)	=	2.471	acres
	=	0.003 861	section (640 acres or 1 mi^2)
kilometer^2 (km^2)	=	0.386 1	mile^2 (mi^2)

Volume

SI unit		U.S. customary equivalent	
centimeter^3 (cm^3)	=	0.061 02	inch^3 (in^3)
decimeter^3 (dm^3)	=	61.02	inches^3 (in^3)
	=	2.113	pints (pt)
	=	1.057	quarts (qt)
	=	0.264 2	gallon (gal)
	=	0.035 31	foot^3 (ft^3)
meter^3 (m^3)	=	35.31	feet^3 (ft^3)
	=	1.308	yards^3 (yd^3)
	=	264.2	gallons (gal)
	=	6.290	barrels (bbl) (petroleum, 1 bbl=42 gal)
	=	0.000 810 7	acre-foot (acre-ft)
hectometer^3 (hm^3)	=	810.7	acre-feet (acre-ft)
kilometer^3 (km^3)	=	0.239 9	mile^3 (mi^3)

Volume per unit time (includes flow)

SI unit		U.S. customary equivalent	
decimeter^3 per second (dm^3/s)	=	0.035 31	foot^3 per second (ft^3/s)
	=	2.119	feet^3 per minute (ft^3/min)

Volume per unit time (includes flow)—Continued

SI unit		U.S. customary equivalent	
decimeter^3 per second (dm^3/s)	=	15.85	gallons per minute (gal/min)
	=	543.4	barrels per day (bbl/d) (petroleum, 1 bbl=42 gal)
meter^3 per second (m^3/s)	=	35.31	feet^3 per second (ft^3/s)
	=	15 850	gallons per minute (gal/min)

Mass

SI unit		U.S. customary equivalent	
gram (g)	=	0.035 27	ounce avoirdupois (oz avdp)
kilogram (kg)	=	2.205	pounds avoirdupois (lb avdp)
megagram (Mg)	=	1.102	tons, short (2 000 lb)
	=	0.984 2	ton, long (2 240 lb)

Mass per unit volume (includes density)

SI unit		U.S. customary equivalent	
kilogram per meter^3 (kg/m^3)	=	0.062 43	pound per foot^3 (lb/ft^3)

Pressure

SI unit		U.S. customary equivalent	
kilopascal (kPa)	=	0.145 0	pound-force per inch^2 (lbf/in^2)
	=	0.009 869	atmosphere, standard (atm)
	=	0.01	bar
	=	0.296 1	inch of mercury at 60°F (in Hg)

Temperature

temp kelvin (K) = [temp deg Fahrenheit (°F)+459.67]/1.8
temp deg Celsius (°C) = [temp deg Fahrenheit (°F)−32]/1.8

PHYSICAL STRATIGRAPHY AND TRILOBITE BIOSTRATIGRAPHY OF THE CARRARA FORMATION (LOWER AND MIDDLE CAMBRIAN) IN THE SOUTHERN GREAT BASIN

By ALLISON R. PALMER and ROBERT B. HALLEY

ABSTRACT

The Carrara Formation consists of three complete and one partial clastic-carbonate sedimentary cycles totaling about 400 meters in thickness and spanning the time from the upper part of the *Olenellus* Zone of Early Cambrian age to the lower part of the *Glossopleura* Zone of Middle Cambrian age. It represents the regional transition from dominantly clastic Early Cambrian miogeoclinal sedimentation to dominantly carbonate Middle and Late Cambrian miogeoclinal sedimentation and can be recognized over an area of about 36,000 square kilometers in southern Nevada and adjacent parts of southeastern California. Nine members can be distinguished between the underlying Zabriskie Quartzite and the overlying massive carbonate rocks of the Bonanza King Formation. These are, from the oldest to youngest: Eagle Mountain Shale, Thimble Limestone, Echo Shale, Gold Ace Limestone, Pyramid Shale, Red Pass Limestone, Pahrump Hills Shale, Jangle Limestone, and Desert Range Limestone. The Lower–Middle Cambrian boundary falls within the lower part of the Pyramid Shale Member. The Thimble and Gold Ace Limestone Members are tongues of the Mule Spring Limestone of the Inyo Mountains region to the west. The younger parts of the formation are replaced to the west by predominantly thin bedded deeper water carbonate and clastic facies of the Emigrant or Monola Formations.

Within the Carrara Formation, the sedimentary cycles are compared with Grand Cycles described from the southern Canadian Rocky Mountains. Each cycle begins with clastics and grades upward to increasingly clean carbonates before being terminated by an abrupt return to clastic sedimentation. Carbonate rocks predominate in western and northwestern exposures of the formation and form tongues with diachronous bases and nearly synchronous tops that extend eastward into a region of predominantly clastic sedimentation. The carbonate sediments can be grouped into two subtidal lithofacies, lime mudstone and oolite, and one intertidal and supratidal lithofacies, an algal-boundstone lithofacies. The time and space relationships of these lithofacies, as well as comparisons with Holocene analogs, provide data to support the suggestion that Grand Cycles reflect changes in rates of subsidence within a miogeocline.

Although the Carrara Formation is not richly fossiliferous, it contains the most complete representation of stratigraphically documented North American trilobite faunas that span the Lower–Middle Cambrian boundary. These trilobites represent part or all of four assemblage zones. The oldest faunas represent the upper part of the *Olenellus* Zone, and three locally useful zonules help to identify the lower part of the Eagle Mountain Shale and the Thimble Limestone Members and the lower part of the Pyramid Shale Member. The next younger "*Plagiura-Poliella*" assemblage zone is poorly fossiliferous and is found in the upper part of the Pyramid Shale Member and lower part of the Red Pass Limestone Member. Trilobites from the upper part of the Red Pass Limestone Member to the lower part of the Jangle Limestone Member represent the *Albertella* assemblage zone. These show the existence of three contemporaneous biofacies with very few shared trilobites. A deeper water biofacies on the west is characterized by *Ogygopsis;* a rich shelf-edge biofacies is characterized by abundant representatives of the Zacanthoididae; and an eastern restricted shelf biofacies is characterized by low-diversity faunas including *Albertella* and *Mexicella*. The Desert Range Limestone Member includes trilobites from the lower part of the *Glossopleura* Zone. The biostratigraphic problems created by the spatial distribution of the trilobites are discussed.

The trilobite fauna includes more than 95 species representing at least 38 genera. Special attention is given to problems of classification within the Olenellidae, Zacanthoididae, and some Ptychopariida. New taxa are *Bristolia anteros* n. sp., *B. fragilis* n. sp., *Olenellus arcuatus* n. sp., *O. brachyomma* n. sp., *O. cylindricus* n. sp., *O. euryparia* n. sp., *O. multinodus* n. sp., *Peachella brevispina* n. sp., *Poliella lomataspis* n. sp., *Oryctocephalus nyensis* n. sp., *Albertella longwelli* n. sp., *A. spectrensis* n. sp., *Albertellina aspinosa* n. gen., n. sp., *Albertelloides rectimarginatus* n. sp., *Mexicaspis radiatus* n. sp., *Paralbertella* n. gen., *Ptarmiganoides crassaxis* n. sp., *P. hexacantha* n. sp., *Zacanthoides variacantha* n. sp., *Caborcella pseudaulax* n. sp., *C. reducta* n. sp., *Elrathina antiqua* n. sp., *Eoptychoparia piochensis* n. sp., *Kochiellina groomensis* n. gen., n. sp., *K. janglensis* n. sp., *Mexicella grandoculus* n. sp., *Nyella immoderata* n. gen., n. sp., *Plagiura extensa* n. sp., *P. minor* n. sp., *P. retracta* n. sp., *Syspacephalus longus* n. sp., *S. obscurus* n. sp., *Volocephalina connexa* n. gen., n. sp., and *V. contracta* n. sp.

INTRODUCTION

The Carrara Formation is a unit of heterogeneous, primarily marine sediments, averaging about 400 m in thickness, that forms the transition between predominantly quartzitic Lower Cambrian rocks and predominantly calcareous Middle and Upper Cambrian rocks in the southern Great Basin in southern Nevada and southeastern California (fig. 1). The formation includes nine members, either of limestone or terrigenous clastic rocks, forming an intertonguing and interlayered complex whose time-space relationships are the subject of the physical stratigraphy part of this report, written by Halley. The formation ranges in age from late Early Cambrian through the early part of the Middle Cambrian *Glossopleura* Zone. Trilobites are the biostratigraphically important fossils in the formation and their systematics, biostratigraphy, and biofacies analysis are described by Palmer.

Structurally uncomplicated sections through the Carrara Formation are excellently exposed in many mountain ranges in the southern Great Basin; a list of the places where sections of the Carrara Formation have been studied follows:

Location	Source
Azure Ridge	Unpublished measured section by Art Richards, Ben Bowyer, and Robert Cohenour, March 7, 1957.
Belted Range	This report; Ekren and others, 1971.
Bare Mountain	Cornwall and Kleinhampl, 1961; measured sections by Bates, 1965.
Cucomungo Canyon	This report; Stewart, 1970.
Delamar Mountains	Unpublished measured section by Allison R. Palmer, 1970.
Dublin Hills	Measured section by Bates, 1965.
Desert Range	This report; Stewart and Barnes, 1966.
Echo Canyon (Funeral Mountains).	This report; Hunt and Mabey, 1966; measured sections by J. F. McAllister, unpublished data, 1963; Bates, 1965; and P. R. Rose, unpublished data, 1969.
Eagle Mountain	This report; Stewart, 1970; measured sections by Bates, 1965.
Frenchman Mountain	Pack and Gale, 1971.
Goldfield Hills	Stewart, 1970.
Groom Range	This report; Barnes and Christiansen, 1967.
Highland Range	Merriam, 1964.
Inyo Mountains	This report; Nelson, 1962, 1965.
Jangle Ridge	Johnson and Hibbard, 1957; Barnes and Palmer, 1961; Barnes, Christiansen, and Byers, 1962.
Last Chance Range	This report; Stewart, 1965.
Las Vegas Range	This report; Stewart, 1970.
Miller Mountain	This report; Nelson and Durham, 1966.
Marble Mountains	This report; Stewart, 1970; Hazzard and Mason, 1936.
Nopah Range	This report.
Northern Panamint Mountains.	Bates, 1965.
Southern Panamint Mountains.	Bates, 1965.
Paymaster Canyon	This report; Albers and Stewart, 1962; Stewart, 1970.
Pahrump Hills	This report; Bates, 1965.
Pioche District	Merriam, 1964.
Providence Mountains	This report; Stewart, 1970; Hazzard, 1954.
Pyramid Peak	This report.
Northern Resting Springs Range.	Bates, 1965.
Southern Resting Springs Range.	This report; Bates, 1965.
Salt Spring Hills	Bates, 1965.
Spectre Range	Burchfiel, 1964.
Striped Hills	This report.
Silurian Hills	Kupfer, 1960; Stewart, 1970.
Sheep Mountain	This report; Hazzard and Mason, 1953.
Spring Mountains	This report.
Titanothere Canyon	This report; Reynolds, 1971; Bates, 1965.
Ubehebe Crater	This report.
Winters Pass	This report; Stewart, 1970.

Study of the stratigraphy and faunas of the formation was begun in 1960 by Palmer in conjunction with problems related to the mapping of Bare Mountain, Nev., by Cornwall and Kleinhampl (1961). At that time, brief reconnaissance visits were also made to the Nevada Test Site and to the Desert Range. Following a more extended series of visits to the Resting Springs Range, Eagle Mountain, Striped Hills, Groom Range, Desert Range, and Bare Mountain in 1961, enough material had been obtained to begin a preliminary study of the systematics of the trilobites. Further fieldwork in 1963 and 1964 included a study of sections in Titanothere Canyon, Echo Canyon, Cucomungo Canyon, the southern Last Chance Range, Dublin Hills, Salt Spring Hills, and Belted Range, in addition to revisiting some previously studied areas. This work established the basic regional stratigraphic framework of the Carrara Formation.

Other activities interrupted study of the Carrara stratigraphy and faunas until 1969 when the study was resumed and expanded to include a detailed sedimentologic-environmental analysis. This assignment was undertaken by Halley with support from National Science Foundation Grant A020318 to Palmer. All major sections were remeasured during 1971 and 1972, and extensive samples for petrographic analysis were collected. All the stratigraphically controlled trilobite collections from earlier work have been placed in the context of Halley's sections and are summarized on plate 17. The results of this joint effort at stratigraphic and paleontologic analysis of rocks and fossils of the Carrara Formation are documented in the remainder of this paper.

The Carrara Formation was chosen for detailed sedimentologic-faunal analysis for several reasons. Regional paleogeography for the Cambrian of North America shows that, in general, a broad belt of generally shallow marine carbonate sediments occupied the outer part of the Cambrian continental shelf. This belt was flanked on its seaward side by silty clastics and dark siliceous thin-bedded carbonates presumably characteristic of deeper waters and on its landward side by predominantly shallow marine noncarbonate clastics. Together, these generalized lithofacies form sedimentary belts that have been designated as the Carbonate Belt and Outer and Inner Detrital Belts (Palmer, 1960, 1972; Robison, 1960). Only in the Carrara Formation is it possible to analyze the depositional environments of individual units of the Carbonate Belt across the facies strike in sufficient detail to relate them to the environments in the adjacent Inner and Outer Detrital Belts and to a dynamic model that might explain their origin.

Results of sedimentologic analysis show that the carbonate belt included carbonate islands near its oceanward (western) margin at specific times and that the vertical and lateral shifts in carbonate and noncarbonate lithofacies within the Carrara Formation most probably

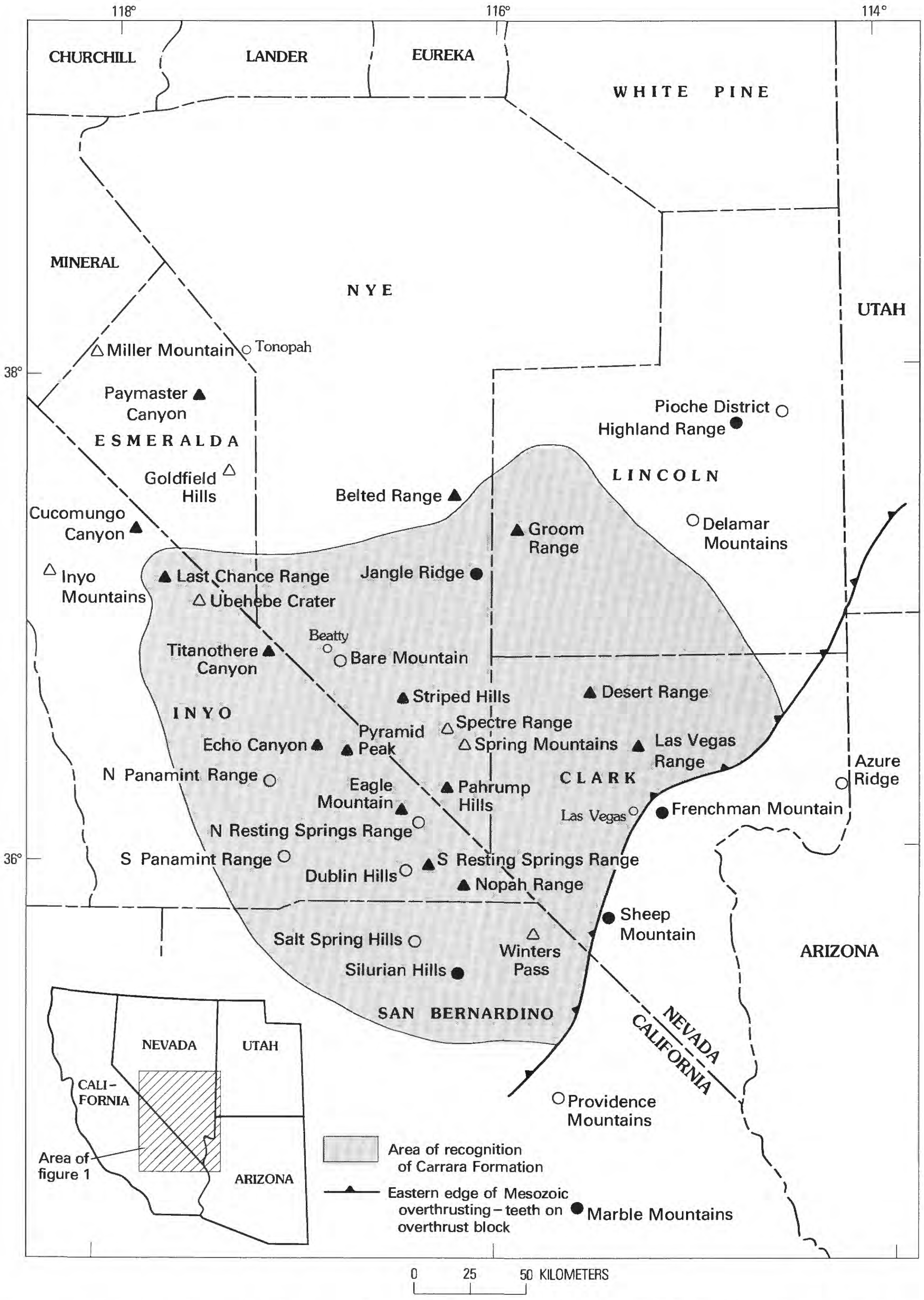

FIGURE 1.—Index map showing localities related to study of the Carrara Formation. Solid triangles, sections measured for this study; open triangles, sections examined but not measured in detail; solid circles, previously described and published sections, not remeasured: large open circles, unpublished sections by others, examined but not remeasured.

resulted from variable rates of basin subsidence.

Lateral facies changes within members and repetition of similar lithologies among stratigraphically distinct members require that some biostratigraphic control be developed to assist with mapping problems in areas where the Carrara Formation has been faulted or where exposures are discontinuous. In addition to this practical problem, the Carrara Formation is the principal unit within which the biostratigraphic and biofacies relationships for the latest Early Cambrian and early Middle Cambrian trilobite faunas of Western United States can be worked out. The paleontological analysis shows that most of the members of the Carrara Formation have distinctive faunas or consistent stratigraphic relations to beds with such faunas so that they can be correctly identified even when isolated by faults or poor exposure from the remainder of the formation. Strong environmental controls on the lateral distribution of some of the trilobites are also indicated so that a biostratigraphy comprised of a single vertical succession of zones and subzones is not practicable. The principal environmental controls seem to have been water depth and contrasts in habitat related to the ocean-facing edge of the Carbonate Belt.

ACKNOWLEDGMENTS

The following U.S. Geological Survey personnel provided guidance in the field, collections, or unpublished descriptions of the Carrara Formation during the 1960's; their valuable help in accumulating the basic field data for the faunal collections is gratefully appreciated: Harley Barnes, Donald Hibbard, C. B. Hunt, Michael Johnson, C. R. Longwell, J. F. McAllister, M. W. Reynolds, and J. H. Stewart. E. W. Bates of the University of California at Los Angeles supplied a copy of his fine Master's thesis (1965) on the stratigraphy and faunas of the Carrara Formation which provided supplemental data on faunal ranges for many Carrara sections. Transportation for a review of the principal Carrara sections was provided in 1969 by A. J. Rowell of the University of Kansas. All field and laboratory work prior to 1966 was supported by the U.S. Geological Survey. Work subsequent to that date has been supported by the facilities of the State University of New York at Stony Brook and by funds from National Science Foundation Grant A020318.

Field assistance for Halley's sedimentologic study was provided by Barbara Halley in 1971 and 1972 and by K. C. Lohmann in 1973. The many amenities provided to both Palmer and Halley by Mr. and Mrs. Phillip D. Pack of Las Vegas, Nev., are also gratefully acknowledged.

STRATIGRAPHY OF THE CARRARA FORMATION

The Carrara Formation was defined by Cornwall and Kleinhampl (1961) from the Bare Mountain quadrangle, Nevada. It was named for the ghost town of Carrara 13 km east-southeast of Beatty, Nev., from which marble quarries in the upper part of the formation were worked at the turn of the century.

At Bare Mountain the typical section of the Carrara Formation is composed of 542 m of interstratified limestone and shale with minor amounts of quartzite, dolomite, and siltstone. The Carrara Formation lies stratigraphically above the Zabriskie Quartzite (identified as Stirling(?) by Cornwall and Kleinhampl (1961) and corrected in a footnote on the same map) and below the Bonanza King Formation. Cornwall and Kleinhampl recognized a predominantly clastic lower half of the Carrara Formation and a carbonate upper half. Within the lower half three subdivisions were described: a lower unit of quartzite, sandstone, siltstone, phyllitic shale, and minor limestone; a middle unit of limestone alternating with shale and capped by a conspicuous cliff-forming "algal" limestone about 46 m thick; and an upper unit of fine-grained clastic rocks. The upper carbonate half of the Carrara Formation was subdivided into two units, the lowest unit being a series of broken cliffs visible from a distance as a broad band of alternating white, orange, pink, and brown limestone, and the upper unit being a dark-gray limestone. The basal quartzites of the Carrara Formation were described as transitional with the underlying Zabriskie Quartzite, and the uppermost limestones of the Carrara Formation were described as gradational into the overlying Bonanza King Formation.

The first published extension of the Carrara Formation beyond its type locality was to the Yucca Flat area of the Atomic Energy Commission Nevada Proving Grounds (Barnes and others, 1962). This extension solved nomenclatural problems on the Nevada Test Site that had arisen from previous attempts to apply existing nomenclature derived from Pioche district, Nevada, (Johnson and Hibbard, 1957) or from the Providence Mountains of California (Barnes and Palmer, 1961). Barnes, Christiansen, and Byers (1962) subdivided the Carrara Formation into seven units, placing the base of the formation at the base of the lowermost fissile shale above the massive quartzites of the Zabriskie. The top of the Carrara Formation was located above the highest argillaceous limestones that are transitional between the Carrara and the Bonanza King Formations.

Quadrangle mapping by the U.S. Geological Survey and various university thesis studies extended recognition of the formation to the southern Nopah Range and the Resting Springs Range (Wilhelms, 1963), the Spectre

<table>
<tr><th>Humphrey (1945)</th><th>Wheeler (1948)</th><th>Johnson and Hibbard (1957)</th><th colspan="2">Barnes and Palmer (1961)</th><th>Cornwall and Kleinhampl (1961)</th><th>Barnes and Christiansen (1967)</th><th>This report</th><th>Series</th></tr>
<tr><td>Burrows Limestone</td><td>Chisholm Shale</td><td>Yucca Flat Formation (part)</td><td rowspan="2">Jangle Member</td><td rowspan="3">Cadiz Formation</td><td rowspan="9">Carrara Formation</td><td>G</td><td>Desert Range Limestone Member</td><td rowspan="5">Middle Cambrian</td></tr>
<tr><td>Peasley Limestone</td><td>Lyndon Limestone</td><td>Jangle Limestone</td><td>Jangle Limestone Member</td><td>Jangle Limestone Member</td></tr>
<tr><td>Chisholm Shale</td><td rowspan="7">Tecopa Shale</td><td>Chisholm Shale</td><td></td><td>E</td><td>Pahrump Hills Shale Member</td></tr>
<tr><td>Lyndon Limestone</td><td>Lyndon Limestone</td><td colspan="2">Chambless Limestone</td><td>D</td><td>Red Pass Limestone Member</td></tr>
<tr><td rowspan="5">Pioche Shale</td><td rowspan="5">Pioche Shale</td><td colspan="2" rowspan="5">Latham Shale</td><td>C</td><td>Pyramid Shale Member</td></tr>
<tr><td>B</td><td>Gold Ace Limestone Member</td><td rowspan="4">Lower Cambrian</td></tr>
<tr><td rowspan="3">A</td><td>Echo Shale Mbr</td></tr>
<tr><td>Thimble Limestone Mbr</td></tr>
<tr><td>Eagle Mountain Shale Member</td></tr>
</table>

FIGURE 2.—Nomenclatural history of the rocks now included within the Carrara Formation.

Range (Burchfiel, 1964), and the Pahrump Hills, Salt Spring Hills, Dublin Hills, Eagle Mountain, Funeral Mountains, Grapevine Mountains, and Panamint Mountains (Bates, 1965). Wright and Troxel (1966) recognized the Carrara Formation in the Silurian Hills of California; Hunt and Mabey (1966) used this formation name throughout the Death Valley region; Stewart and Barnes (1966) reported the formation in the Desert Range of Nevada; and Stewart (1965) extended recognition of the formation to the southern Last Chance Range of California. Barnes and Christiansen (1967) described the Carrara Formation in the Groom Range, Nev., superseding the nomenclature derived from the Pioche district and used there by Humphrey (1945). Stewart (1970), in a regional study of the upper Precambrian and Lower Cambrian clastic rocks of the southern Great Basin, described the lower part of the Carrara Formation and its stratigraphic relationships to equivalent formations east and west of the Carrara outcrop area. Ekren and others (1971) described intervals in the Belted Range of the northern Nellis Bombing Range, Nye County, Nev., that are equivalent to and in part like the Carrara Formation but seem to be transitional between the Carrara Formation and correlative strata to the west. The study area of this paper and the locations of sections discussed in the text are illustrated in figure 1. The history of the various stratigraphic nomenclatures applied to the Carrara Formation and their relation to the present nomenclature are shown in figure 2.

Surrounding the area in which the Carrara Formation can be identified are four areas that contain correlative strata that have been described and named (fig. 1). To the northeast, in the Highland Range and vicinity, units correlative with the Carrara Formation are the Pioche Shale, the Lyndon Limestone, and the Chisholm Shale (Merriam, 1964). To the east, in French Mountain and the Grand Canyon, the correlative rocks are the Tapeats Sandstone and the Bright Angel Shale (McKee and Res-

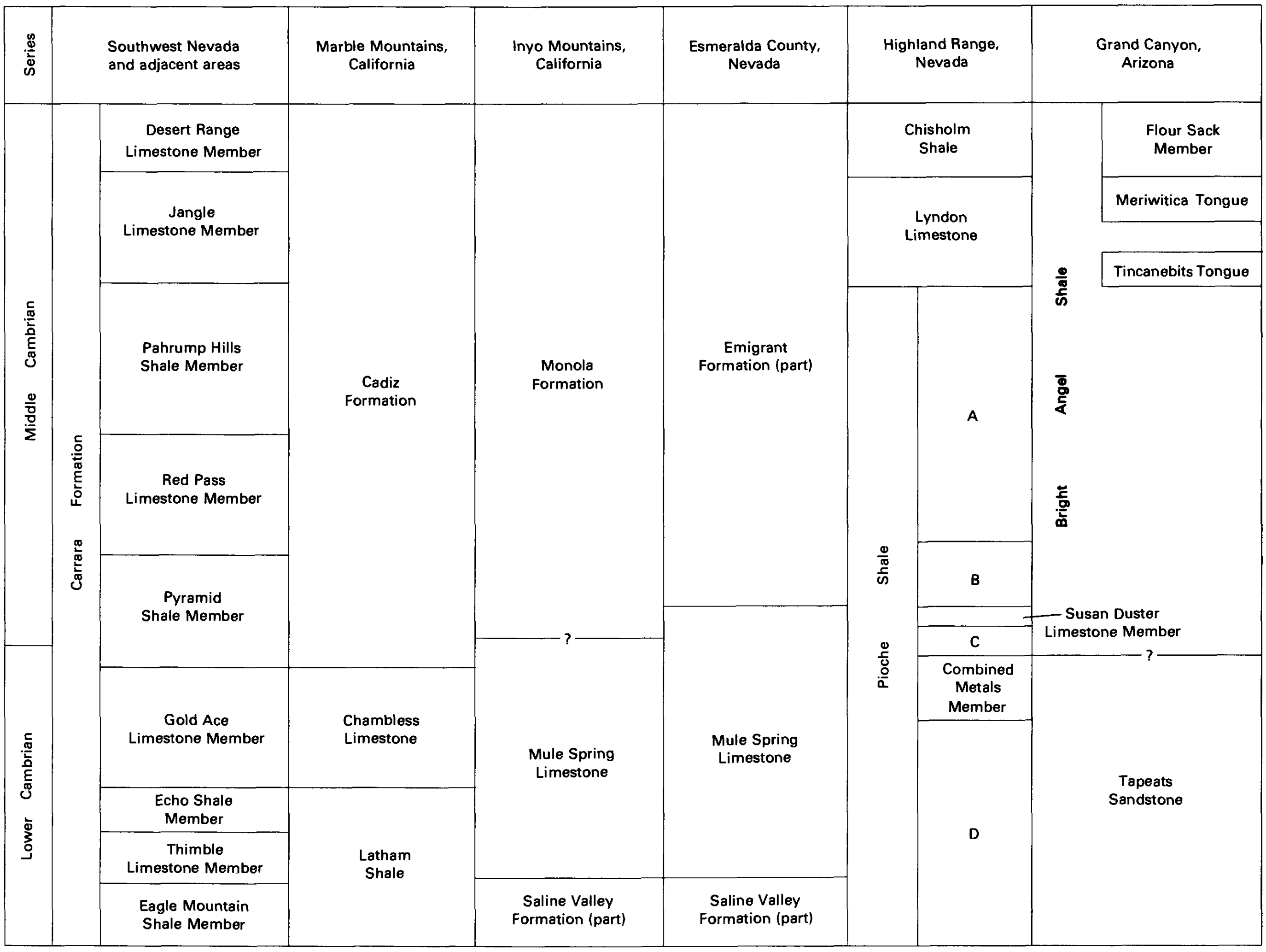

FIGURE 3.—Members of the Carrara Formation and correlation with adjacent regions.

ser, 1945); where the Lyndon Limestone is recognized at the top of the Bright Angel Shale (as at Frenchman Mountain), the overlaying shale is the Chisholm Shale, South of the Carrara area, the correlative strata are the Latham Shale, the Chambless Limestone, and the Cadiz Formation in the Providence and Marble Mountains of California (Hazzard and Mason, 1936; Hazzard, 1954; Stewart, 1970). Finally, to the northwest, stratigraphic units correlative with the Carrara Formation include part of the Saline Valley Formation, the Mule Spring Limestone, and the Monola Formation (Nelson, 1962, 1965), or the lower part of the Emigrant Formation (Albers and Stewart, 1962; Stewart, 1965). Details of correlation of members of the Carrara Formation with these formations are discussed below and shown in figure 3.

DESCRIPTION OF MEMBERS

The basic data for this study are stratigraphic measurements and descriptions from 36 locations where the Carrara Formation or correlative strata are exposed. Subdivision of the Carrara Formation is based on 23 sections which lie within the area in which the formation is typically developed (fig. 1).

Nine members can be recognized within the Carrara Formation over most of the study area. They are, in ascending order: Eagle Mountain Shale Member, Thimble Limestone Member, Echo Shale Member, Gold Ace Limestone Member, Pyramid Shale Member, Red Pass Limestone Member, Pahrump Hills Shale Member, Jangle Limestone Member, and Desert Range Limestone

Member (fig. 3). In addition to these members, a quartzitic unit formerly included within the Carrara Formation is here designated as the Emigrant Pass Member of the underlying Zabriskie Quartzite.

All contacts between members appear to be conformable although the tops of some limestone members, where they are represented by supratidal lithologies, must represent hiatuses. Most of the members represent tongues from formations that surround the Carrara Formation. Their regional relationships are shown schematically in figure 11 and will be clarified during the following discussions of individual members.

EMIGRANT PASS MEMBER OF THE ZABRISKIE QUARTZITE

Cornwall and Kleinhampl (1961) included a transition zone above the Zabriskie Quartzite in the base of the Carrara Formation. This unit is primarily quartzite and sandstone with minor amounts of siltstone and phyllitic shale. Stewart (1970) placed the lower contact of the Carrara Formation at the lowermost occurrences of siltstone, phyllitic siltstone, and shale above massive vitreous quartzite of the Zabriskie. He suggested that this contact is sharp and well defined although the quartzites above the contact are very much like the Zabriskie Quartzite. The quartzite and shale transition interval is here named the Emigrant Pass Member for exposures at its type locality in the southern Nopah Range (fig. 1), north of Emigrant Pass, NW¼ sec. 25, T. 21 N., R. 8 E., Tecopa quadrangle, California.

The Emigrant Pass Member is recognized in 18 of the sections considered in this study; it varies in thickness from 0 to 51 m.

In many eastern sections, the Emigrant Pass Member has a distinctive unit of maroon, brown, and yellow mudstone and shale in its lower 2–15 m. This unit is locally sandy or silty, and contains chamosite grains in some sections. In western sections the lowermost shales within the Emigrant Pass Member are pale-green phyllitic shales interbedded with siltstones and quartzites. Overlying the shaly unit is the orthoquartzitic remainder of the member, a medium-bedded, pink, white, or pale-green quartz arenite. Usually, beds of this unit are composed of single sets of laminated or low-angle crossbeds. Most beds are moderately well sorted; maximum grain sizes are medium to coarse sand and vary from bed to bed. Siltstone interbeds occur between quartzite beds. The upper unit of the member varies in thickness from 0–30 m over the study area.

In thin section the quartzites are composed of well-rounded monocrystalline quartz grains with few polycrystalline grains (figs. 4*D*–*F*). Smaller, less-rounded grains form supporting matrices of some samples. The quartz wackes of the shaly intervals contain chamosite, mica, and calcite in their matrix (figs. 4*B*, 4*C*, 4*E*, 4*F*).

Mudcracks occur in the upper half of the member from the Desert Range to the southern Last Chance Range (fig. 4*A*). Adjacent sets of crossbeds occasionally dip in opposite directions. At Cucomungo Canyon and in the Last Chance Range, stromatolites and bird's-eye limestones immediately overlie this member. These limited observations suggest intermittent exposure and perhaps intertidal deposition for parts of this member.

An isopach map of this unit would probably not reflect its true geometric shape because of major difficulties in placement of the base of the member. This problem becomes apparent when measurements of the member taken by different workers at the same locality are compared. The section at Echo Canyon has been measured on at least four occasions. The thickness of the Emigrant Pass Member has been variously reported as 20 ft by Hunt and Mabey (1966), 70 ft by J. F. McAllister (unpub. data, 1963), 101 ft by Bates (1965), and 106 ft by P. R. Rose (unpub. data, 1969). This last measurement was confirmed by Halley in 1972. Because the highest quartzite bed in the section is an unmistakably prominent bed with more than a hundred meters of shales and limestones overlying it, the discrepancies of measurement obviously lie in the choice of a base for the section.

Because quartzites of the Emigrant Pass Member are indistinguishable from the main body of the Zabriskie Quartzite, recognition of the Zabriskie-Carrara contact in earlier work has depended on recognition of shales or mudstones at the base of the Emigrant Pass Member. Where the shales or mudstones are not present or exposed, or where there is a considerable thickness of interbedded shales and quartzites, the assignment of quartzites to either the Carrara or the Zabriskie has been arbitrary. Stewart (1970) found these difficulties in identification of the formational contact in the Groom, Desert, and Las Vegas Ranges, and at sections south of Winters Pass.

Geographic limitations on stratigraphic nomenclature also obscure the regional relationships of the Emigrant Pass Member. For example, at Cucomungo Canyon in the northern Last Chance Range, Calif., the Carrara Formation and Zabriskie Quartzite are not recognized and their partial equivalents are the Saline Valley Formation, the Mule Spring Limestone, and the Emigrant Formation (Stewart, 1970). The nomenclature from the Inyo Mountains of California was used in this area because the Cambrian section was believed to have more in common with the stratigraphies from that region and Esmeralda County, Nev., to the west and north, than with the Carrara Formation to the east. However, several intervals at Cucomungo Canyon have direct counterparts within the Carrara Formation in the southern Last

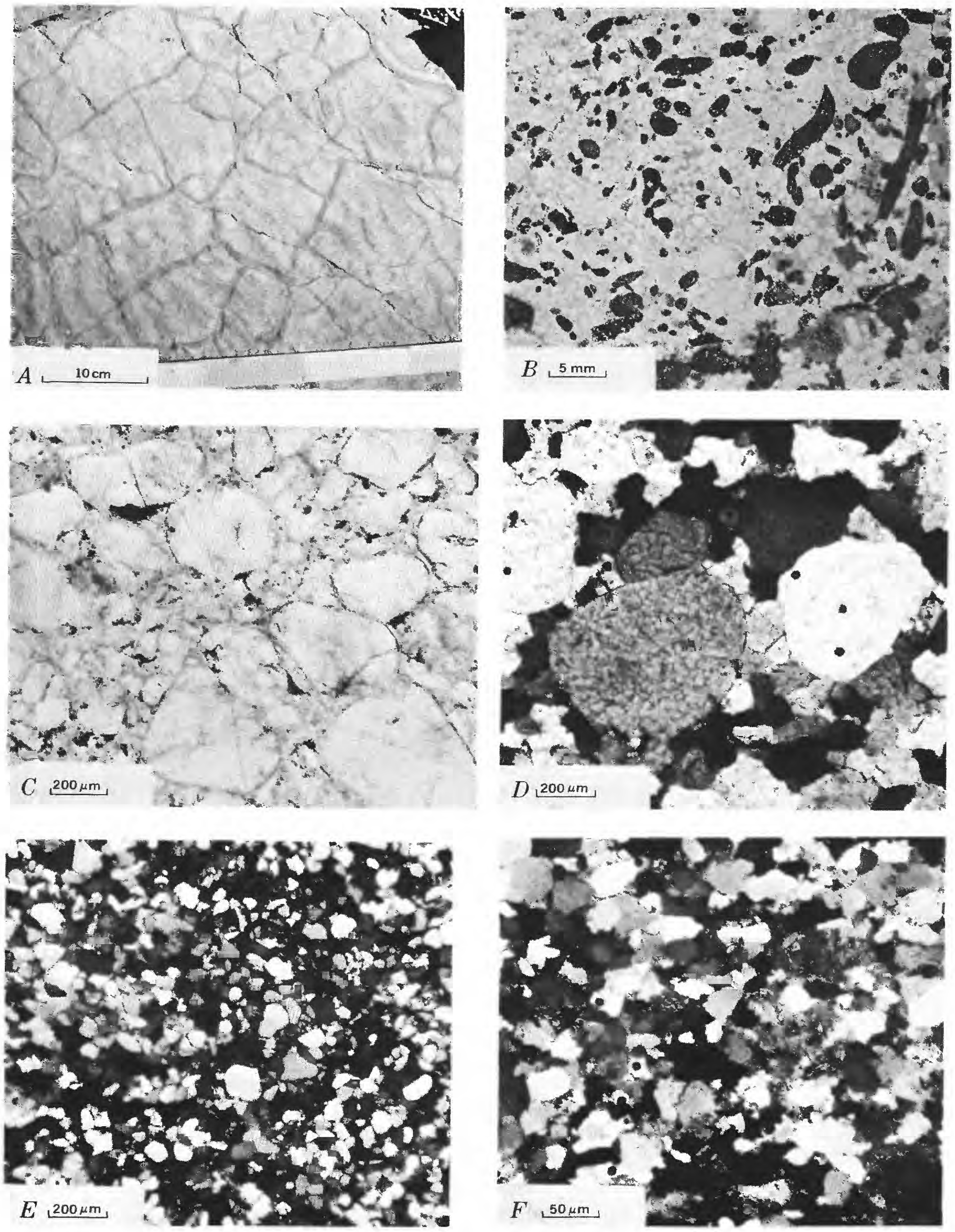

FIGURE 4.—Some lithologic features of the Emigrant Pass Member of the Zabriskie Quartzite. *A*, Outcrop of mudcracks in rippled upper surface of the Emigrant Pass Member, Desert Range section, Nevada. *B*, Photomicrograph of well-rounded, poorly sorted sandstone containing large dark chamosite grains (pellets?). Some of the chamosite grains contain a significant portion of quartz silt. Matrix is predominantly clay minerals. Bottom of Emigrant Pass Member, Resting Springs Range section, California. *C*, Photomicrograph of orthoquartzite (quartz arenite), poorly sorted; larger grains are well rounded; dark minerals and grain rims are iron oxide, which gives rock a pink coloration in outcrop. Bottom of Emigrant Pass Member, Echo Canyon section, California. *D*, Different view of same thin section as *C*, here with nicols crossed. *E*, Photomicrograph of very fine grained sandstone consisting almost entirely of monocrystalline quartz grains in a carbonate and clay matrix. Uppermost part of Emigrant Pass Member, Echo Canyon section, California. *F*, Photomicrograph of siltstone composed of predominantly quartz and dolomite with minor amounts of calcite and feldspar. Uppermost part of Emigrant Pass Member, Echo Canyon section, California.

Chance Range 21 km to the southeast. In particular, the upper beds of the Saline Valley Formation have their counterpart in the Emigrant Pass Member in the southern Last Chance Range.

The Emigrant Pass Member is here removed from the Carrara Formation to become the uppermost member of the Zabriskie Quartzite because the member is lithologically more like the underlying Zabriskie than the overlying Carrara. Also, the depositional environment of the member may resemble that of the Zabriskie Quartzite which is also at least in part intertidal in origin (Barnes and Klein, 1975). Finally, the contact between the Zabriskie Quartzite and the Carrara Formation is more consistent when set at the top of the last prominent quartzite bed below the thick shales or limestones of the Carrara Formation. This change precludes the necessity of having to assign transitional beds arbitrarily to either the Carrara Formation or the Zabriskie Quartzite when the lower shaly unit of the Emigrant Pass Member is either absent or not exposed.

MEMBERS OF THE CARRARA FORMATION

Figures 5 and 6 show the areal distribution and regional changes in thickness of each of the members of the Carrara Formation. Their individual lithological and faunal characteristics are discussed on the following pages.

EAGLE MOUNTAIN SHALE MEMBER

The Eagle Mountain Shale Member comprises the first major shale and siltstone accumulations above the massive quartzites of the Zabriskie and is here considered to be the basal member of the Carrara Formation. It is named for its thickest development at its type locality on the west side of Eagle Mountain, Inyo County, Calif. (fig. 5*A*).

The Eagle Mountain Shale Member is typically a green to gray-brown, slope-forming, silty shale. Locally, maroon color is related to obvious oxidation zones along fractures. Interbedded with the shale are thin beds (1–10 cm) of terrigenous or carbonate silt- and sand-size material. The quartz sand interbeds are usually lenses a few meters in length. One 8-cm-thick graded bed occurs at Echo Canyon and has coarse sand and granules at the base. Such terrigenous clastic interbeds are more common at the base of the member. In the upper half of the Eagle Mountain Shale Member carbonate interbeds predominate. These are again lensoidal and thin bedded and consist of echinoderm and trilobite fragment packstones with a muddy carbonate and terrigenous matrix. Occasional "floating" quartz sand occurs in these limestone interbeds. Typical lithologies of the Eagle Mountain Shale Member are illustrated in figure 7.

The upper contact of the Eagle Mountain Shale Member is placed at the base of the first limestone ledges greater than 0.5 m thick in the Carrara Formation and is readily recognized in most sections of the formation. The Eagle Mountain Shale Member is almost twice as thick at Eagle Mountain as at any other section. It is not recognized in the Nopah Range because the overlying Thimble Limestone Member is missing and the Eagle Mountain Shale Member cannot be separated from the Echo Shale Member. Farther to the east and north, beds that correlate with the Eagle Mountain Shale Member lie in the upper Tapeats Sandstone at Frenchman Mountain, the Latham Shale in the Marble Mountains, and the Pioche Shale at Pioche, Nev. (fig. 3).

Westward, in the southern Last Chance Range, the Eagle Mountain Shale Member is replaced by limestone assigned to the lower part of the generally overlying Thimble Limestone Member. The lowermost limestone unit here assigned to the Thimble Limestone Member lies directly upon the Zabriskie Quartzite. These limestones consist of stromatolitic bioherms that are well laminated only in their lower parts. The laminated parts of the bioherms are as much as 20 cm high and 30 cm wide, but the bioherms as a whole are 2 m wide and as much as 0.5 m high. Individual bioherms are separated by thin-bedded pelloidal calcarenite. Two other types of limestones occur higher in the part of the Thimble Limestone Member that is correlative with the Eagle Mountain Shale Member at this locality. These are an unusual pisolite bed and a thin-bedded fine-grained presumed pelletal calcarenite with ripple marks, microcross-laminations, and rare trilobite and oncolite grains. The latter limestone lithology is typical of the remainder of the Thimble Limestone Member here and throughout the region.

At Cucomungo Canyon in the northern Last Chance Range, the Carrara Formation was not recognized by Stewart (1971), and beds correlative with the Eagle Mountain Shale Member are included in the upper few meters of the Saline Valley Formation (fig. 3). Farther to the northwest, at Paymaster Canyon, this interval is not recognizable and the transition to the stratigraphy of the White-Inyo Mountain region is complete.

FAUNAL CHARACTERISTICS

This member is generally poorly fossiliferous. In the Titanothere Canyon and Echo Canyon sections, green micaceous siltstones in the basal few meters of the member have yielded two olenellid species, *Olenellus arcuatus* n. sp. and *O. cylindricus* n. sp., which characterize the *O. arcuatus* Zonule, and *O. nevadensis* (Walcott), which

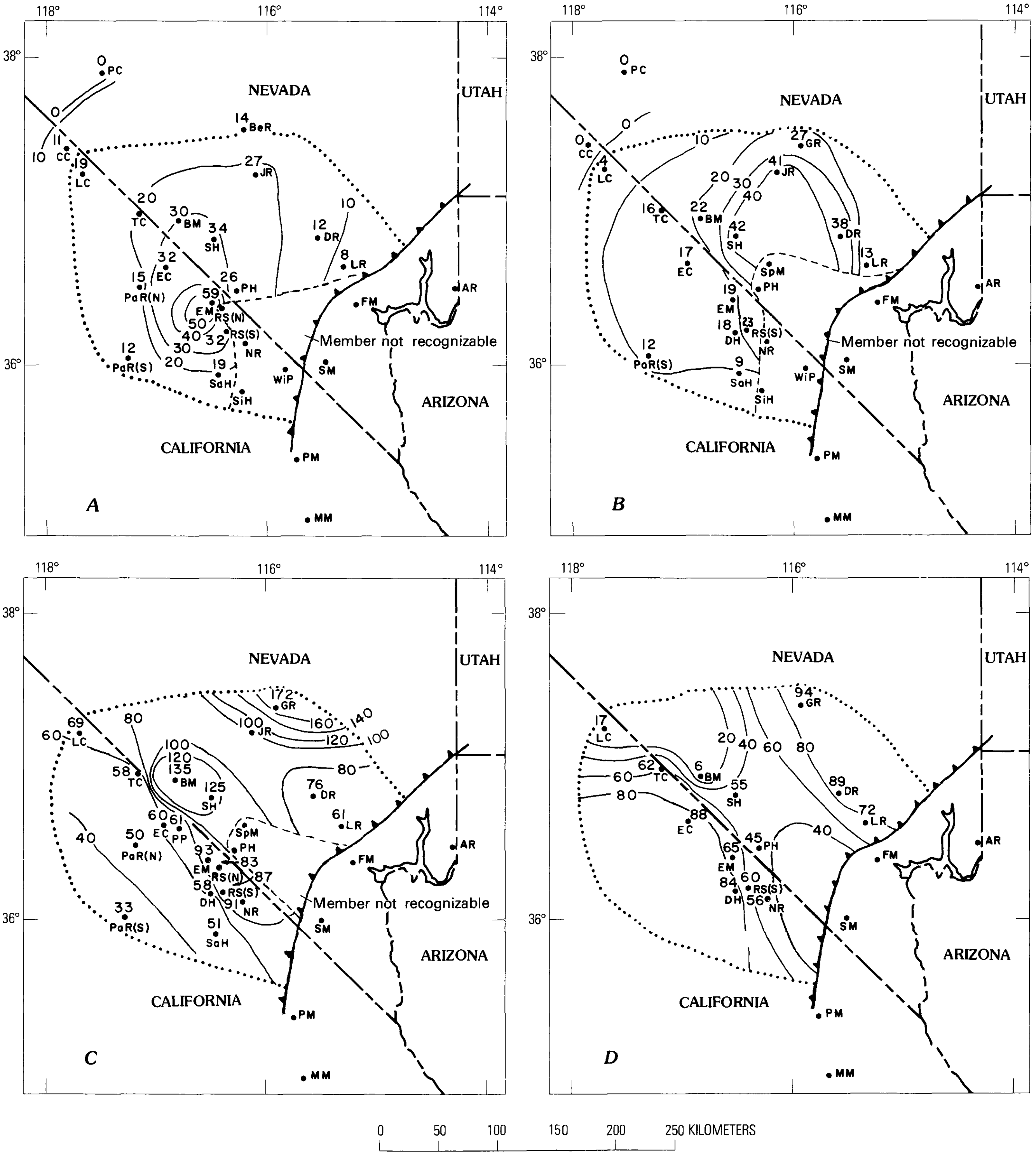

FIGURE 5.—Isopach maps of the shale members of the Carrara Formation. *A*, Eagle Mountain Shale Member; *B*, Echo Shale Member; *C*, Pyramid Shale Member; *D*, Pahrump Hills Shale Member. Contour interval, 10 m for *A*, 20 m for *B*, *C*, and *D*. **AR**, Azure Ridge; **BeR**, Belted Range; **BM**, Bare Mountain; **CC**, Cucomungo Canyon; **DH**, Dublin Hills; **DR**, Desert Range; **EC**, Echo Canyon; **EM**, Eagle Mountain; **FM**, Frenchman Mountain; **GR**, Groom Range; **In**, Inyo Mountains; **JR**, Jangle Ridge; **LC**, Last Chance Range; **LR**, Las Vegas Range; **MM**, Marble Mountains; **PaR (S)**, Southern Panamint Mountains; **PC**, Paymaster Canyon; **PH**, Pahrump Hills; **PM**, Providence Mountains; **PP**, Pyramid Peak; **RS (N)**, Northern Resting Springs Range; **RS (S)**, Southern Resting Springs Range; **SaH**, Salt Spring Hills, **SH**, Striped Hills; **SiH**, Silurian Hills; **SM**, Sheep Mountain; **SpM**, Spring Mountains; **TC**, Titanothere Canyon; **WiP**, Winters Pass. Compare area and section localities in figure 1. Dotted line encloses area of recognition of Carrara Formation; sawtooth line, eastern edge of Cretaceous overthrusting (teeth on overthrust block).

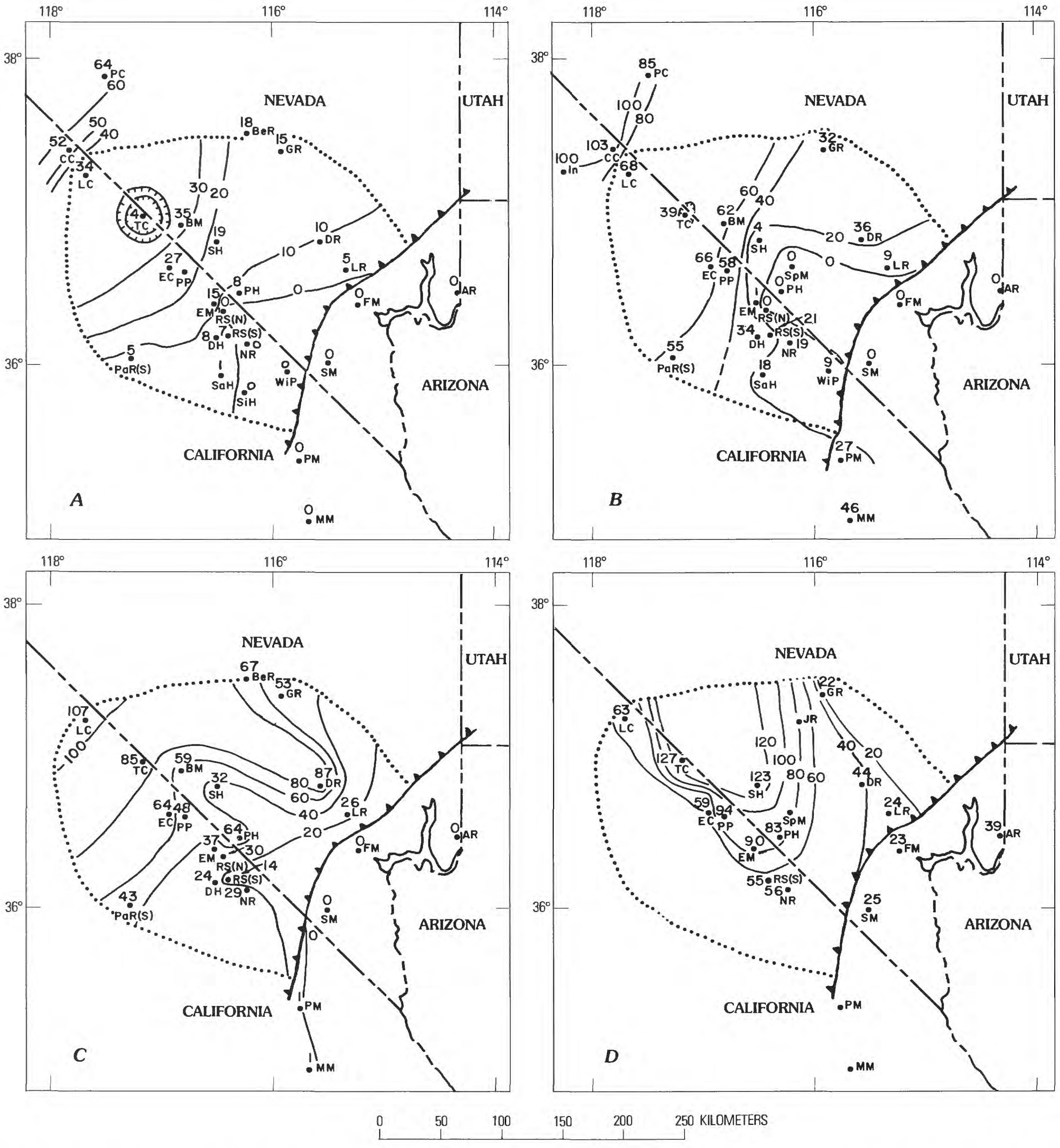

FIGURE 6.—Isopach maps of the limestone members of the Carrara Formation. *A*, Thimble Limestone Member; *B*, Gold Ace Limestone Member; *C*, Red Pass Limestone Member; *D*, Jangle Limestone Member. Contour interval, 10 m for *A*, 20 m for *B*, *C*, and *D*. Abnormal thinness of the Thimble and Gold Ace at Titanothere Canyon (TC) may indicate obscured faulting near the base of the section. AR, Azure Ridge; BeR, Belted Range; BM, Bare Mountain; CC, Cucomungo Canyon; DH, Dublin Hills, DR, Desert Range; EC, Echo Canyon; EM, Eagle Mountain; FM, Frenchman Mountain; GR, Groom Range; In, Inyo Mountains; JR, Jangle Ridge; LC, Last Chance Range; LR, Las Vegas Range; MM, Marble Mountains, PaR (S), Southern Panamint Mountains; PC, Paymaster Canyon; PH, Pahrump Hills; PM, Providence Mountains; PP, Pyramid Peak; RS (N), Northern Resting Springs Range; RS (S), Southern Resting Springs Range; SaH, Salt Spring Hills; SH, Striped Hills; SiH, Silurian Hills; SM, Sheep Mountain; SpM, Spring Mountains, TC, Titanothere Canyon; WiP, Winters Pass. Compare area and section localities in figure 1. Dotted line, area of recognition of Carrara Formation; sawtooth line, eastern edge of Cretaceous overthrusting (teeth on overthrust block).

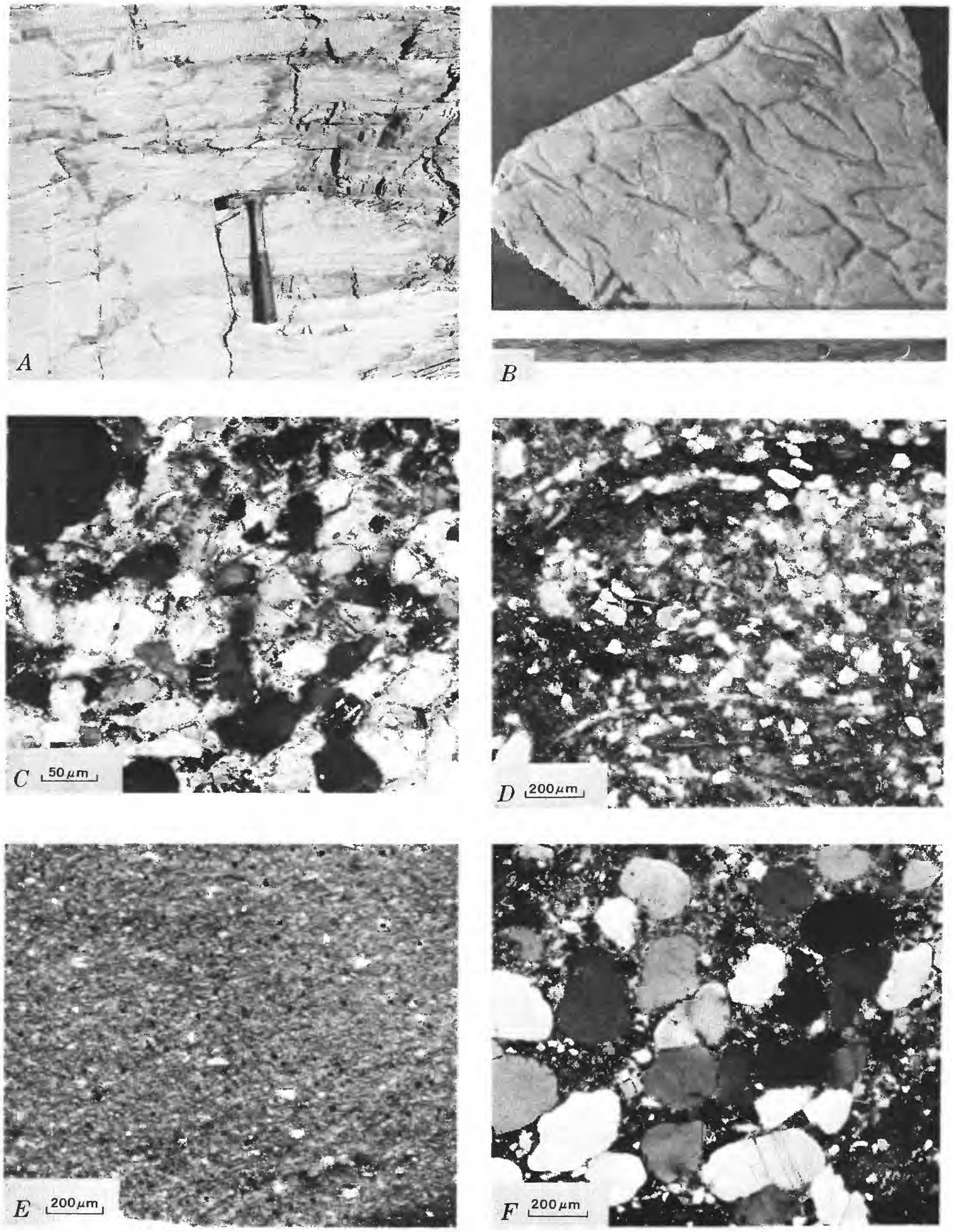

FIGURE 7.—Outcrops, vertical-cut surfaces, and thin sections showing some of the features of the Eagle Mountain Shale Member. *A*, Water-smoothed outcrop surface. The white lenses are fine sand or silt, the medium-gray matrix is argillite, and the dark band under the hammer handle is a carbonate-cemented siltstone. Middle part of the Eagle Mountain Shale Member, southern Last Chance Range section, California. *B*, vertical-cut surface showing incomplete mudcracks in siltstone. Base of the Eagle Mountain Shale Member, southern Last Chance Range section, California. *C*, Photomicrograph of carbonate-cemented siltstone composed of quartz, feldspar, and pyrite. Middle part of the Eagle Mountain Shale Member, Echo Canyon section, California. *D*, Photomicrograph of sandy shale containing very fine grains of quartz and chlorite and trilobite skeletal fragments. The elongate skeletal fragment near the base of the photomicrograph has been partly replaced by quartz and chlorite. Base of the Eagle Mountain Shale Member, Titanothere Canyon section, California. *E*, Photomicrograph of silty shale with quartz silt scattered throughout a clay mineral matrix. Eagle Mountain Shale Member, Daylight Pass section, California. *F*, Photomicrograph of quartz wacke, medium-sized quartz sand in a matrix of clay minerals and quartz silt, from a graded sandstone bed. Central part of the Eagle Mountain Shale Member, Echo Canyon section, California.

is also found in the *Bristolia* Zonule in the overlying Thimble Limestone Member. Locally, thin limestone interbeds in the upper part of the member yield representatives of the *Bristolia* Zonule, which characterizes the overlying Thimble Limestone Member.

THIMBLE LIMESTONE MEMBER

This member conformably overlies the Eagle Mountain Shale Member. It is overlain by the Echo Shale Member, and is recognized throughout the area indicated in Figure 6*A*. This unit is best exposed at its type locality on the west side of Titanothere Canyon (fig. 1), below Thimble Peak from which its name is derived, in the Grapevine Mountains, Calif.

The Thimble Limestone Member is characterized by black, brown, and orange thin-bedded argillaceous dolomitic limestone which varies in argillaceous content throughout the study area. The base of the member is placed at the base of the first limestone ledge in the Carrara Formation thicker than 0.5 m. Typically, limestones of the member are bedded on the scale of 1–10 cm. Each bed is a couplet consisting of a lower dark-gray limestone part and an upper orange argillaceous or dolomitic part. The lower part of each couplet contains trilobite debris, quartz silt, and argillaceous orange "rip-up" limestone or dolomite pebbles. In the Striped Hills and Resting Springs Range each couplet is a graded bed, the lower gray part consisting of a fine calcarenite that overlies an erosion surface and grades into the overlying orange argillaceous upper part. Small-scale current structures are common. In the eastern sections the limestones are relatively barren of fossil debris, but oncolite, hyolithoid, echinoderm, and trilobite fragments become more common northwestward. Oolite grainstones are interbedded in this unit in the southern Last Chance Range and at Titanothere Canyon, and in correlative beds within the Cucomungo Canyon and Paymaster Canyon sections; at Paymaster Canyon this interval also contains pelletoid fenestral limestones. At Echo Canyon in the Funeral Mountains the member contains a bed of low-relief stromatolites. These are subovate—in plain view, 20–30 cm long, 3–5 cm high—and are composed of a well-laminated continuous exterior and a discontinuous "digitate" interior.

The Thimble Limestone Member is an extremely widespread, relatively thin unit throughout most of the Carrara Formation. It is absent in the northern Resting Springs Range and sections to the southeast (fig. 6*A*) and reaches a thickness of more than 50 m in the north and west. At Paymaster Canyon and Cucomungo Canyon, the thickness of apparently correlative beds within the Mule Spring Limestone is estimated conservatively at more than 50 m. The eastward correlatives of the Thimble Limestone Member are clastic sediments which lie in the Tapeats Sandstone at Frenchman Mountain, the Pioche Shale of the Delamar and Highland Ranges, and the Latham Shale of the Marble Mountains.

FAUNAL CHARACTERISTICS

This member typically has abundant and diverse olenellid trilobites and rare associated ptychopariid trilobites which characterize the *Bristolia* Zonule. Locally, as many as nine distinct olenellid species have been recovered from a few meters of beds. The total known fauna includes: *Bristolia anteros* n. sp., *B. bristolensis* n. sp., *B. fragilis* n. sp., *Olenellus clarki* (Resser), *O. euryparia* n. sp., *O. fremonti*? (Walcott), *O. howelli*? Meek, *O. puertoblancoensis* (Lochman), *Peachella brevispina* n. sp., *P. iddingsi* (Walcott), and two undetermined species of ptychopariid trilobites.

ECHO SHALE MEMBER

This member is a green micaceous platy shale that separates the Thimble and Gold Ace Limestone Members of the Carrara Formation. It is named for exposures at the "Narrows" of Echo Canyon, its type locality (fig. 1), and is separately recognized only where both overlying and underlying limestone members are present. This unit is similar to the Eagle Mountain Shale Member, although somewhat more calcareous and at some localities consisting of interbedded shale and limestone. The more calcareous intervals are brown or orange. This member becomes more silty in the Desert Range and Jangle Ridge sections.

The geometry of the Echo Shale member resembles that of the earlier Eagle Mountain Shale Member in that it thins northwestward from the maximum thickness in the Striped Hills area (fig. 5*B*). To the northwest this shale thins to zero at Paymaster and Cucomungo Canyons and is represented by an argillaceous interval of the Mule Spring Limestone. The eastward equivalents of the Echo Shale Member lie in the Tapeats Sandstone at Frenchman Mountain, the Pioche Shale of the Delamar and Highland Ranges, and the Latham Shale of the Marble Mountains (fig. 3).

FAUNAL CHARACTERISTICS

This member is generally unfossiliferous. A single collection from the Titanothere Canyon section in the Grapevine Mountains yielded a few specimens identified as *Olenellus clarki* (Resser) and *Olenellus* sp. undet. 1.

GOLD ACE LIMESTONE MEMBER

This name is applied to the "conspicuous dark-gray cliff-forming algal limestone" (Cornwall and Kleinhampl, 1961) at the top of the second unit from the bottom of the Carrara Formation in the canyon 0.8 km northwest of Carrara Canyon, near the Gold Ace mine, Bare Mountain quadrangle, Nye County, Nev. (the type section of both the Carrara and the Gold Ace). It is primarily a burrowed oncolitic lime mudstone that becomes increasingly argillaceous toward the east and increasingly "clean" toward the west. The lower contact is somewhat gradational with the underlying Echo Shale Member through a series of argillaceous limestones. The contact with the overlying Pyramid Shale Member is very sharp.

The bulk of the Gold Ace Limestone Member is a microspar limestone, presumed to have been a lime mudstone or a pelleted lime mudstone when deposited. Although this unit forms massive cliffs where it is thick, it is composed of thin- to medium-bedded limestones defined by irregular slightly argillaceous dolomitic burrowed horizons. In contrast to the Thimble Limestone Member, most of the upper part of the Gold Ace Limestone Member does not separate along the boundaries of these thin beds (because they are not as argillaceous) and does not weather into flaggy or platy pieces. The monotony of the extremely homogeneous lime mudstone is interrupted by a variety of burrows, both open (calcite spar filled) and sediment filled, by recrystallized and unrecrystallized oncolites, and by sparse skeletal wackestone and mudstones. The burrow mottling and the frequency of skeletal fragments and oncolites increase northwestward, within the study area, and also southeastward, beyond the study area, in the Chambless Limestone of the Providence and Marble Mountains. Dolomite normally accounts for less than 15 percent of the Gold Ace Limestone Member. It is confined largely to some burrows, some oncolites, and some irregular coarsely crystalline patches of calcite.

At Paymaster Canyon, the upper 50 m of the Mule Spring Limestone, the westward correlative of the Gold Ace Limestone Member, is dolomite. Although dolomitization has obliterated many of the primary depositional features of this interval, oncolites, skeletal fragments, and some seidmentary structures, such as small crossbeds and fenestral fabrics, can be recognized. This partly dolomitized section is important because it and the section in the Goldfield Hills area are the only places where peritidal lithologies occur in beds correlative with the Gold Ace Limestone Member. A minor amount of oolite also occurs in the base of the interval at Paymaster Canyon that is correlative with the Gold Ace Limestone Member.

In eastern sections the Gold Ace Limestone Member thins and pinches out. Concomitant with this thinning is an increase in the terrigenous content of the limestone, a change in color from the usual dark gray or black to orange brown, and a change in weathering to a rubbly ledge-forming limestone.

The Gold Ace Limestone Member is absent in the Pahrump Hills and the Resting Springs Range in the eastern part of the outcrop area of the Carrara Formation and in the Belted Range to the north. It thickens northwestward across the study area (fig. 6*B*), and correlative parts of the Mule Spring Limestone in Paymaster Canyon, Cucomungo Canyon, and the Inyo Mountains are more than 80 m thick. In other areas, beds approximately correlative with the Gold Ace Limestone Member are the Combined Metals Member of the Pioche Formation in the Delamar and Highland Ranges, the Chambless Limestone of the Marble and Providence Mountains, and the uppermost beds of the Tapeats Sandstone at Frenchman Mountain. Fieldwork in 1975, however, proved that trilobites of the *Olenellus multinodus* Zonule occur in the upper beds of the Combined Metals Member of the Pioche Formation in the Delamar Range and that the top of this member is thus slightly younger than the top of the Gold Ace Limestone Member.

FAUNAL CHARACTERISTICS

Although this member is moderately fossiliferous, it rarely yields identifiable specimens. Fragments of trilobites can be seen on many weathered surfaces, but only two small collections, both from the Titanothere Canyon section of the Grapevine Mountains, were obtained. One included only *Olenellus puertoblancoensis* (Lochman) and *O. howelli*? (Meek), one of two species pairs recognized within the olenellid assemblages of the Carrara Formation. The other included only fragments of an undescribed olenellid with unusual granular surface ornamentation, *Olenellus* sp. undet. 1.

PYRAMID SHALE MEMBER

This member is named for exposures at its type locality, the west base of Pyramid Peak (fig. 1) in the Funeral Mountains, Calif. It overlies the Gold Ace Limestone Member and underlies the Red Pass Limestone Member. Where the Gold Ace Limestone Member is absent, the Pyramid Shale Member is inseparable from the Echo Shale Member.

The member is primarily a green shale interbedded with brown and maroon siltstone and shale with minor amounts of quartzite and limestone. It is generally more shaly toward the base and more silty toward the top. Throughout much of the study area the base of the member is a fossiliferous fissile green and brown micaceous shale (fig. 8*A*). The predominant fossils are disarticulated and rarely complete trilobites scattered on bedding surfaces. Some beds of bioclastic debris occur in this lower part. These are accumulations of transported or winnowed trilobite and echinoderm debris forming

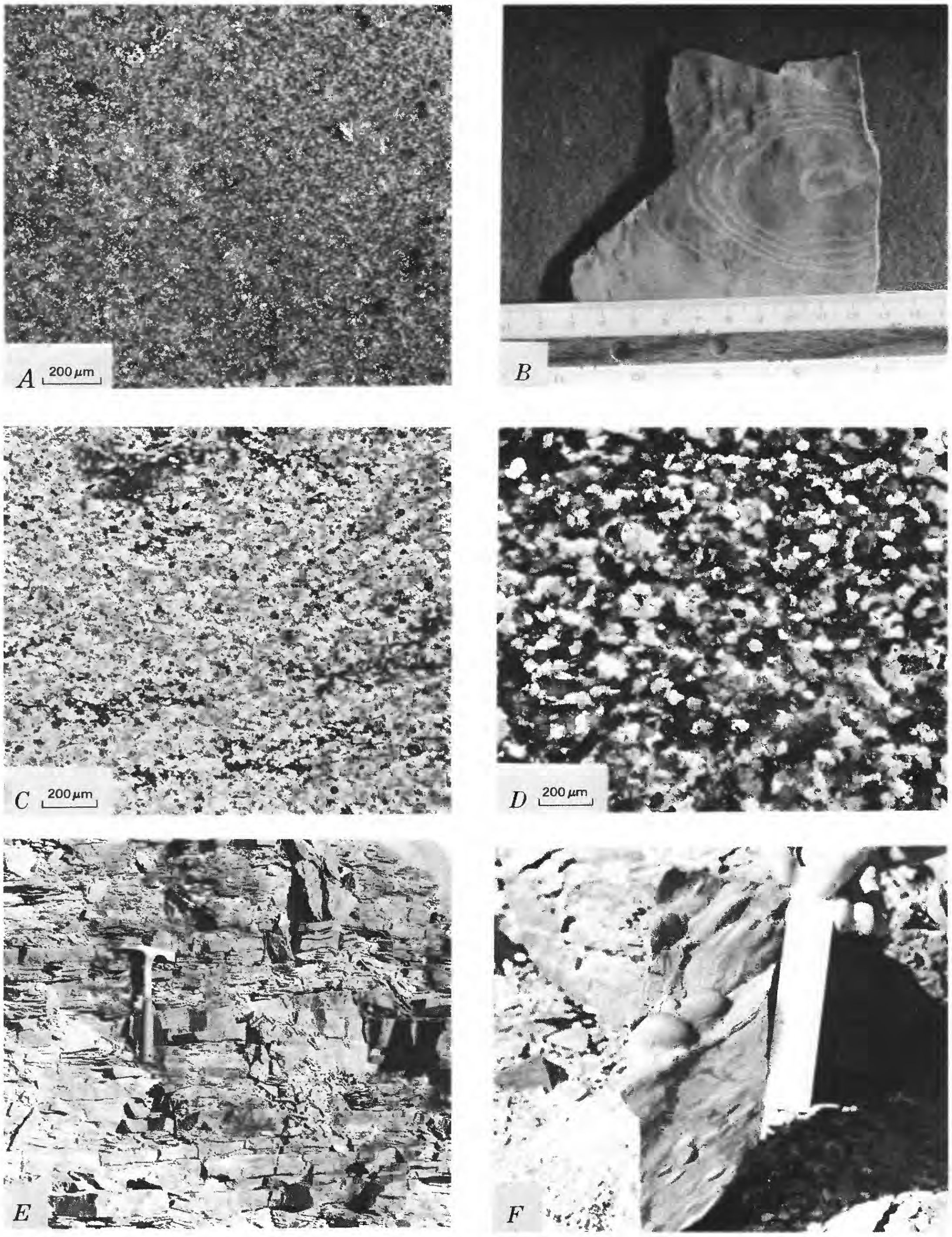

FIGURE 8.—Outcrops, float blocks, and thin sections showing some of the lithologic features of the Pyramid Shale Member or correlative beds. *A*, Photomicrograph of micaceous shale. Basal part of the Pyramid Shale Member, Titanothere Canyon section, California. *B*, Float block of well-indurated normally green shale (light gray) which has been oxidized in a pattern of red Liesegang-like rings (dark gray). Lower half of the Pyramid Shale Member, Titanothere Canyon section, California. *C*, Photomicrograph of micaceous siltstone with mica grains parallel to the horizontal and quartz silt set in a clay matrix. Middle part of the Pyramid Member, Striped Hills section, Nevada. *D*, Photomicrograph of siltstone composed of quartz and dolomite grains with minor feldspar from the Cadiz Formation, Providence Mountains, Calif. *E*, Outcrop of thin lensoidal siltstone beds interbedded with micaceous shale. One bed thins to the left beneath the hammer handle. Upper part of the Pyramid Shale Member, Pahrump Hills section, Nevada. *F*, Flute casts on the base of a siltstone float block. Upper part of the Pyramid Shale Member, Pahrump Hills section, Nevada.

lenses of argillaceous packstones or grainstones. Higher in the member, brown siltstones and maroon shales become more abundant. The maroon coloration appears to be secondary and forms Liesegang-like rings of red and green on some of the shales (fig. 8*B*). The siltstone beds are usually lensoidal (fig. 8*E*), but some occur as more continuous beds. Two such continuous beds, one in the southern Resting Springs Range and one in the southern Nopah Range, display structures believed to be downslope slump fold indicative of penecontemporaneous deformation. Two blocks of graded siltstone from this member showing flute casts (fig. 8*F*) were found as float at Pahrump Hills. The slump folds and flute casts are slight evidence for some depositional slope in this area during deposition of this member. Bioturbation increases in the silty upper part of the Pyramid Shale Member but does not become sufficient to homogenize the sediment. Some typical burrows from this member are illustrated in figures 9*B* and 9*C*.

Thickness variations in this member are shown in figure 5*C*. The member thickens northeastward, largely due to the development of an ochre mudstone at the top of the member at the Groom Range and the Belted Range. The upper silty part of the member becomes finer to the west and is absent in the southern Last Chance Range. The member thins toward the west and northwest as do the underlying Echo and Eagle Mountain Shale Members.

The westward correlative of this member is the shale interval at the base of the Monola and Emigrant Formations (fig. 3). At Paymaster Canyon a thin layer of coarse-grained carbonate-cemented quartz sand overlies the Mule Spring Limestone. It occurs nowhere else in the base of the Pyramid Shale Member or its correlatives. To the east, beds correlative with the Pyramid Shale Member probably include maroon and green sandstone and shale intervals within the lower part of the Bright Angel Shale described by Pack and Gayle (1971) from Frenchman Mountain, the C-shale member of the Pioche Shale in the Highland Range, and the lower part of the Cadiz Formation in the Providence and Marble Mountains.

FAUNAL CHARACTERISTICS

Throughout the area of outcrop of the Carrara Formation, the lower 10 m of this member, or correlative

FIGURE 9.—Tracks, trails, and burrows from the upper part of the Pyramid Shale Member, Titanothere Canyon section, California. *A*, Casts of *Cruziana*-like arthropod feeding or locomotion trails preserved on the underside of a siltstone block. *B*, Cast of hook-shaped horizontal burrow preserved on the underside of a siltstone lens. *C*, Casts of subhorizontal burrows preserved on the underside of a siltstone bed. ▶

beds in the east where the underlying Gold Ace Limestone Member is absent, contain the distinctive association of olenellids characteristic of the *Olenellus multinodus* Zonule. This fauna typically includes four species: *Olenellus clarki* (Resser), *O. fremonti* Walcott, *O. gilberti* (Meek), and *O. multinodus* n. sp. Rare ptychopariid trilobites and *Olenellus brachyomma* n. sp. have also been found in the lower part of this member. *Olenellus multinodus* n. sp. has been found at Frenchman Mountain in the basal part of the Bright Angel Shale in association with the unusual olenellid *Biceratops nevadensis* Pack and Gayle (1971).

The remainder of this member is generally unfossiliferous. However, in the western sections, in the Groom and Belted Ranges, a thin limestone unit in the middle of the member has yielded the earliest Middle Cambrian trilobites found within the Carrara Formation. These constitute the *Poliella lomataspis* Zonule and include *Poliella lomataspis* n. sp. and undetermined kochaspid trilobites. Shales immediately overlying this limestone in the Belted Range yielded *Syspacephalus longus* n. sp., *Oryctocephalus nyensis* n. sp., and *Pagetia* sp. Aside from those occurrences only a single specimen questionably identified as *Mexicella? stator* (Walcott) was found on a float piece from the middle part of this member in the Titanothere Canyon section in the Grapevine Mountains.

RED PASS LIMESTONE MEMBER

This member overlies the Pyramid Shale Member conformably and is the only limestone member of the Carrara Formation that has no limestone correlatives in surrounding areas. The member was named by Reynolds (1971) for Red Pass, about 1 km east of the Titanothere Canyon section (fig. 1), the type locality for the member, in the Grapevine Mountains, Calif.

The Red Pass Limestone Member generally forms a prominent cliff and consists of burrowed, oncolitic, and skeletal-fragment lime mudstones, oolite, and a variety of laminated lime mudstones and fenestral limestones. The oncolitic or skeletal-fragment lime mudstones are identical to those in the Gold Ace Limestone Member, but much less abundant. Oolite, however, is much more abundant in this member and comprises the bulk of the member in eastern sections. The laminated lime mudstone and fenestral limestones form a relatively thin cap of very light gray or white limestone at the top of this member in western sections. In more easterly sections the lime mudstones and oolites of the Red Pass Limestone Member are interbedded with green and brown calcareous shales, and the member forms a less prominent feature.

The base of the Red Pass Limestone Member is placed at the first limestone bed 0.5 m thick or thicker above the Pyramid Shale Member. This somewhat arbitrary contact generally defines the base of the limestone body although some shale beds may lie above it. The upper contact is placed at the abrupt limestone-shale or limestone-siltstone contact with the overlying Pahrump Hills Shale Member in many centrally located sections, such as Pyramid Peak, Titanothere Canyon, Echo Canyon, and the Desert Range. In western sections, such as the southern Last Chance Range, the upper boundary is put at the contact between the clean cliff-forming limestones of the Red Pass Limestone Member and overlying argillaceous recessive-weathering limestones of the Pahrump Hills Shale Member.

The thickness of the Red Pass Limestone Member shows a general increase toward the northwest (fig. 6*C*) comparable to the limestone members lower in the section. The member is present in every section of the Carrara Formation, but it is absent to the east at Sheep Mountain, Frenchman Mountain, and Azure Ridge, and it is not clearly developed to the northeast in the Delamar and Highland Ranges. Southward, a single 1-m-thick oolite bed in the middle of the Cadiz Formation of the Providence and Marble Mountains may be the last remnant of the Red Pass Limestone Member in this area. The westward correlatives of the Red Pass Limestone Member lie in the Emigrant and Monola Formations of Esmeralda County, Nev., and Inyo County, Calif., respectively (fig. 3).

FAUNAL CHARACTERISTICS

The Red Pass Limestone Member is poorly fossiliferous at most localities. However, both its upper and lower beds have yielded trilobites. The lower beds are dominated by trilobites of the Kochaspid Zonule of the "*Plagiura-Poliella*" Zone. These include: *Fieldaspis?* sp., *Kochaspis augusta* (Walcott), *K. liliana* (Walcott), *Kochiellina groomensis* n. gen., n. sp., *K. janglensis* n. gen., n. sp., *Plagiura extensa* n. sp., *P. retracta* n. sp., *P.* cf. *P. cercops* (Walcott), *Schistometopus* sp., and two undetermined ptychopariid trilobites.

The upper few meters of the member are locally rich in trilobites of the Zacanthoidid Zonule of the *Albertella* Zone (p. 59) in the Groom Range and the Nevada Test Site. Three collections yielded a total of 21 species of trilobites as well as several species of molluscs. Although the fauna from these beds is remarkably similar to that of the Naomi Peak Tongue of the Twin Knobs Formation in northern Utah and southeastern Idaho, the units are not correlative (Palmer and Campbell, 1975). Rather, this zonule is the local expression of a distinctive trilobite biofacies that characterizes the ocean-facing margin of the carbonate shelf throughout the time represented by the *Albertella* Zone (fig. 36). The trilobites from these beds are: *Albertelloides mischi* Fritz, *Kootenia germana* Resser, *Nyella granosa* (Resser), *N. clinolimbata* (Fritz), *N. immoderata* n. sp., *Oryctocephalina? maladensis* (Resser), *Oryctocephalites typicalis* Resser, *Pachyaspis gallagari* Fritz, *Pagetia resseri* Kobayashi, *Paralbertella bosworthi* (Walcott), *Peronopsis lautus* (Resser), *Poliella germana* (Resser), *Ptarmiganoides crassaxis* n. sp., *P. hexacantha* n. sp., *Zacanthoides* cf. *Z. alatus* (Resser), *Z. variacantha* n. sp., and five indeterminate ptychopariid species.

The boundary between the "*Plagiura-Poliella*" and *Albertella* Zones falls somewhere within the Red Pass Limestone member.

PAHRUMP HILLS SHALE MEMBER

This member is named for exposures above the Red Pass Limestone Member and below the Jangle Limestone Member at its type locality in the Pahrump Hills (fig. 1), northwest of Pahrump, Nye County, Nev. This is the uppermost predominantly terrigenous clastic member beneath hundreds of meters of Middle and Upper Cambrian limestones and dolomites. The Pahrump Hills Shale Member consists of tan siltstones, red and green mudstones, and shales, with minor amounts of argillaceous limestone and fine-grained sandstone. Its lower contact with the Red Pass Limestone Member is usually sharp and easily defined. Its upper contact with the Jangle Limestone Member is more gradational and is placed at the base of the first dark oolite or lime mudstone thicker than 2 m.

The most common lithology in the lower half of the Pahrump Hills Shale Member is an orange-brown carbonate-cemented siltstone (fig. 10*A*). This thin-bedded siltstone is usually laminated with thin fine sand laminations along which the bed may part causing the rock to appear as a sandstone on bedding surfaces. Load casts are common along the undersides of these siltstone beds. At several western localities where this lithology overlies the cap of fenestral limestones in the Red Pass Limestone Member, the siltstone is mudcracked and contains rare salt-crystal casts, tracks, and trails (figs. 10*B*-*F*). Southeastward in the southern Resting Springs and Nopah Ranges, the basal lithology of the Pahrump Hills Shale Member is a brown silty calcareous shale containing echinoderm fragments. In the Groom Range the lowest bed of the Pahrump Hills Shale Member is a black papery fossiliferous shale. An identical black shale occurs above the Red Pass Limestone Member in the Belted Range, although the Pahrump Hills Shale Member is not recognized there because the remainder of the member is replaced by thin-bedded limestones of the Emigrant(?) Formation.

The upper half of the member consists of a heterogeneous sequence of red, brown, and green mudstones and shales, chloritic and cryptalgal limestones, thin chloritic oolites, and pelloidal limestones. The red mudstones, in particular, form a series of distinctive beds that thicken southeastward from Echo Canyon.

The Pahrump Hills Shale Member forms a saddle-shaped three-dimensional unit (fig. 5*D*) which thickens both to the northeast and the southwest. The member thins to the northwest and somewhat less to the southeast, as do the underlying shale members.

A general lithologic change occurs northwestward in the Pahrump Hills Shale Member toward increasing amounts of limestone. At Bare Mountain and in the southern Last Chance Range the Pahrump Hills Shale Member is largely replaced by limestone. This change reflects the intertonguing transition westward of the Pahrump Hills Shale Member with limestones that are assigned to the Jangle Limestone Member.

Farther west, beds correlative with the Pahrump Hills Shale Member are included with the Emigrant and Monola Formations. To the east the correlative clastics are believed to be beds of red and maroon sandstones, siltstones, and shales in the Bright Angel Shale below the Lyndon Limestone at Frenchman Mountain and Sheep Mountain, at least part of the A-shale member of the Pioche Shale in the Highland Range, and the upper red siltstones, sandstones, and shales of the Cadiz Formation in the Marble Mountains (fig. 3).

FAUNAL CHARACTERISTICS

The Pahrump Hills Shale Member is poorly fossiliferous, but collections from different areas contain elements of both the Zacanthoidid and *Albertella-Mexicella* Zonules of the *Albertella* Zone. The trilobites identified from western sections of this member in the Groom and Grapevine Ranges and the Nevada Test Site include: *Albertelloides rectimarginatus* n. sp., *Caborcella pseudaulax* n. sp., *C. reducta* n. sp., *Chancia* cf. *C. venusta* (Resser), *Kootenia germana* Resser, *Pachyaspis gallagari* Fritz, *Pagetia resseri* Kobayashi, *Syspacephalus obscurus* n. sp., *Volocephalina connexa* n. gen., n. sp., *Zacanthoides*? sp., and one indeterminate species each of a ptychopariid and a corynexochid trilobite. These have their strongest affinities with the faunas of the Zacanthoidid Zonule.

Collections from sections in the Desert and Spectre Ranges in the central part of the study area include: *Albertella longwelli* n. sp., *A. spectrensis* n. sp., *Albertellina aspinosa* n. gen., n. sp., *Mexicella grandoculus* n. sp., *M. mexicana* Lochman, *Nyella granosa* (Resser), *Plagiura minor* n. sp., and *Volocephalina connexa* n. gen., n. sp. These collections have their greatest affinities with the faunas of the *Albertella-Mexicella* Zonule.

In the Belted Range, thin-bedded limestones correlative with the lower beds of the Pahrump Hills Shale Member yield a rich assemblage of trilobites of the *Ogygopsis* Zonule of the *Albertella* Zone. The fauna includes: *Chancia? maladensis* (Resser), *Elrathina antiqua* n.

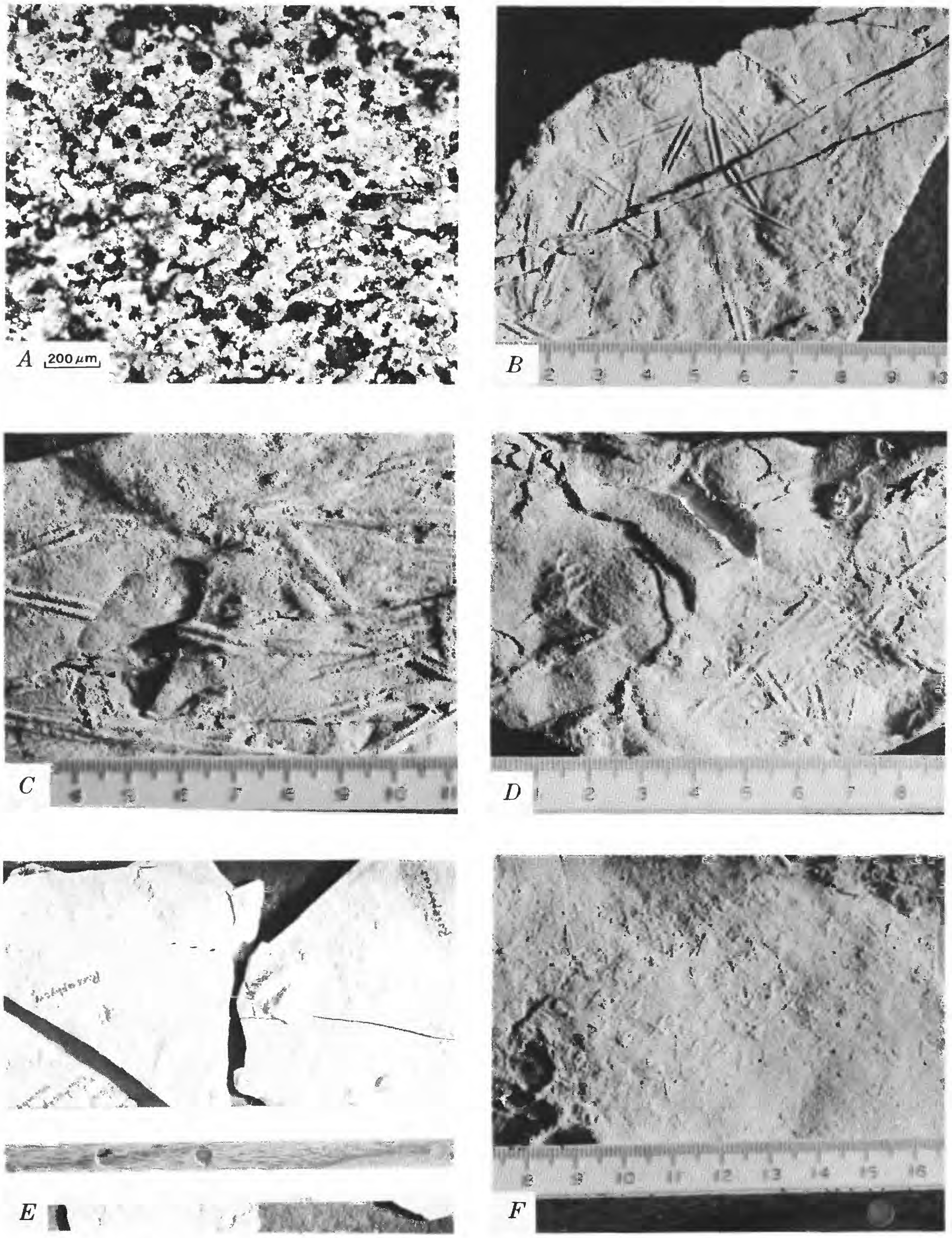

FIGURE 10.—Typical lithologies of the basal part of the Pahrump Hills Shale Member. *A*, Photomicrograph of carbonate-cemented micaceous siltstone containing iron oxide cement and grains (black). Both dolomite and calcite are present. Note the spherical grains surrounded by iron oxide in the upper central area of the photomicrograph. Pyramid Peak section, Funeral Mountains, Calif. *B*, *C*, *D*, Straight, superimposed, and bigrooved trails preserved on the undersides of siltstone beds. Such trails are characteristic of the base of the Pahrump Hills Shale Member. Pyramid Peak section, Funeral Mountains, Calif. *E*, *Rusophycus*-like arthropod resting traces preserved on undersides of siltstone beds. Titanothere Canyon section, Grapevine Mountains, Calif. *F*, Halite crystal casts in siltstones. Pyramid Peak section, Funeral Mountains, Calif.

sp., *Ogygopsis typicalis* (Resser), *Pagetia maladensis* Resser, *P. rugosa* Rasetti, *Peronopsis lautus* (Resser), *P.* sp., *Thoracocare idahoensis* (Resser), and an undetermined oryctocephalid trilobite.

JANGLE LIMESTONE MEMBER

This member, which conformably overlies the Pahrump Hills Shale Member, was named by Johnson and Hibbard (1957. p. 339) from Jangle Ridge (fig. 1), in the Halfpint Range, Nev. It is the third and uppermost cliff-forming limestone in the Carrara Formation. Throughout the central part of the study area, the Jangle Limestone Member consists of from one to as many as five limestone units separated by argillaceous recessive-weathering limestone or calcareous shales. The lower boundary of the Jangle Limestone Member is fairly well defined by the first burrowed lime mudstones or oolites more than 2 m thick above the clastics of the Pahrump Hills Shale Member. The upper boundary is less consistent and is generally drawn between clean massive limestones of the upper part of the Jangle Limestone Member and argillaceous thin-bedded limestones of the overlying Desert Range Limestone Member. This upper contact is difficult to draw on a lithologic basis in western sections, such as Bare Mountain and the southern Last Chance Range, because the argillaceous content of the limestones of the Desert Range Limestone Member is reduced. The contact is arbitrarily drawn at the topographic break at the top of the cliff-forming Jangle Limestone Member.

The lithologies of the Jangle Limestone Member include lime mudstones, trilobite- and echinoderm-fragment wackestones, packstones, and grainstones, oolite, fenestral-fabric and laminated limestones. The stratigraphic distribution of lithologies within the Jangle Limestone Member is more varied than in the Red Pass or Gold Ace Limestone Members. The laminated and fenestral-fabric limestones in particular appear to occur in a greater variety of settings in the Jangle Limestone Member than in the underlying limestone members. Although these lithologies still are restricted to the western parts of the member, they occur at several levels throughout the member in different sections. In the Desert Range these lithologies are restricted to the upper half of the Jangle Limestone Member, and at Echo Canyon the Jangle Limestone Member consists of two prominent cliffs, each having fenestral-fabric and laminated limestone in its upper part. Also, the east-west continuity of these lithologies seems to be less in the Jangle Limestone Member than in the Red Pass Limestone Member. Lateral transitions in the Jangle Limestone Member from light-gray or white laminated limestone to black burrowed mudstones are evident in the sections at Echo Canyon, Pyramid Peak, and Eagle Mountain.

Isopachs for the Jangle Limestone Member (fig. 6*D*) show the member thickening to the northwest and thinning to the southeast and southwest. The thickening is accompanied by a decrease in the argillaceous interbeds; the several limestone ledges that make up the Jangle Limestone Member in the southern Resting Springs Range coalesce northwestward to form a single cliff-forming limestone in the Groom Range, at Bare Mountain, and in the southern Last Chance Range.

To the west, the Jangle Limestone Member correlates with undifferentiated intervals in the Emigrant and Monola Formations. Eastward and southeastward the Jangle Limestone Member correlates with the Lyndon Limestone and with oolitic limestones in the upper part of the Cadiz Formation (fig. 3).

FAUNAL CHARACTERISTICS

The lower part of the Jangle Limestone Member in the southeastern part of the outcrop area of the Carrara Formation has yielded several small low-diversity collections of trilobites that are typical of the *Albertella-Mexicella* Zonule of the *Albertella* Zone. The total fauna includes: *Albertella longwelli* n. sp., *A. spectrensis* n. sp., *Albertelloides* sp., *Mexicaspis radiatus* n. sp., *Plagiura minor* n. sp., and *Volocephalina contracta* n. gen., n. sp.

A slightly more diverse single collection from the middle of the Jangle Limestone Member in the Grapevine Mountains contains a fauna with affinities to both the Zacanthoidid and *Albertella-Mexicella* Zonules of the *Albertella* Zone. It includes: *Mexicella grandoculus* n. sp., *Mexicaspis radiatus* n. sp., *Nyella clinolimbata*? (Fritz), *Ptarmiganoides hexacantha* n. sp., and *Volocephalina connexa* n. sp.

Inasmuch as the faunas of the overlying Desert Range Limestone Member contain abundant representatives of *Glossopleura* in many sections, the boundary between the *Albertella* and *Glossopleura* zones falls at or near the top of the Jangle Limestone Member.

DESERT RANGE LIMESTONE MEMBER

This member, the uppermost member of the Carrara Formation, forms a recessive interval between the Jangle Limestone Member and the Bonanza King Formation. It is named for exposures at its type locality, the Desert Range, about 64 km northwest of Las Vegas, Nev. (fig. 1). The Desert Range Limestone Member is typically a thin-bedded black argillaceous limestone with orange dolomitic partings. Occasional trilobite packstones and wackestone characterize this member. In the Striped Hills and Nopah Range thin green or brown shale intervals are present but account for only a few meters of the thickness of the member.

The thickness of the Desert Range Limestone Member varies considerably and inconsistently throughout the Carrara study area. It is often involved in faulting between the Bonanza King and the Carrara Formations, which precludes or distorts thickness measurements. Also, even where unfaulted, the Desert Range Limestone Member is gradational into the overlying Bonanza King Formation, and the contact is arbitrarily placed at a point where generally more argillaceous limestones of the Carrara Formation become indistinguishable from those of the Bonanza King Formation. For these reasons, no isopach map of this interval has been plotted. The base of the Desert Range Limestone Member is easily recognized and is placed at the top of the cliff-forming Jangle Limestone Member. Usually this point corresponds to an abrupt break in slope and a color change from white or light gray to dark gray or brown.

The westward correlatives of the Desert Range Limestone Member in Esmeralda County lie within the Emigrant Formation. In the Inyo Mountains it is not known if the correlative rocks lie in the upper part of the Monola Formation or in the lower part of the Bonanza King Formation. To the southeast, correlatives probably lie within the upper part of the Cadiz Formation of Hazzard and Mason (1936). To the east and north the correlative unit is the Chisholm Shale (fig. 3).

FAUNAL CHARACTERISTICS

This member includes thin beds rich in the disarticulated remains of species of *Glossopleura* at many localities. Additional trilobites are rare and the faunal diversity is characteristically low. Decent specimens are difficult to obtain from rocks of this member without heating and rapid chilling to loosen the matrix.

The faunas of this member are characteristic for only the lower part of the *Glossopleura* Zone. The time span for the entire zone includes both the Desert Range Limestone Member and at least 150 m of limestones in the lower part of the overlying Bonanza King Formation. The trilobite fauna from the Desert Range Limestone Member includes: *Glossopleura walcotti* Poulsen, *G. lodensis* (Clark), *Alokistocarella*? cf. *A. brighamensis* (Resser), and at least four other specifically indeterminate ptychopariid trilobites.

REGIONAL LITHOSTRATIGRAPHIC RELATIONS

Wheeler and Mallory (1956) addressed the problem of lateral and vertical distributions of rock bodies that transcend formation and facies boundaries. Their solution was to create the term, "lithosome," to denote rock masses essentially uniform in lithologic character that have intertonguing relationships with adjacent masses of differing lithology. In a regional sense, the members of the Carrara Formation are tongues of lithosomes (fig. 11).

One limestone lithosome is formed by the Mule Spring Limestone with tongues extending eastward to form the Thimble and Gold Ace Limestone Members. A younger limestone lithosome is recognized in the southern Last Chance Range where the Pahrump Hills Shale Member is largely replaced by argillaceous limestone joining the Red Pass and Jangle Limestone Members. To the east and intertonguing with the limestone lithosomes lies a terrigenous clastic lithosome, which represents deposits of the Inner Detrital Belt of Palmer (1960); this is composed of the Eagle Mountain, Pahrump Hills, and Echo Shale Members of the Carrara Formation, the Latham Shale, the Cadiz Formation, the Bright Angel Shale, the Pioche Shale, and the Chisholm Shale. A model explaining these relationships is suggested on p. 51.

LITHOFACIES DESCRIPTION AND INTERPRETATION

During the past 20 years, descriptions of a number of Holocene carbonate sedimentary environments have provided a framework for interpreting ancient carbonate rocks. The classic areas of carbonate study have become the Florida and Bahama Platforms, the south coast of the Persian Gulf, Shark Bay in Western Australia, the Campeche Bank of Mexico, and the Great Barrier Reef of Australia. Several of these areas have aspects in common with the patterns of carbonate sedimentation within the Carrara Formation.

Three types of limestones displaying primary depositional textures dominate the carbonates of the Carrara Formation and characterize distinctive lithofacies. These are (following the classification of Dunham, 1962) (1) the lime-mudstone lithofacies—burrowed and current-laminated pelletal lime mudstone, oncolite and skeletal-fragment lime mudstones, and oncolite and skeletal-fragment wackestones, packstones, and minor grainstones; (2) the oolite grainstone facies—oolite grainstone, skeletal-fragment and oncolite grainstones and packstones, intraclast grainstones, and minor amounts of cryptalgal limestone; and (3) the algal boundstone facies—a variety of cryptalgalaminites, fenestral-fabric limestones, intraclast grainstones, stromatolites, and pelletal mudstones. Subdivision of the algal boundstones follows the classification of Aitken (1967) for cryptalgal carbonates. Limestones displaying fenestral fabrics (Tebutt and others, 1965) are lime mudstones or pelletal lime mudstones containing unsupported spar-filled voids and are equivalent to dismicrites of Folk (1959) and the bird's-eye limestone of Shinn (1968). Al-

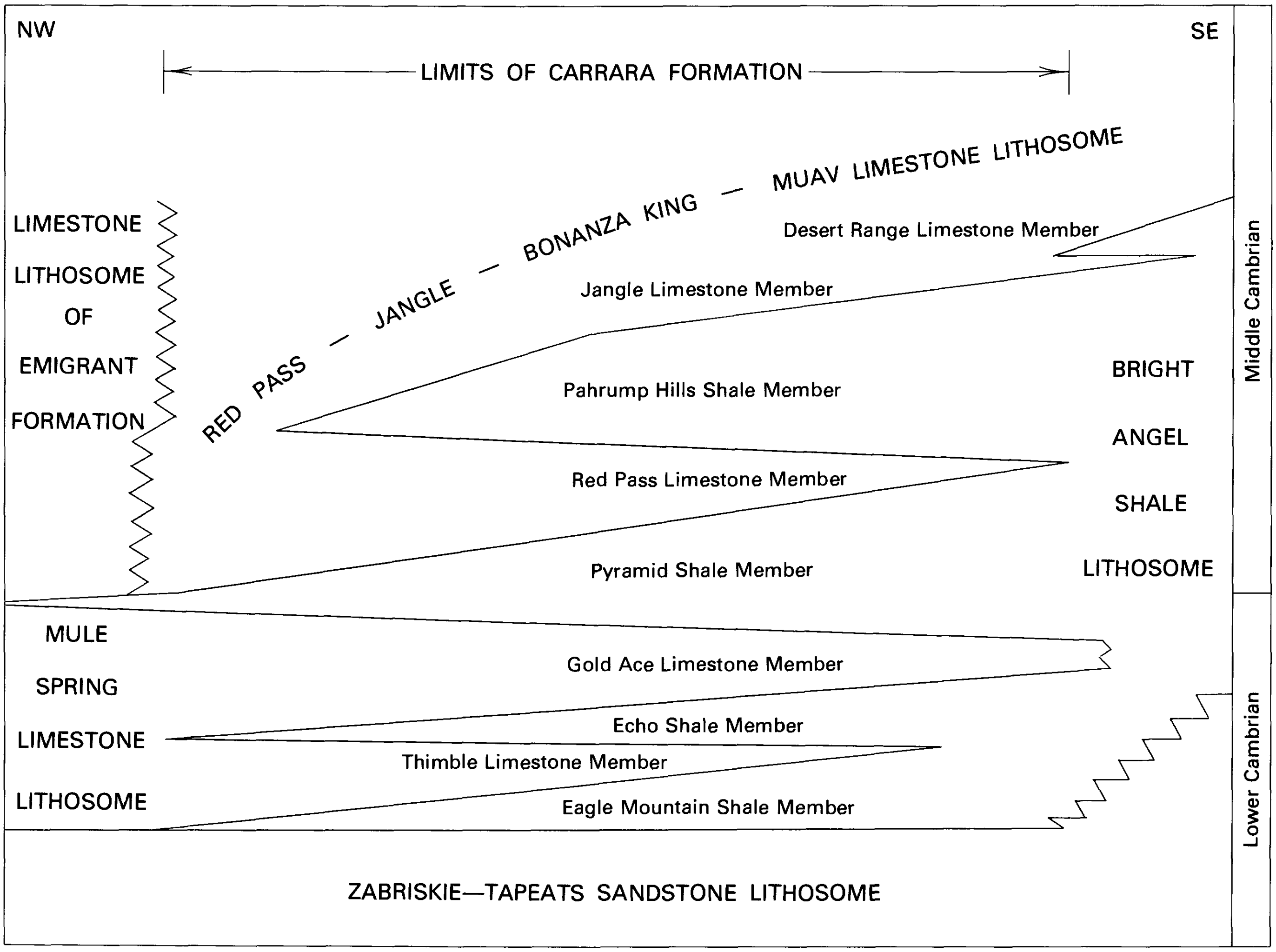

FIGURE 11.—Generalized cross section along Nevada-California border from central Esmeralda County, Nev., to eastern Clark County, Nev., showing lithosomal relationships of the members of the Carrara Formation. Horizontal distance about 300 km. No vertical scale. Thicknesses in the middle of the figure are proportional to member thicknesses in the Echo Canyon section, California.

though a great variety of fenestral fabrics exists in the Carrara limestones, no attempt has been made to differentiate them in the present study. The areal and stratigraphic distribution of the rocks of each lithofacies in each of the limestone members are shown in figures 31–33.

Diagenetic changes, rather than metamorphic alterations, account for the majority of postdepositional changes of the carbonate rocks of the Carrara Formation. Locally, metasomatic lead and zinc ores and marbles and hornfels occur along faults and near intrusives, but they bear no information concerning the depositional history of the formation. Some diagenetic effects, on the other hand, do bear directly on the depositional history of the Carrara Formation, and their presence and absence will be discussed in some detail.

In general, diagenetic fabrics can be recognized and differentiated from primary depositional features. However, the timing and mechanism of formation of many of these diagenetic features is beyond the scope of this work and only the more obvious will be considered here.

THE LIME-MUDSTONE LITHOFACIES

The lime-mudstone lithofacies of the Carrara Formation is composed predominantly of low-magnesium calcite. Other minerals which occur in the lime mudstone include quartz, dolomite, chlorite, micas and clay minerals, albite, microcline, pyrite, hematite, chert, and apatite, approximately in order of decreasing abundance.

The basic building blocks of the lime mudstones are equant grains of calcite, 2–30 micrometers (μm) in diameter. This size range spans the "micrite curtain," a gap in the size distributions of small calcite grains described by Folk (1965, p. 32) to occur between 3 and 4 μm. The gap separates micrite (1–3.5 μm) from microspar (3.5–30 μm) in the study of recrystallization in ancient limestones by Folk (1965). The existence of this gap in grain size distribution within lime mudstones of the Carrara Formation is problematical. In some samples the complete range of sizes from 2–30 μm is evident, whereas in others the grain size may be either micrite or microspar. Where micrite and microspar occur together, both porphyrotopic and poikilotopic fabrics are developed (fabric terminology after Friedman, 1965).

Folk (1965, p. 32) noted that limestones containing microspar or micrite-microspar associations are characteristically interbedded with shales. The microspar-bearing lime mudstones of the Carrara Formation, although not interbedded with shales, usually have a significant insoluble residue content composed predominantly of quartz-silt, mica, and clay minerals (fig. 12*E*). Even in the relatively clean parts of limestone members this residue rarely falls below 5 percent. Thus, perhaps the terrigenous content of a limestone is the significant factor to be correlated with the appearance of abundant microspar.

Many of the limestones of the lime-mudstone facies are pelletal in thin section. The preservation and recognition of pelleted textures seems fortuitous, because pelletal limestones often grade into micrites or microspar limestones in which little pelletal texture is recognizable (fig. 12*F*). Small pockets of pelmicrites and pelsparites are scattered throughout the lime-mudstone facies (fig. 13*A*). Pelleted lime mudstones may contain as much as 30 percent quartz silt and clay without losing their primary depositional texture (fig. 13*B*), while in relatively clean limestones, pellets may be only barely recognizable. The preservation of pelleted texture is probably a function of early diagenesis (cementation) of the pellets themselves. It is possible that where pelleted textures are preserved, the pellets were cemented at the time of final deposition. Uncemented pellets, on the other hand, could compact very easily and become indistinguishable from micrite mud.

Evidence for this comes from some lime mudstones of the Carrara Formation that are seen to be micrite or microspar in thin section but display a variety of current-formed sedimentary structures in outcrop. Features, such as ripples, parallel lamination and crossbedding indicate that the sediment was acting as sand or coarse silt when deposited. In these instances, it seems probable that the lime mudstone was pelleted at the time of deposition and that its primary depositional fabric has been obscured postdepositionally, perhaps during later compaction. Pelletal textures are also obscured during recrystallization as illustrated in figure 13*C*. Pelletal textures seem to have been diagenetically obscured in many of the limestones of the Carrara Formation. Much more of the lime-mudstone facies was probably deposited as pelleted lime mud than is now evident.

Besides pellets, a variety of other allochems are abundant in the lime mudstones of the Carrara Formation. These include oncolites, here considered to be of doubtful skeletal origin[1], and trilobite, hyolithoid, brachiopod, and echinodermal skeletal debris.

Oncolites are quantitatively the most important allochems in the lime-mudstone facies besides pellets. They constitute an average of about 15 percent of the exposed surfaces in the lime-mudstone facies, and locally they may constitute an oncolite packstone (fig. 13*D*); but the bed-to-bed variation is great. Oncolites vary in size from 10 cm in diameter to an undetermined minimum diameter of less than 1 mm. Typically, diameters range from 1 to 4 cm. The oncolites are sometimes circular, but more often they are ellipsoidal in cross section, and a trilobite or hyolithoid fragment characteristically forms the nucleus (figs. 13*E*, 13*F*, 14*A*). Although oncolites appear concentrically laminated in outcrop, they are discontinuously laminated on polished surfaces or in thin section (fig. 13*E*). The laminations, formed by slight color and (or) grain-size differences, suggest periods of growth interrupted by only occasional rotation of the oncolites. In thin section, oncolites are composed of microspar calcite finer than the spar replacing skeletal grains (figs. 14*A*, 14*B*). Rarely, the oncolitic calcite displays small tubelike molds of *Girvanella*. As illustrated in figure 14*B*, the oncolite surface layers differ markedly from the surrounding matrix because they do not contain skeletal fragments or silt-sized quartz grains. This suggests that these oncolites are not formed by algal trapping and binding of surrounding sediments, the process which is responsible for oncolite development on the Great Bahama Bank (Buchanan and others, 1972). Rather, oncolites in the Carrara Formation were probably formed from a primary precipitate of calcium carbonate stimulated by algae represented by the occasionally preserved tubes of *Girvanella*.

Although all oncolites of the Carrara Formation are tentatively assumed to have essentially the same origin,

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[1] Bathurst (1971a, p. 64) considered *Girvanella* oncolites to be probable codiacean remains.

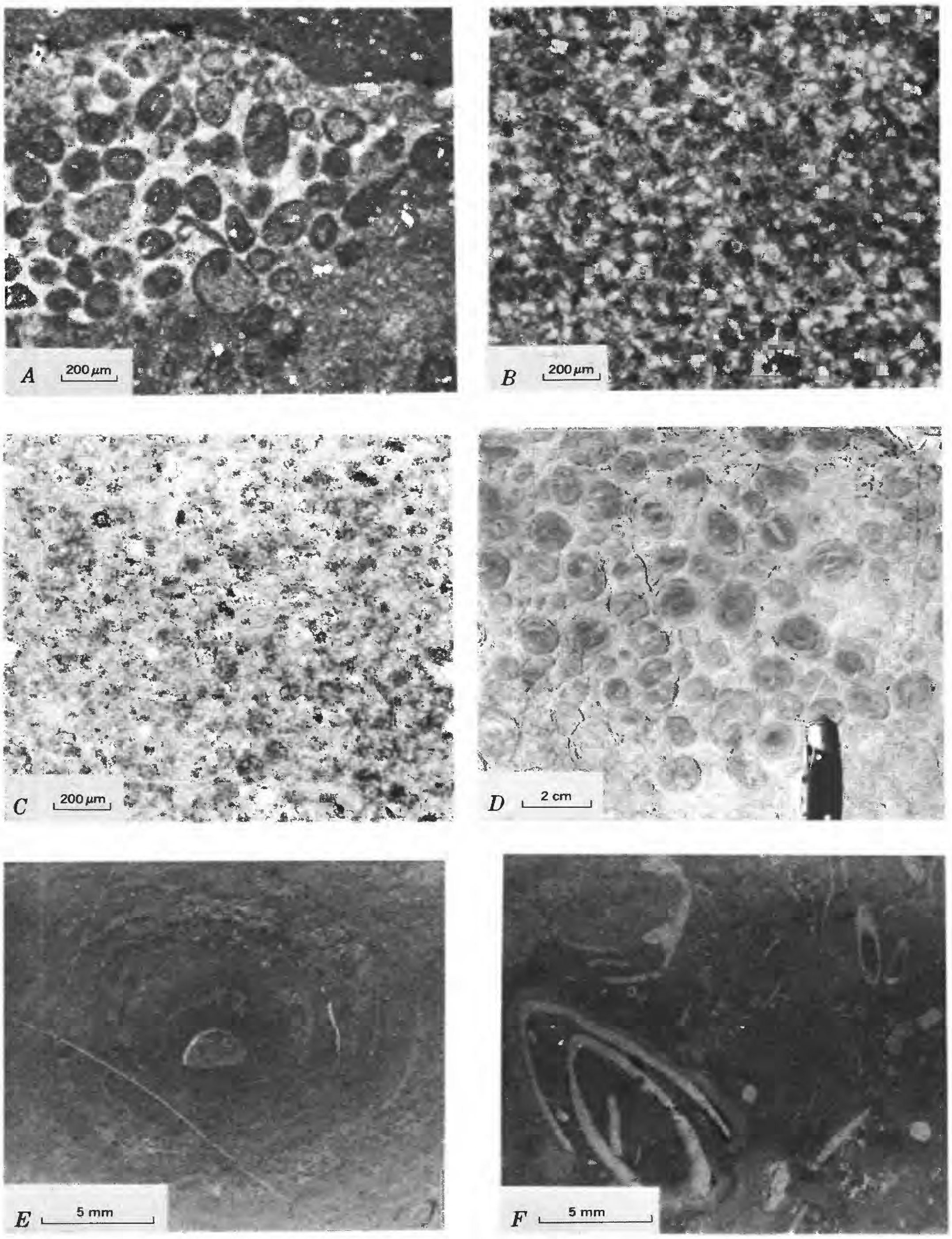


FIGURE 12.—Photomicrographs of lime-mudstone textures. *A*, Micrite (in center of photo) surrounded by microspar calcite. Largest grains about 10μm in diameter. Thimble Limestone Member, Echo Canyon section, California. *B*, Micrite (dark area in center of photo and elsewhere in field of view) surrounded by microspar forming a poikilotopic fabric typical of the Carrara lime mudstones. Jangle Limestone Member, southern Last Chance Range section, California. *C*, Small patches of micrite surrounded by microspar calcite. Large opaque grain in upper right is pyrite. Mule Spring Limestone, Paymaster Canyon section, California. *D*, Microspar calcite grading into sparry calcite (lower left corner). Jangle Limestone Member, Pyramid Peak section, California. *E*, Argillaceous microspar limestone containing some platy mica grains, lighter colored quartz silt grains, hematite grains, and hematite-coated dolomite grains in a microspar and clay-mineral matrix. Red Pass Limestone Member, Titanothere Canyon section, California. *F*, Diagenetic blurring of pelleted texture in micrite and microspar lime mudstone—well preserved only in the left half of the photo. Light grains are quartz silt. Red Pass Limestone Member, Eagle Mountain section, California.

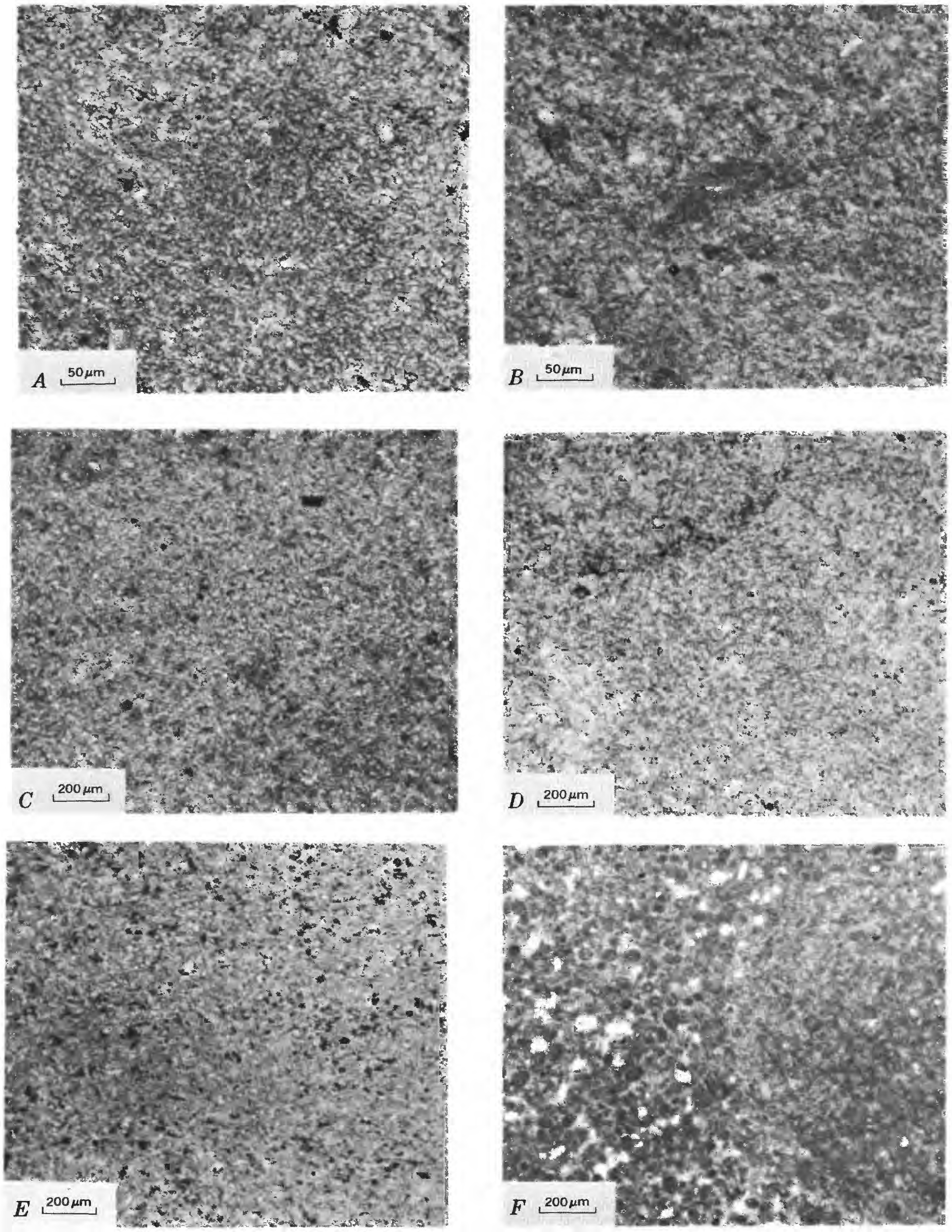


FIGURE 13.—Photomicrographs and outcrop photo of rocks of the lime-mudstone lithofacies. *A*, Small pocket of pelsparite surrounded by unpelleted micrite. Red Pass Limestone Member, Eagle Mountain section, California. *B*, Pelleted lime mudstone (pelmicrite) containing about 30 percent quartz silt. The pelleted texture of the sediment is not lost even though the limestone contains a significant proportion of terrigenous clastic material. Red Pass Limestone Member, Resting Springs Range section, California. *C*, Dolomitic microspar that contains a remnant pelletal fabric despite recrystallization. Some pellet ghosts are floating in microspar matrix. Titanothere Canyon section, California. *D*, Outcrop photo of oncolite packstone (oncolitic biomicrudite) in a bedding-plane exposure. Gold Ace Limestone Member, Echo Canyon section, California, *E*, Large oncolite with hyolithoid fragment as a nucleus. Note the discontinuity of concentric laminations in the structure. Jangle Limestone Member, Titanothere Canyon section, California. *F*, Hyolithoid-, trilobite-, and echinoderm-fragment wackestone with a probable algal coating around the outer margin of the large hyolithoid fragment in the lower left corner. That specimen may have been an incipient oncolite. Chambless Limestone, Marble Mountains section, California.

this may have not been the case. A peculiar relationship exists between oncolite preservation and the proximity of argillaceous units in the Gold Ace and Thimble Limestone Members. Oncolites seem to be ubiquitous in these members, but those that are near shales or in argillaceous limestones appear to be better preserved than those in the clean limestones. Better preservation is expressed by well-defined laminations, preserved nuclei, large size, and preservation of some *Girvanella* tubes seen in thin section. In contrast, those oncolites in massive, less argillaceous limestones are replaced by coarsely crystalline calcite, dolomite, and iron oxide.

The two styles of oncolite preservation suggest two possibilities for the origin and diagenetic history of these algal structures. First, the differing modes of preservation may reflect only differing diagenetic histories—the diagenetic history of oncolites in the cleaner limestone being more complex and leading toward total obliteration of the structure. Alternatively, the original depositional environment of the better preserved oncolites may have been sufficiently different, at least more muddy, to allow a different type of oncolite to develop, perhaps with a different primary porosity or mineralogy which would lead to a different diagenetic history. Evidence supporting either interpretation must await further detailed study of the oncolites.

The matrix around oncolites may be mudstone and free of skeletal grains, but more commonly it contains other allochems common to the lime-mudstone lithofacies. The most abundant of these are trilobite fragments which in thin section appear as circles, hooks, S-shaped fragments, and more irregular grains replaced by a sparry mosaic of calcite (figs. 14*C*–*F*). The fragments may have algal encrustations or oolitic coatings. Articulated trilobites are extremely rare in the lime-mudstone lithofacies, the only occurrence being an unusual 1-m-thick bed in the Pahrump Hills Shale Member in the Groom Range (USGS colln. 3692–CO, pl. 17).

The other abundant biogenic allochems—echinoderm fragments—are also rarely articulated in the lime mudstones of the Carrara Formation. They appear as sand-size calcite grains that are composed essentially of single crystals. In some well-preserved examples (figs. 15*A*–*C*), echinoderm plates appear to have serrated edges. These were probably produced by lime-mud filling the pores around the edges of the porous postmortem fragments. The porous interiors of the grains have been filled with calcite in optical continuity with the rest of the skeletal grain. Excellent descriptions of this porosity and cementation were given by Bathurst (1971a, p. 50–55). Usually, echinoderm fragments do not retain their original shape but are rounded and fractured during transport. Small pockets and thin beds of well-rounded echinoderm and trilobite debris form thin calcarenites both within the lime-mudstone facies and in some terrigenous clastic units of the Carrara Formation (fig. 15*D*). Micrite envelopes (Bathurst, 1966), although noted on some echinoderm fragments (fig. 15*E*), were never seen on trilobite or hyolithoid debris and are rare.

Other fossil fragments are grains and complete, often nested, cones of hyolithoids which are recognized by their subtriangular cross sections (figs. 13*E*, 17*F*). These are most common in the Chambless Limestone and the Gold Ace Limestone Member of the Carrara Formation. These fragments are more coarsely crystalline than associated trilobite fragments.

Intraclasts are exceedingly rare in the lime-mudstone facies but can be found near the interfaces of the lime-mudstone facies and the algal-boundstone facies. Although such occurrences are uncommon, they are qualitatively important and are discussed in more detail under "Spatial Relations of the Carbonate Lithofacies."

Quartz sand and silt occur in the lime-mudstone facies and silt can account for as much as 40 percent of the rock. Micas, chlorite, and clay make up the very fine terrigenous fraction.

The most pervasive sedimentary structure of the lime mudstones is thin bedding (figs. 16*D*, 17*B*, 18*A*–*D*), characteristically between 1 and 10 cm in thickness. It is often wavy, nodular, or irregular and is formed by orange-brown dolomitic silty argillaceous limestone that weathers recessively to form partings between thin dark-gray or black lime-mudstone beds. This thin bedding reflects the eastward facies change from lime mudstone to shale. Thin-bedded lime mudstones are replaced to the east by lime mudstone and shale, and then by a shale with thin interbeds of more calcareous material.

Within the thin beds of lime mudstone, a variety of structures can be seen. Rarely, near the eastern limits of the Thimble and Gold Ace Limestone Members, the thin beds are graded (figs. 16*A*, 16*C*); an irregular erosional base which contains trilobite fragments and quartz silt grades upward into a dolomitic argillaceous micrite or microspar. More often the thin beds are simply parallel, current laminated, and burrowed (figs. 16*B*, 17*A*). In thin section, these laminations are formed by concentrations of clay minerals or, where preserved, by slight variation in pellet size or fabric. Small crossbeds and cut-and-fill channels, never more than one bed thick, are the features most often associated with the current-laminated thin-bedded lime mudstones (figs. 16*D*, 17*C*, 18*A*). Although these features are produced in micrite or microspar, they also occur in small lenses or beds of skeletal grainstone, packstone, or intraclast packstone (figs. 17*B*, 17*D*).

The Carrara Formation contains a complete gradation

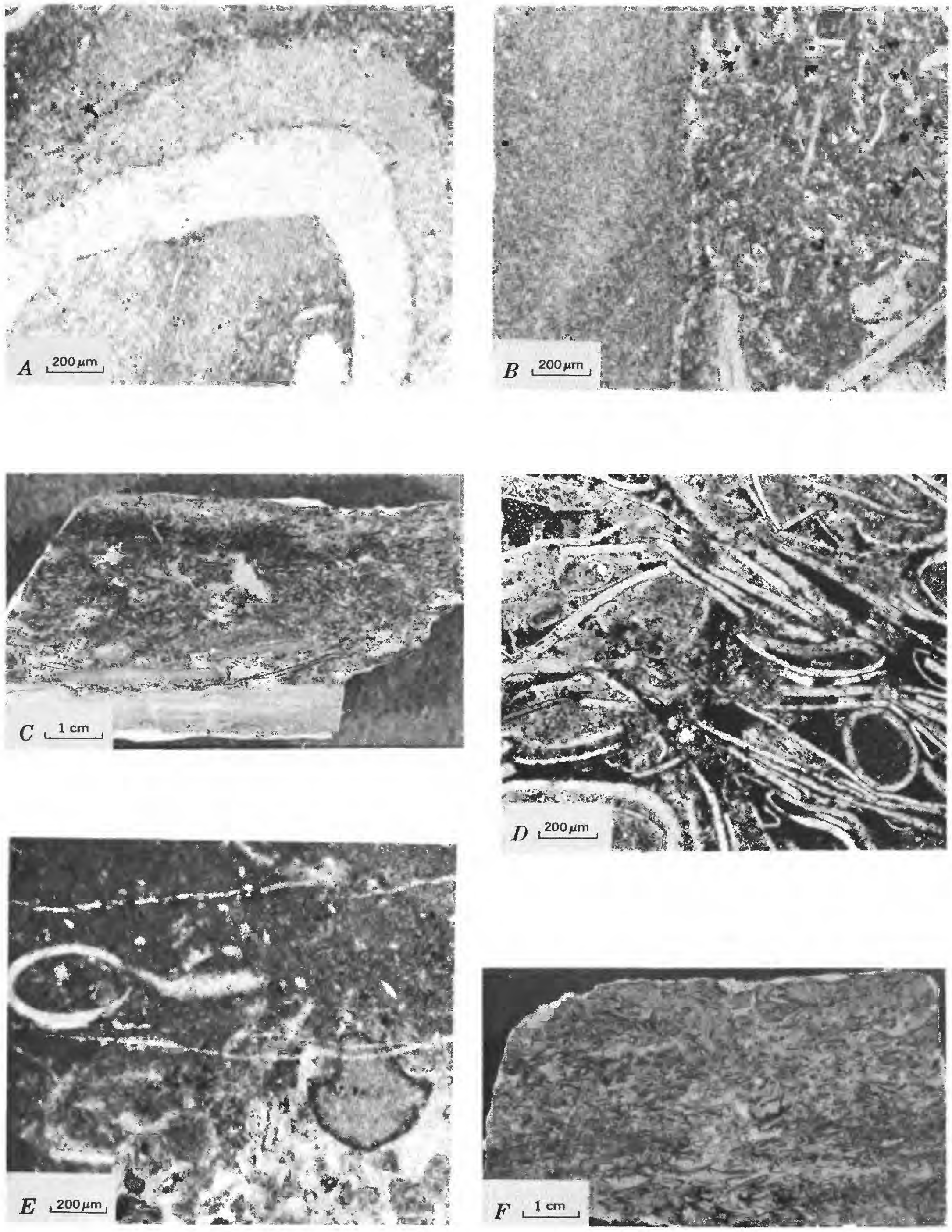


FIGURE 14.—Photomicrographs and photos of cut surfaces of selected lime-mudstone lithotypes. *A*, Detail of algal(?) microspar coating outside of replaced hyolithoid grain. Chambless Limestone, Marble Mountains section, California. *B*, Oncolite, microspar (left) and skeletal-grain wackestone matrix, which show markedly different compositions in thin section. Many of the small white grains in the matrix of the wackestone are quartz silt, a grain type that is totally absent from the oncolitic microspar. Chambless Limestone, Marble Mountains section, California. *C*, Cut surface, perpendicular to bedding, of trilobite and lithoclast packstone. Thimble Limestone Member, Echo Canyon section, California. *D*, Characteristics of bioclastic debris from trilobite-fragment packstone. Thimble Limestone Member, Echo Canyon section, California. *E*, Typical hook-shaped cross section of a trilobite cephalic margin in a lime-mudstone sample. Gold Ace Limestone Member, Echo Canyon section, California. *F*, Cut surface, perpendicular to bedding, of trilobite-fragment packstone. Jangle Limestone Member, Pahrump Hills section, Nevada.

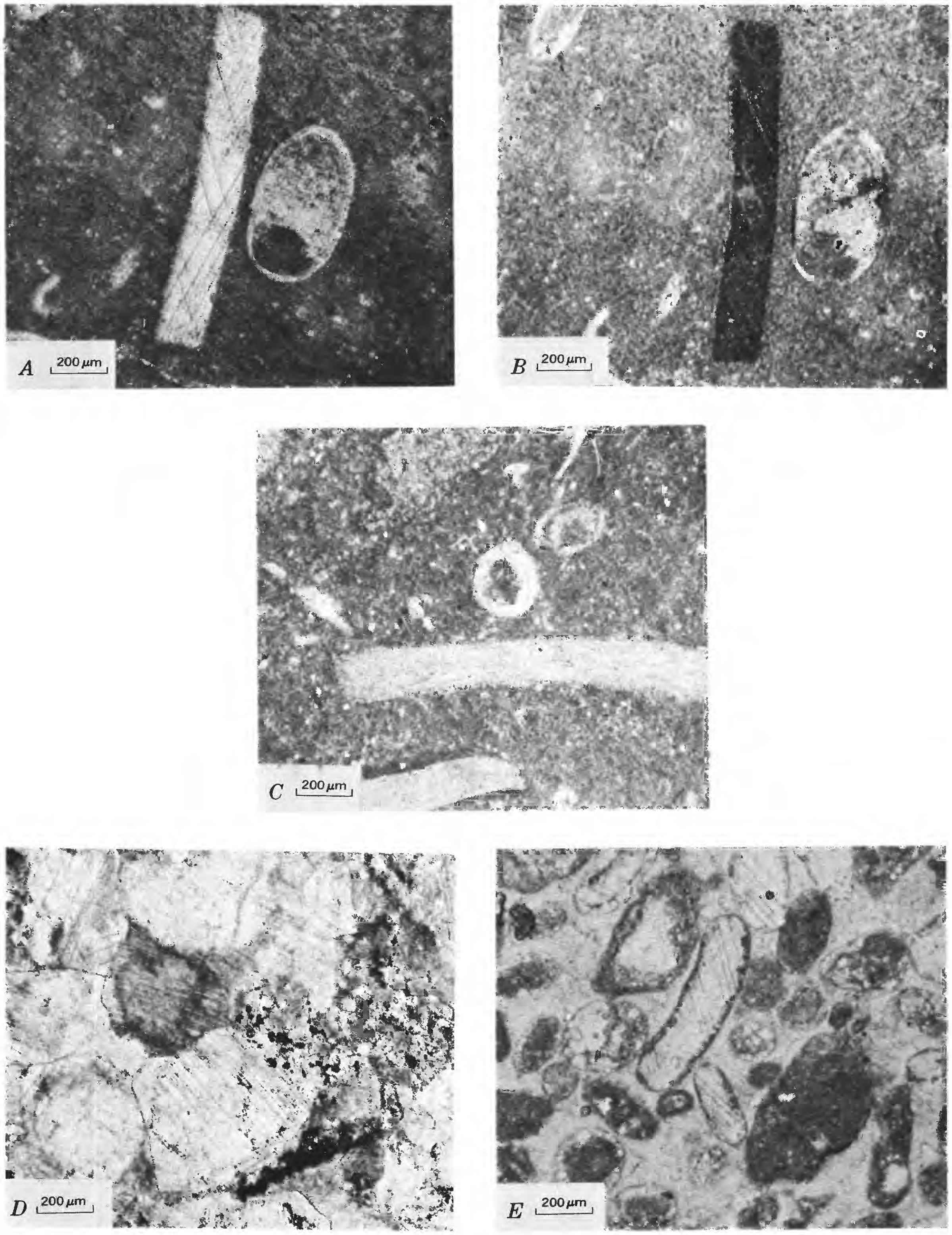


FIGURE 15.—Photomicrographs of echinoderm debris. *A*, Large, well-preserved echinoderm fragment adjacent to a trilobite spine in a mudstone. Chambless Limestone, Marble Mountains section, California. *B*, Same as *A* with crossed polarization. *C*, Echinoderm plate showing well-preserved marginal serration indicative of post-mortem porosity. Chambless Limestone, Marble Mountains section, California. *D*, Echinoderm grainstone with syntaxial calcite cement. Pyramid Shale Member, Eagle Mountain section, California. *E*, Well-rounded echinoderm fragments, pellets, and lithoclasts in grainstone. Central large echinoderm fragment has a micrite envelope. Jangle Limestone Member, Eagle Mountain section, California.

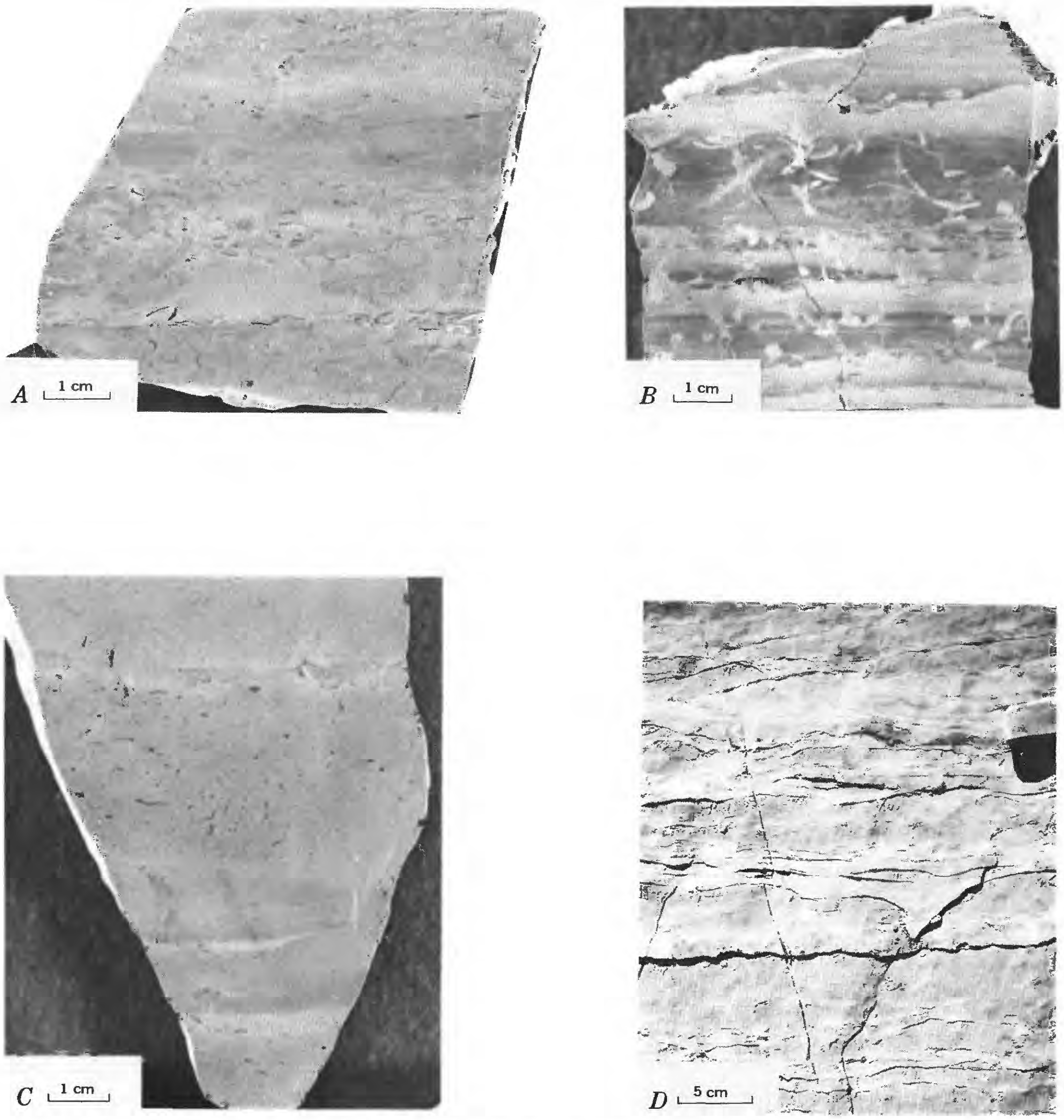


FIGURE 16.—Photographs of vertical-cut surfaces or outcrops of rocks from the lime-mudstone lithofacies. *A*, Cut surface of thin-bedded crudely graded lime mudstone. The base of each bed is defined by concentrations of quartz sand and echinoderm and trilobite skeletal fragments. The basal layer grades upward into current-laminated pelletal micrite or microspar which in turn is overlain by red argillaceous dolomitic lime mudstone. Thimble Limestone Member, Echo Canyon section, California. *B*, Cut surface of thin-bedded current-laminated burrowed pelmicrite. Argillaceous limestone interbeds (light gray in photo) are red in outcrop. Thimble Limestone Member, Echo Canyon section, California. *C*, Cut surface of thin-bedded graded lime mudstone. Each bed consists of an erosion surface which is overlain by a calcarenite or packstone which grades upward into current-laminated pelmicrite and argillaceous red microspar. Thimble Limestone Member, Striped Hills, Nev. *D*, Outcrop photo of thin-bedded limestone (dark gray) and more argillaceous and resistant weathering interbeds (light gray). Note current laminations and ripple crossbed within the dark lime-mudstone beds. Mule Spring Limestone, Paymaster Canyon section, Nevada.

from thin-bedded unburrowed lime mudstones with current-dominated depositional textures to homogeneously bioturbated lime mudstone (figs. 17*C*–*E*). However, the end-member lithologies comprise distinct microfacies that are discussed under "Environment of Deposition."

Both vertical and horizontal burrows occur in the lime-mudstone facies, but by far the most common type of burrowing is subhorizontal, leading to a mottled appearance for many of the lime-mudstone beds. A few open burrows occur scattered throughout the lime-mudstone facies and range from about 1 mm to 1 cm in

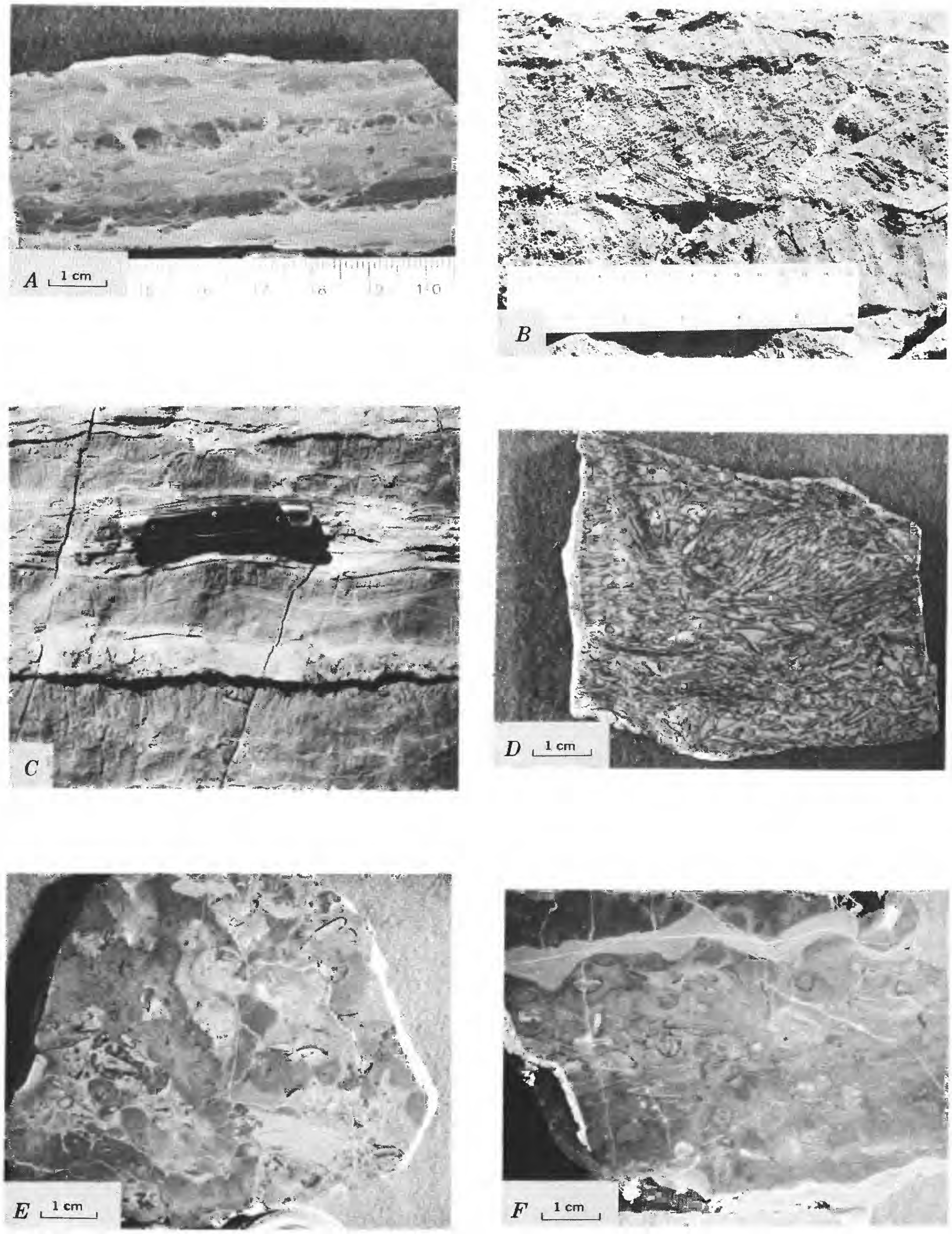


FIGURE 17.—Photographs of vertical-cut surfaces or outcrops of rocks from the lime mudstone lithofacies. *A*, Cut surface of thin-bedded argillaceous limestone. Current-laminated pelmicrite constitutes the dark material of the slab, and argillaceous dolomitic micrite or microspar constitutes the light material. Burrows have displaced the argillaceous limestone. Thimble Limestone Member, Echo Canyon section, California. *B*, Outcrop photo of crossbedded intraclast grainstone within typically thin-bedded lower Mule Spring Limestone, Paymaster Canyon section, Nevada. *C*, Outcrop photo of ripple-bedded pelleted dark lime mudstone and thin argillaceous light-colored limestone interbeds that weather more resistantly. Mule Spring Limestone, Paymaster Canyon section, Nevada. *D*, Cut surface of trilobite packstone with trilobite fragments crossbedded, suggesting current reworking of such fragments. Thimble Limestone Member, Echo Canyon section, California. *E*, Cut surface of burrowed dolomitic lime mudstone containing oncolites and hyolithoid- and trilobite-skeletal fragments. Chambless Limestone, Marble Mountains, Calif. *F*, Cut surface of burrow-mottled lime mudstone containing numerous hyolithoid cross sections. Light-colored dolomite bounds the thin bed and is associated with stylolites. Gold Ace Limestone Member, Pyramid Peak section, California.

diameter. These are filled with clear or white calcite spar (figs. 19*A*, 19*B*), and some cement infills show evidence of concentric zonation toward the interior of the burrow.

The interbeds or partings of orange, brown, or red argillaceous dolomitic siltstone or silty limestone within the lime-mudstone lithofacies show some evidence of diagenetic alteration. Because they define the thin bedding of this facies and because these interbeds are usually horizontal, they appear to be essentially of primary origin. They commonly are more intensely burrowed than the surrounding limestone. Orange argillaceous dolomitic limestone often extends from these horizons into overlying and underlying dark-gray or black limestone suggesting selective bioturbation of these more argillaceous zones. However, the concentrations of dolomite rhombohedra, the pervasive iron oxide stain, and the

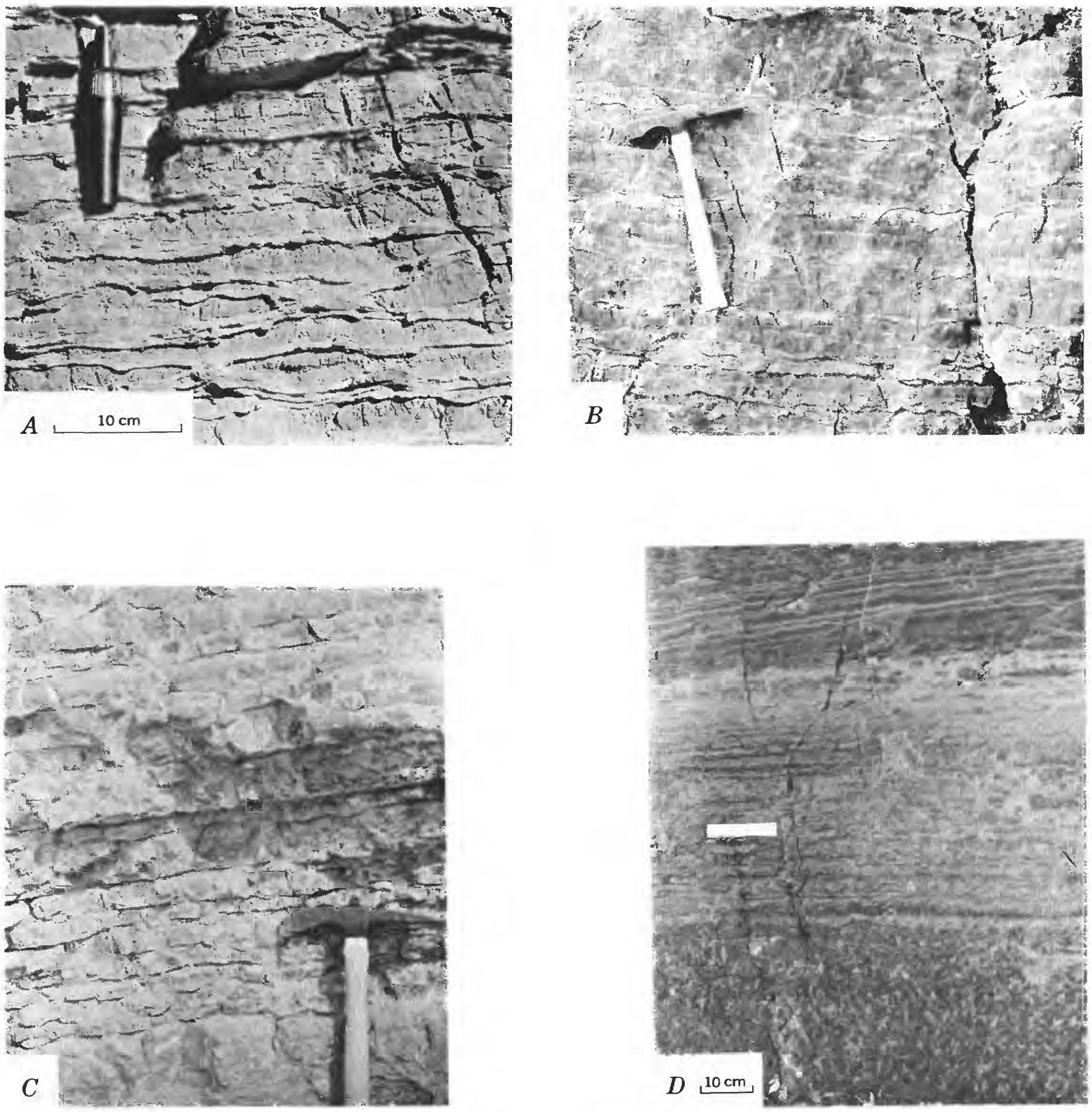


FIGURE 18.—Outcrop photos of rocks from the lime-mudstone lithofacies. *A*, Characteristic thin bedding. Weather-resistant argillaceous interbeds illustrate conformity with primary internal laminations in cleaner lime mudstone. Vertical rills are a weathering phenomenon unrelated to the primary depositional fabric of the limestone. Red Pass Limestone Member, Pyramid Peak section, California. *B*, Thin beds separated by more irregular and burrowed argillaceous interbeds than those illustrated in *A*. Gold Ace Limestone Member, Pyramid Peak section, California. *C*, Argillaceous interbeds of lime mudstone weathered recessively so that the unit usually forms a flaggy or platy slope. In such units the interbeds may be shale. Gold Ace Limestone Member, Pyramid Peak section, California. *D*, Argillaceous limestone interbeds showing three different degrees of irregularity. The lower third of the photo is very irregular both as a result of burrowing and as a result of subsequent solution along stylolites; the middle third is less so; and the upper third is very evenly interbedded. Jangle Limestone Member, Pyramid Peak section, California.

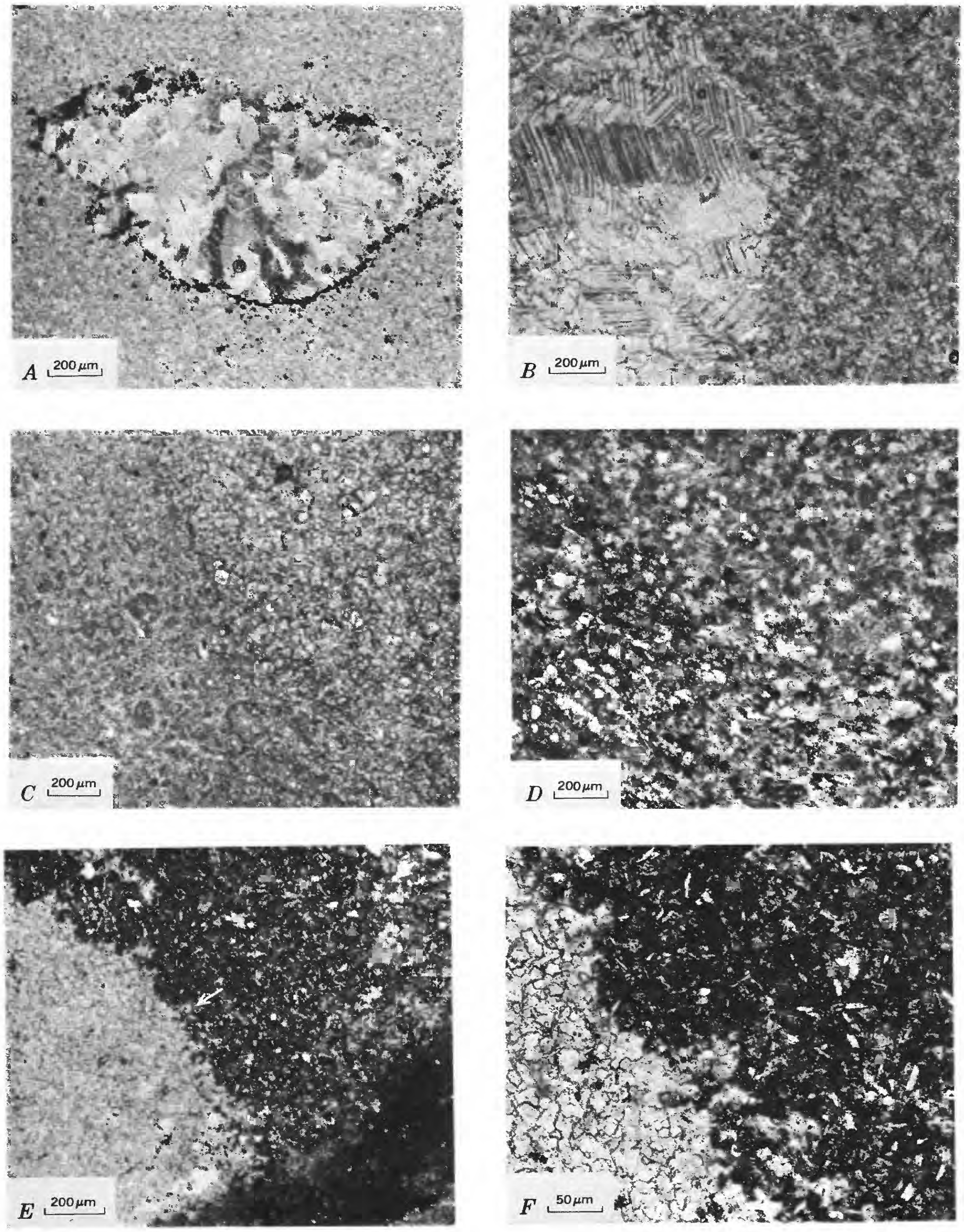


FIGURE 19.—Photomicrographs of rocks from the lime-mudstone lithofacies. *A*, A spar-filled burrow, now somewhat flattened and ringed by small dark pyrite grains. Structure is in homogeneous microspar. Thimble Limestone Member, Titanothere Canyon section, California. *B*, Wall of spar-filled burrow (right) and large calcite crystals expanding toward the center of the burrow (left). Structure is in pelletal micrite and microspar. Jangle Limestone Member, southern Last Chance Range section, California. *C*, Pelletal micrite and microspar (lower left) being replaced by dolomite (upper right). Jangle Limestone Member, Striped Hills section, Nevada. *D*, Silty, argillaceous pelletal micrite (upper right) adjacent to even more argillaceous, silty, and dolomitic limestone (lower left). The dolomite here as in most other photomicrographs is coated with iron oxide and appears opaque. Jangle Limestone Member, Resting Springs Range section, California. *E*, Part of a recrystallized ooid (lower left) in argillaceous, micaceous, iron oxide stained dolomite matrix. Eagle Mountain Shale Member, southern Last Chance Range section, California. *F*, Detail of area marked by arrow in *E*, showing relationship between recrystallized ooid and dolomitized matrix.

association of these interbeds with stylolites and relatively insoluble terrigenous clastics suggest diagenetic alteration of the interbeds from their original state. Some of the irregularities of these interbeds are undoubtedly caused by solution rather than bioturbation. Such solution takes place along swarms of microstylolites and has been described from very similar limestones in the Middle Cambrian of the Grand Canyon (Wanless, 1973). Primary composition and fabric differences of the more argillaceous horizons could have provided permeable pathways along which dolomitization, solution, and oxidation produced the interbed features seen today.

Dolomitization in the lime-mudstone lithofacies often extends beyond the argillaceous interbeds of the lime mudstone (figs. 19*C*, 20*C*, 21*A*–*D*) and selectively alters burrows and grains. Dolomitization of burrows is often associated with a displacement along burrows of argillaceous material from the orange interbeds (fig. 19*C*). The selective dolomitization of oolites, intraclasts, and oncolites is difficult to explain. Usually, the dolomitization appears random. For example, one oncolite may be completely altered to dolomite while another in the same thin section only millimeters away remains calcite, as does the cement between. Always, the replacement is by dolomite rhombohedra, 1–50 μm across, coated or zoned by iron oxide (figs. 21*A*, 21*B*).

Occasionally, rhombs of iron-stained calcite are noted on exposed surfaces. This calcite is assumed to be a modern dedolomite. (See, for example, Evamy, 1969.)

Small irregular spar-filled cracks ramify throughout the lime-mudstone facies of the Carrara Formation. These cracks are filled with calcite that appears black in outcrop and are restricted to the lime-mudstone facies. They were formed before the straighter spar-filled fractures that are found in all facies, which are assumed to be associated with the structural deformation of these limestones. These latter fractures appear white in outcrop (figs. 20*B*–*D*).

Distribution of the lime-mudstone lithofacies of each of the four limestone members of the Carrara Formation is illustrated in figures 31-33. The distribution of lime mudstone in the Thimble and Gold Ace Limestone Members is similar. The northwestern limit of these lime mudstones is far beyond the study area. In the east-central part of the outcrop area of the Carrara Formation, the lime-mudstone lithofacies of the Thimble Limestone Member goes beyond that of the Gold Ace Limestone Member and extends to the Spring Mountains and Pahrump Hills. However, to the southeast, the lime-mudstone lithofacies of the Gold Ace Limestone Member extends beyond that of the Thimble Limestone Member to the Nopah Range and Winters Pass. At Winters Pass, Eagle Mountain, and the Desert Range the lime-mudstone lithofacies of the Gold Ace Limestone Member interfingers with shales. To the south, the continuation of this limestone unit in the Providence and Marble Mountains is separately recognized as the Chambless Limestone.

The northwestern limit of the lime-mudstone lithofacies of the Red Pass Limestone Member is outside the study area. It is marked by the facies change into thin-bedded deeper water limestones of the Emigrant Formation although the lateral transition is nowhere exposed. To the southeast, the lithofacies interfingers with shales. Within the member, it interfingers with the oolite lithofacies and, in the upper part of the member, with the algal boundstone lithofacies.

The lime-mudstone lithofacies of the Jangle Limestone Member has a northwestern limit that is somewhere between the Belted Range and the Groom Range. The eastern margin of this lithofacies is beyond the study area. At Frenchman Mountain, Sheep Mountain, and Azure Ridge, the correlative Lyndon Limestone contains lime mudstone but the lithofacies disappears eastward toward the Grand Canyon where the laterally equivalent units appear to be the Tincanebits and Meriwitica Tongues of McKee (McKee and Resser, 1945).

ENVIRONMENT OF DEPOSITION

The lime-mudstone lithofacies of the Carrara Formation is a subtidal marine accumulation. It contains none of the fabrics or sedimentary structures recognized as characteristic of supratidal and intertidal deposition. When Holocene subtidal lime-mud accumulations are compared with the lime-mudstone lithofacies of the Carrara Formation, two problems arise. The first concerns the origin of the lime mud. In the Holocene, two contrasting mechanisms have been assumed for the production of shallow-water (nonpelagic) lime mud: physical precipitation directly from sea water, and accumulation of finely comminuted algal skeletal carbonate. Attempts to analyze the origin of Holocene lime muds have been made at only a few localities and in each case the solution differs (Cloud, 1962; Matthews, 1966; Stockman and others, 1967; Kinsman and Holland, 1969). Without agreement on the source of lime mud in the Holocene it is impossible to suggest any one source for the lime mud of the lime-mudstone lithofacies of the Carrara Formation. The second problem concerns the fact that few investigators of Holocene sediments have studied the fraction of the sediment finer than 62 μm. Emphasis has been placed on identification of the grains larger than 62 μm, and only the bulk weight of the finer fraction has been recorded. Some workers have considered all carbonate sediment finer than 62 μm to be "carbonate mud." Thus,

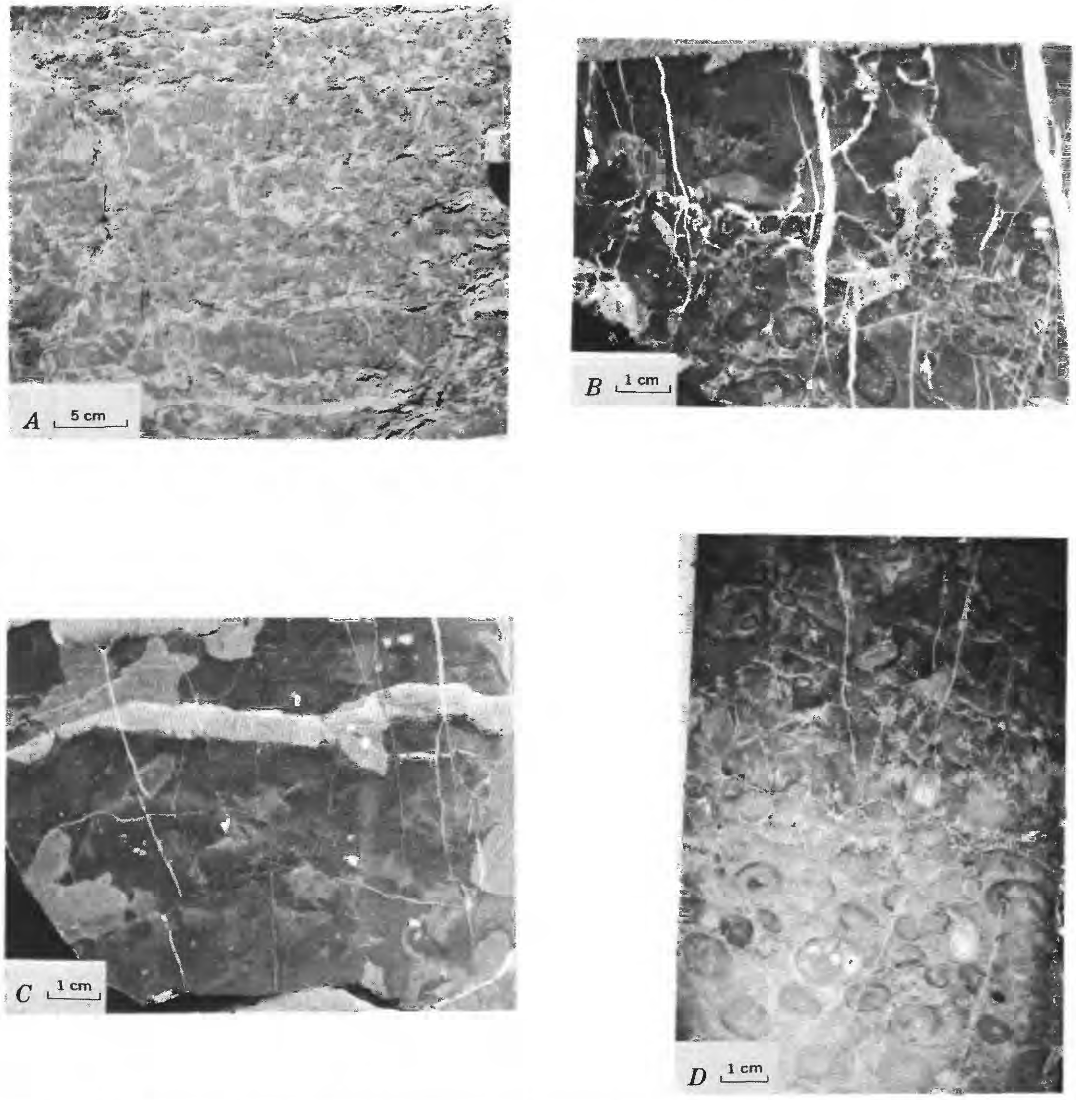


FIGURE 20.—Photographs of a natural exposure and vertical-cut surfaces of rocks of the lime-mudstone lithofacies. *A*, Outcrop photo of thin-bedded lime mudstone (dark) with argillaceous dolomitic partings and burrows (light). Hammerhead on right margin for scale. Compare this interval with that illustrated in figure 18*A*. Red Pass Limestone Member, Nopah Range section, California. *B*, Vertical-cut surface of oncolitic lime mudstone overlain by homogeneous lime mudstone. The oncolites are severely recrystallized and individual crystals can be seen in the photo. The overlying mudstone is also recrystallized in the upper left to a coarse calcite spar. Large tectonic vertical fractures are filled with white calcite. Gold Ace Limestone Member, Echo Canyon section, California. *C*, Vertical-cut surface of burrowed dolomitized lime mudstone. The dolomite (light) occurs both as a prominent horizontal interbed in the upper third of the sample and as a general mottling associated with the filled burrows. Gold Ace Limestone Member, Echo Canyon section, California. *D*, Slab photo of oncolitic lime mudstone overlain by burrowed lime mudstone. Oncolites are not severely recrystallized and retain their characteristic concentric lamination although portions are replaced by white crystalline calcite. Compare with *B*. Gold Ace Limestone Member, Echo Canyon section, California.

particle size of Holocene lime muds can range from silt to clay.

Despite these difficulties, some generalizations about accumulation of lime mud seem possible. Accumulation occurs generally in a protected setting, although that protection may vary considerably. Examples of such accumulation are (1) Harrington Sound, Bermuda, where most of the muddy sediments accumulate in more than 16 m of water (Neuman, 1965); (2) the interior of the Great Bahama Bank at depths of 0–6 m of water, in the lee of Andros Island and separated from strong tidal currents near the bank edge by oolite shoals (Purdy,

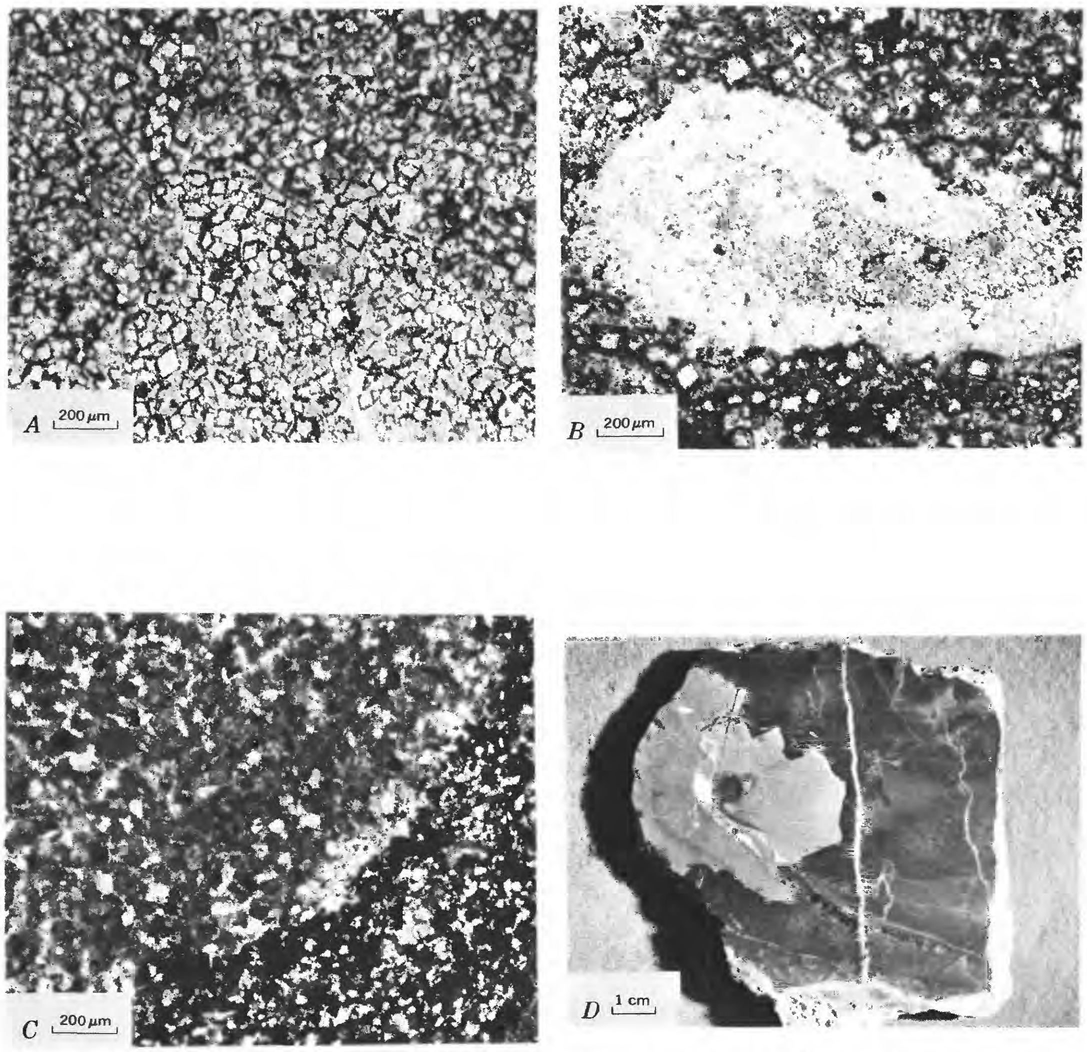


FIGURE 21.—Photomicrographs and photographs of vertical-cut surfaces of rocks from the lime-mudstone lithofacies. *A,* Unusually large rhombs of dolomite with iron oxide coating most crystals. Smaller coated rhombs are typical of replacement dolomite in the Carrara lime mudstones. Chambless Limestone, Marble Mountains, Calif. *B,* Recrystallized-calcite trilobite fragment in replacement dolomite. Calcite sediment within the fragment has remained unaffected. Chambless Limestone, Marble Mountains, Calif. *C,* Example of increase in insoluble residue of argillaceous dolomitic interbeds. Normal pelletal lime mudstone (upper left) contains significantly less quartz silt than the interbed (lower right). Note concentration of silt along the contact of the two lithologies. Jangle Limestone Member, Eagle Mountain section, California. *D,* Vertical-cut surface of dark homogeneous lime mudstone illustrating neomorphic recrystallization to coarse-grained spar (right center), irregular dolomitization (light area on left), and fracture filled with dark calcite spar broken by fracture filled with white calcite. Gold Ace Limestone Member, Echo Canyon section, California.

1963); (3) landward side of the Great Barrier Reef, Australia in about 45 m of water (Swinchatt, 1970); (4) in the Southern Shelf Lagoon of British Honduras in more than 9 m of water (Matthews, 1966; Scholle and Kling, 1972); (5) in the Persian Gulf in more than 15 m of water near Qatar (Houbolt, 1957); and (6) in less than 9 m of water in lagoons behind oolite deltas and islands of the Persian Gulf Abu Dhabi complex (Kinsman, 1964).

The lime-mudstone lithofacies of the Red Pass and Jangle Limestone Members of the Carrara Formation interfingers with the oolite and algal-boundstone lithofacies to the west and with shales to the east. The oolite grainstone and algal boundstone lithofacies, which formed shoals and islands (p. 41, 49), could have provided a physical barrier to the west. Eastward, depth probably played an increasingly important role in providing a relatively quiet environment for lime-mud accumulation.

During the deposition of the Carrara Formation the cratonic shoreline was several hundred kilometers to the east, in the vicinity of the eastern Grand Canyon. A broad shelf lagoon dominated by terrigenous clastic deposition lay between the cratonic shoreline and the outer carbonate-producing shoals. The presence of a slight depositional slope at the western edge of the clastic area of the shelf lagoon is indicated by rare graded beds, slump folds, and sole markings present in the Eagle Mountain, Echo, and Pyramid Shale Members of the Carrara Formation. The interfingering of these shales with oncolitic and skeletal lime mudstones indicates that depths were not great. One hundred meters of water is deep enough to permit significant sediment transport and yet still shallow enough so that biological activity could produce abundant skeletal carbonates. The depth of the shelf lagoon may have decreased from perhaps 100 m at the clastic-carbonate interface in the center to sea level westward where the lime mudstones interfinger with intertidal deposits (fig. 37).

The lower parts of the limestone members of the Carrara Formation are characteristically dominated by lime mudstones displaying current features; whereas the upper parts are dominated by burrowed lime mudstones. There is no obvious method of determining whether this change is an upward increase in the activity of burrowing animals or an upward decrease in current activity. However, an upward decrease in current activity may reflect the development of barrier islands or shoals to the west which altered the open shelf to a protected shelf lagoon.

The outstanding sedimentary structure of the lime-mudstone lithofacies is thin bedding. Such bedding has no known counterpart in carbonate muds being deposited today. Although burrowing has been a significant destructive agent of sedimentary structures within beds, little between-bed burrowing took place in the lime-mudstone lithofacies of the Carrara Formation. Most Holocene lime muds are thoroughly homogenized by burrowers, such as *Callianassa* (Shinn, 1968). Perhaps the thin bedding of the lime mudstones of the Carrara Formation and many other lower Paleozoic limestones, indicates that burrowers were not as abundant or that they burrowed less deeply in the past than today.

THE OOLITE LITHOFACIES

The oolites of the Carrara Formation are composed of low-magnesium calcite as are virtually all ancient undolomitized, unsilicified oolites. Accessory minerals in the oolite lithofacies are dolomite, hematite, quartz, chlorite, and clay minerals, all of which account for less than 5 percent of the rock. Compared to the lime-mudstone lithofacies, the oolite lithofacies is relatively free of terrigenous clastic sediment.

The oolite lithofacies is constructed almost entirely of oolite grainstone, with minor amounts of intraclastic grainstone, composite grains, grapestonelike grains, and quartz sand. The oolites are typical of many ancient oolites and show a wide range of preservation style. Individual ooids range in diameter from 100 μm to about 1 mm.

Most ooids possess both a radial and concentric microstructure characteristic of ancient oolites (fig. 22*A*). These microstructures are delineated by crystal boundaries, and by micrite, microspar, and sparry calcite grain-size variations. The concentric microstructure of the oolites is a retention of the primary concentric fabric found in all Holocene aragonite oolites. The radial structure of ancient oolites is thought to be acquired during neomorphism (Shearman and others, 1970).

Most ooids show evidence of rim cement which is now preserved as ghosts or as oriented calcite-spar grain boundaries. Much of the cement between ooids is composed of silt-sized calcite grains. The matrix between ooids in some eastern localities contains quartz silt (figs. 22*B*–*D*). Usually, the ooids themselves are composed of micrite and microspar.

The preservation of oolites is little affected by structural deformation. Both radial and concentric structure of ooids is still evident despite tectonic deformation (figs. 22*D*, 22*E*).

Other events, not related to tectonism, caused more severe alterations of the oolite texture. Some ooids have been completely altered to micrite (fig. 22*C*). Others, although texturally not as obscure, have been in part replaced by quartz and chlorite (figs. 23*A*, 23*B*) or by microspar calcite of only slightly smaller grain size than that of the surrounding matrix (fig. 23*C*). Solution of oolites takes place along stylolites (fig. 23*D*) resulting in fabrics similar to those described by Carozzi (1961).

Almost all types of grains in the Carrara Formation may serve as nuclei for ooids. Trilobite or echinoderm fragments, or quartz silt grains are the most common nuclei. The shape of the ooid is determined somewhat by the shape of the nucleus (fig. 23*E*). Most often, however, the ooids have no obvious nuclei, only a micrite or microspar interior. It is possible that these fine-grained centers were pellets. Alternatively, the nuclei may have been minute particles of calcium carbonate which are now impossible to recognize in recrystallized ooid centers.

In some ooids, almost the entire grain is micrite (fig. 23*F*) with only very vague indications of radial and concentric structure preserved. Where the interior of these micritized ooids is composed of more coarsely crystalline calcite, the center also contains iron oxide stained dolomite rhombs (fig. 24*A*).

The oolites of the Carrara Formation display a sur-

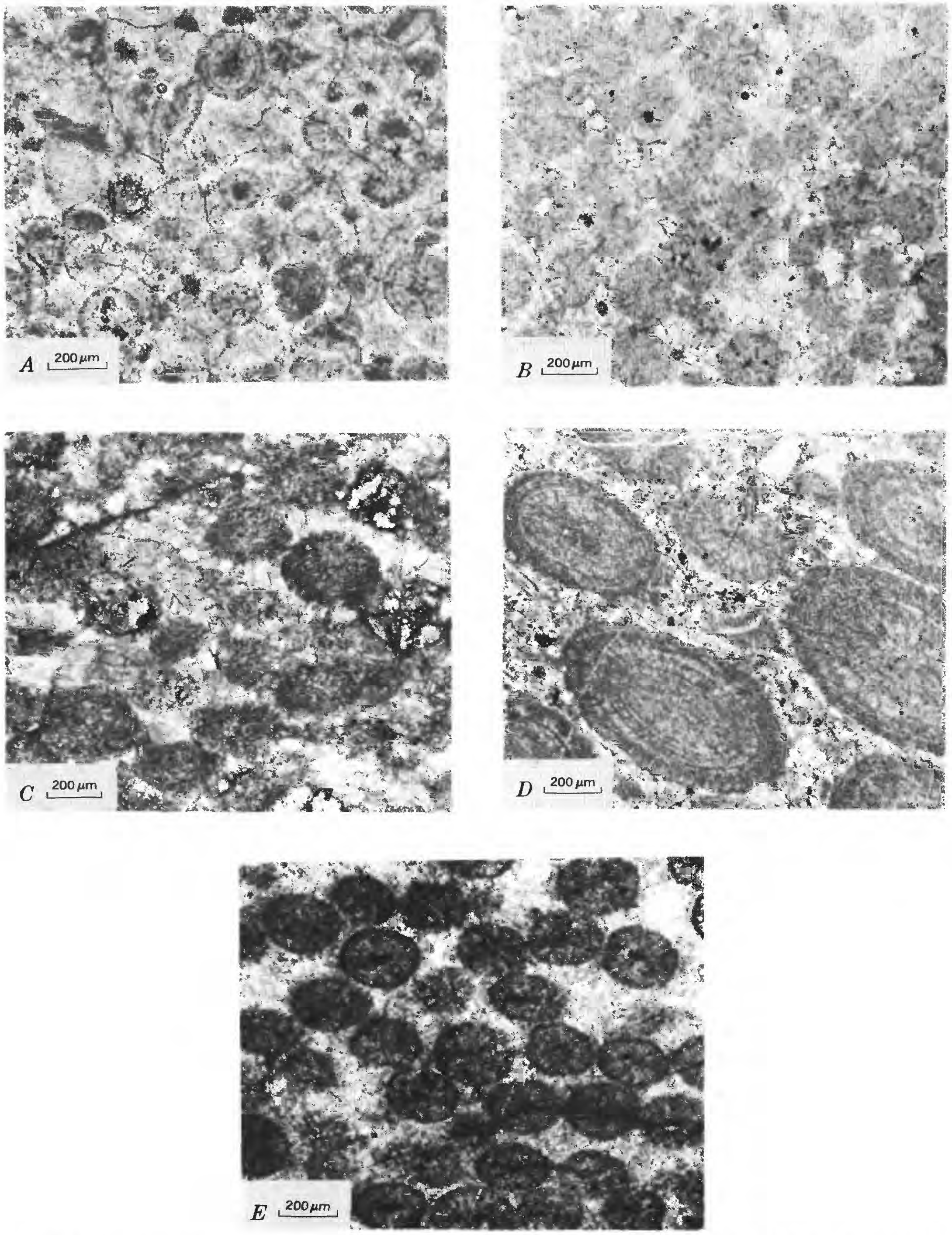


FIGURE 22.—Photomicrographs of rocks from the oolite lithofacies. *A,* Oolite illustrating radial and concentric microstructure of ooids (top center). Less distinct structure in some ooids is due to the tangential plane of the thin section. Ovoid micrite interiors of some ooids suggest that pellets may have served as nuclei. Alternatively, the interiors may be preferentially micritized. Red Pass Limestone Member, Titanothere Canyon section, California. *B,* Ooids with vague concentric structure but formed of radially arranged calcite crystals. Quartz silt grains occur both as nuclei and in matrix. Red Pass Limestone Member, Striped Hills section, Nevada. *C,* Ooids altered almost completely to micrite and microspar. Three ooids are recrystallized to a coarser spar. A few white quartz silt grains are scattered throughout the spar cement. Red Pass Limestone Member, Winters Pass, Calif. *D,* Tectonically deformed ooids. The radial and concentric microstructure of the grains is clearly visible. The matrix contains a significant amount of quartz silt. Red Pass Limestone Member, Spring Mountains, Nev. *E,* Well-sorted ooids. Basal part of the Mule Spring Limestone, Paymaster Canyon, Nev.

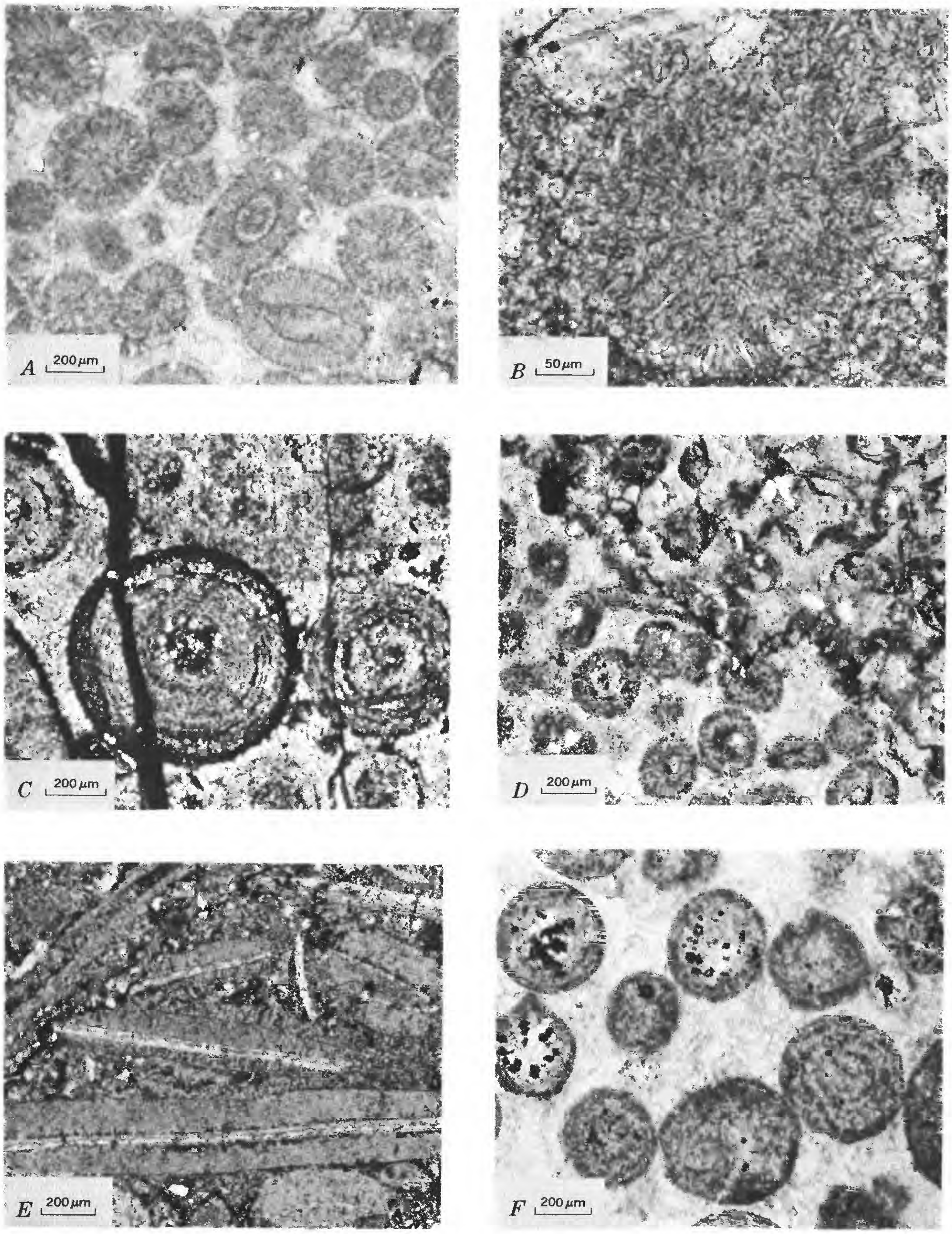


FIGURE 23.—Photomicrographs of rocks of the oolite lithofacies. *A*, Ooids containing authigenic silt-sized quartz grains in the outer rims and chlorite crystals arranged radially throughout the ooids. These minerals replace skeletal fragments also in this thin section. Pahrump Hills Shale Member, Pahrump Hills section, Nevada. *B*, Detail of *A*, illustrating lath-shaped chlorite crystals in an ooid. *C*, Ooids replaced by dolomite and microspar calcite, and with iron oxide rims. Matrix is only slightly more coarsely crystalline than ooids. Note that only the concentric microstructure is apparent in these ooids. Cadiz Formation, Marble Mountains, Calif. *D*, Ooids which are dissolved and compacted in the upper right, presumably as a result of pressure-solution diagenesis, and are separated by a prominent styolite from the uncompacted ooids on the lower left. Red Pass Limestone Member, Eagle Mountain section, California. *E*, Extremely elongate ooids conforming to the shape of trilobite-fragment nuclei. The skeletal fragments themselves have been replaced by quartz. Thimble Limestone Member, Titanothere Canyon section, California. *F*, Partly micritized ooids with poorly developed rim cement. More coarsely crystalline ooids contain iron oxide stained dolomite rhombs. Note that only the concentric microstructure is visible. Red Pass Limestone Member, Eagle Mountain section, California.

prisingly small variety of sedimentary structures. As with the lime-mudstone lithofacies, the oolite lithofacies is predominantly thin bedded. The thin beds are burrowed or are composed of single sets of crossbeds (figs. 24*B–D*). In some western sections, however, internal sedimentary structure is difficult to recognize in the oolite lithofacies. At Titanothere Canyon in the southern Last Chance Range, the oolite in the Red Pass Limestone Member is very well sorted, relatively fine grained, unburrowed, and forms a massively bedded unit. The unit is difficult to recognize as an oolite until thin sections are prepared. Where there is enough variation in grain size and sorting to see sedimentary structures, the oolite is medium bedded (10–100 cm) and contains small festoon or trough crossbeds (fig. 24*E*). The most common nonooid grain types in western sections are skeletal grains. The top of the Red Pass Limestone Member in the Groom Range is an echinoderm-trilobite-fragment calcarenite and is included in the oolite lithofacies.

In contrast, oolites of the Red Pass Limestone Member in the Resting Springs, Nopah, Funeral, and Las Vegas Ranges and in the Striped Hills and Pahrump Hills are thin bedded, burrowed, and interbedded with shales. The few exceptions are several beds about 1 m thick with large-scale high-angle crossbeds. Usually, oolites in this area are composed of somewhat coarser, more poorly sorted ooids than those in northwestern sections. Typically, they are more orange colored and iron stained than the northwestern oolites owing to more replacement by iron-stained dolomite rhombs. The dolomitization tends to mimic low-angle crossbedding resulting in orange and black striping informally called "tiger striping." Thin sections of eastern oolites contain occasional skeletal fragments and some grapestonelike composite grains (fig. 24*F*).

Ooids occur outside of the oolite lithofacies most commonly in association with cryptalgal structures. In this setting they are a relatively minor grain constituent, secondary to lithoclasts, skeletal fragments, and quartz grains.

An unusual oolite bed occurs in the lower part of the Jangle Limestone Member in the Pahrump Hills. This bed consists of plate-shaped oolite clasts, as much as 40 cm long, centered in an oolite matrix (fig. 25*A*). The clasts are recognizable because the dark pigment in a layer of oolite just below the surface of the clasts has been removed; thus, the light-colored zone in figure 25*A* lies just within the clast and is not the outermost surface of the clast. In this section several more characteristics of this unusual oolite intraclast bed may be picked out. Figure 25*B* is a photomicrograph of the oolite clast boundary. The prominent vertical line in the left third of the photo is the clast-matrix contact—clast to the right, matrix to the left. Most of the ooids outside the clast are not touching in the plane of the thin section, although they are probably in grain contact. Within the clast most ooids are touching, suggesting some solution along grain contacts. The cement within the clast is finer grained than that outside the clast. Also, on the right side of figure 25*B* and the left side of figure 25*C* are lighter colored ooids that have been replaced by a more clear calcite spar, in some instances by single crystal grains of calcite. These are the ooids that form the light margins of the clasts seen in the outcrop.

Oolite clasts in an oolite matrix indicate early cementation and redeposition of this lithology in the Pahrump Hills area. Similar early cementation was described by Ball (1967) from the Cat Cay sand belt of the Bahama Islands. Ball (1967, p. 563) interpreted this phenomenon as the result of cementation in areas where ooid grains are immobile for some time.

Oolites were identified in the Gold Ace Limestone Member and correlative units at Paymaster Canyon and Cucomungo Canyon and in the southern Last Chance Range. This member also contains oolites in the southern Panamint Range (Bates, 1965) where they may represent an eastward advance of the oolite lithofacies beyond its limits in the earlier Thimble Limestone Member (fig. 32).

The oolite lithofacies of the Red Pass Limestone Member is found throughout the Carrara Formation and its eastern limit coincides with the approximate eastern limit of thrust faults. Although the present eastern limit of this facies is structurally controlled, it clearly extends much farther to the east than did the equivalent lithofacies of the Thimble or Gold Ace Limestone Members (fig. 32). Very small accumulations of oolites in the middle of the Cadiz Formation may represent the last vestiges of this lithofacies in the Providence and Marble Mountains.

The Jangle Limestone Member has a northwestern oolite lithofacies limit similar to that of the Red Pass Limestone Member. The exception is in the Belted Range where the entire interval correlative with the Jangle Limestone Member is replaced by lithologies typical of the Emigrant Formation. The oolite lithofacies is found throughout the Jangle Limestone Member. Its distribution to the north in the Highland Range and Delamar Range is not known. The southeastern limit of the oolite lithofacies is east of Frenchman Mountain where 0.5 m of oolite occurs at the base of the Lyndon Limestone, and west of Azure Ridge where no oolite is found. Oolites in the upper part of the Cadiz Formation probably represent this lithofacies in the Providence and Marble Mountains to the southeast of the study area.

ENVIRONMENT OF DEPOSITION

The oolite lithofacies of the Carrara Formation shares some features with Holocene oolite accumulations but is identical to none of them. Holocene oolites have been

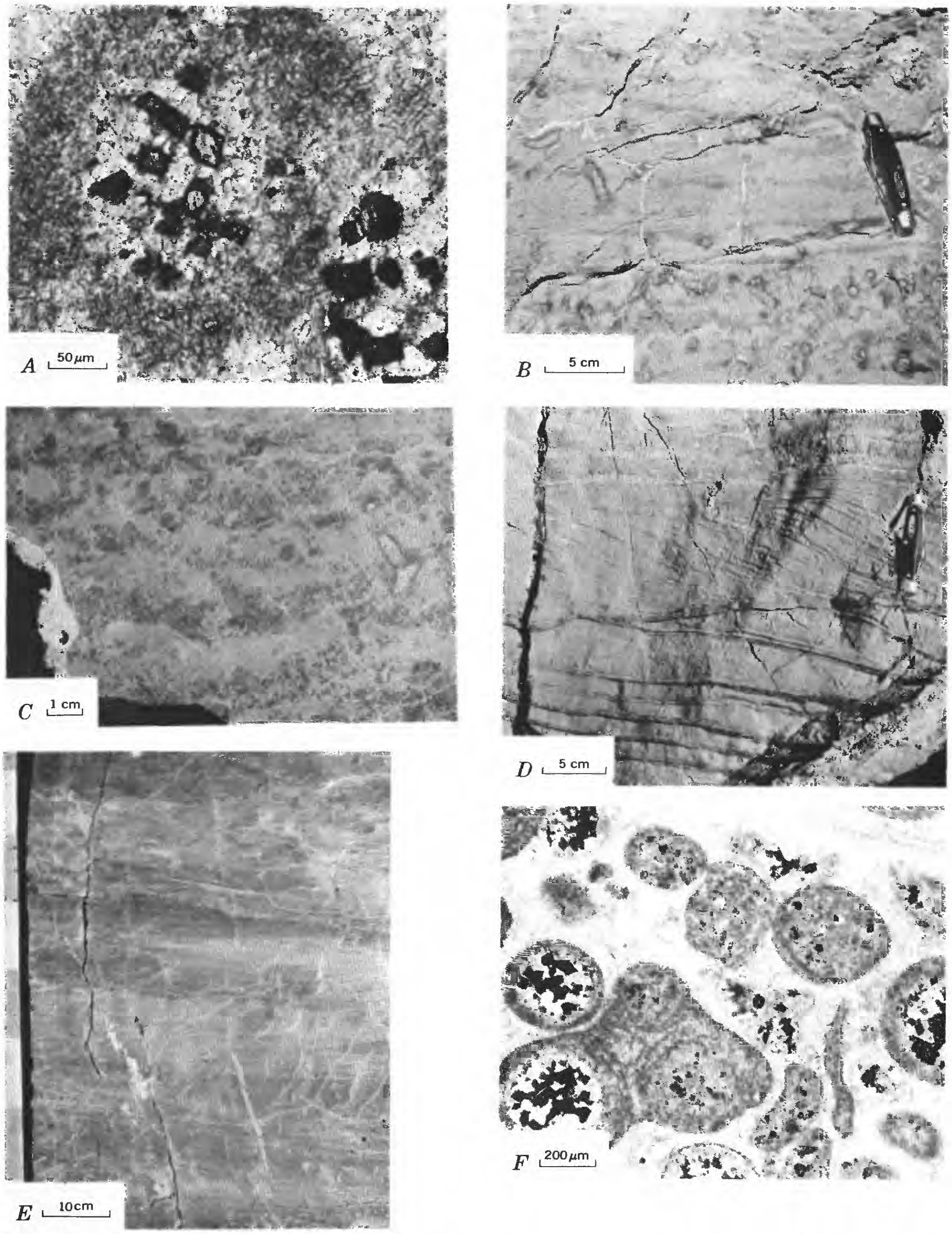


FIGURE 24.—Photographs of thin sections, vertical-cut surfaces, and outcrops of rocks of the oolite lithofacies. *A*, Well-developed dolomite rhombs coated with iron oxide in recrystallized centers of ooids. Red Pass Limestone Member, Eagle Mountain section, California. *B*, Outcrop photo of thin-bedded oolite. Dolomitic lime-mud-filled burrows occur on the center left and toward the bottom of the photograph. Red Pass Limestone Member, Eagle Mountain section, California. *C*, Vertical-cut surface of burrowed oolite illustrating the light and dark beds of ooids formed from variations in sorting and dolomitization of the grains. Red Pass Limestone Member, Eagle Mountain section, California. *D*, Outcrop photo of topsets and foresets in one of the larger crossbed sets in the Red Pass Limestone Member, Nopah Range section, California. *E*, Outcrop photo of medium-bedded trough crossbedded oolite. Variations in shade are believed to be caused indirectly by sorting variations between crossbed sets. Each dark bar on the left is 10 cm. Red Pass Limestone Member, Titanothere Canyon section, California. *F*, Photomicrograph illustrating a large composite grain similar to some grapestone grains described from Holocene deposits. Dark polygonal grains are iron oxide coated dolomite. Red Pass Limestone Member, Eagle Mountain section, California.

described from a variety of environments including shoreline accumulations (Rusnak, 1960; Logan and others, 1970; Loreau and Purser, 1973), tidal-delta and channel accumulations (Kinsman, 1964; Jindrich, 1969; Ball, 1967; Loreau and Purser, 1973), and tidal-bar belts and platform-interior blanket sands (Purdy, 1963; Ball, 1967; Loreau and Purser, 1973). If the oolite lithofacies of the Carrara Formation clearly represented any one of these environments, clues to its environment of deposition should be found in the associated lithologies and the internal sedimentary structures. There are, however, few distinctive sedimentary structures in the oolite lithofacies. One of the most characteristic features of several types of modern oolite sand bodies is the spillover lobe, a series of convex upward cross-sets that may be truncated at their upper surface. The conspicuous absence of this structure from the oolite lithofacies suggests that the oolite is not a tidal-bar belt, bank-edge sand belt or tidal delta—oolite bodies that frequently contain spillover lobes. The mud content, grapestonelike grains, presence of burrows, and cementation horizons of the oolite lithofacies in sections in the Pahrump Hills, Eagle Mountain, Nopah Range, Winters Pass, and Striped Hills suggest that the best modern analog for this lithofacies is the platform-interior blanket sands of the Bahamian Platform described by Ball (1967, p. 573–576). In more westerly stratigraphic sections, such as in Titanothere Canyon and the southern Last Chance Range, the better sorted mud-free festooned nature of the oolite in the Red Pass Limestone Member indicates more active deposition, perhaps closer to an active sand belt. However, nowhere in the area of distribution of the Carrara Formation are there large-scale crossbeds that should characterize such a belt.

The narrowness of Holocene oolite shoals and sand belts studied by Ball (1967) contrasts with the outcrop pattern of the oolite lithofacies of the Carrara Formation (fig. 31). Few Holocene oolite shoal areas exceed 10 km in width. Given the structure and distribution of strati-

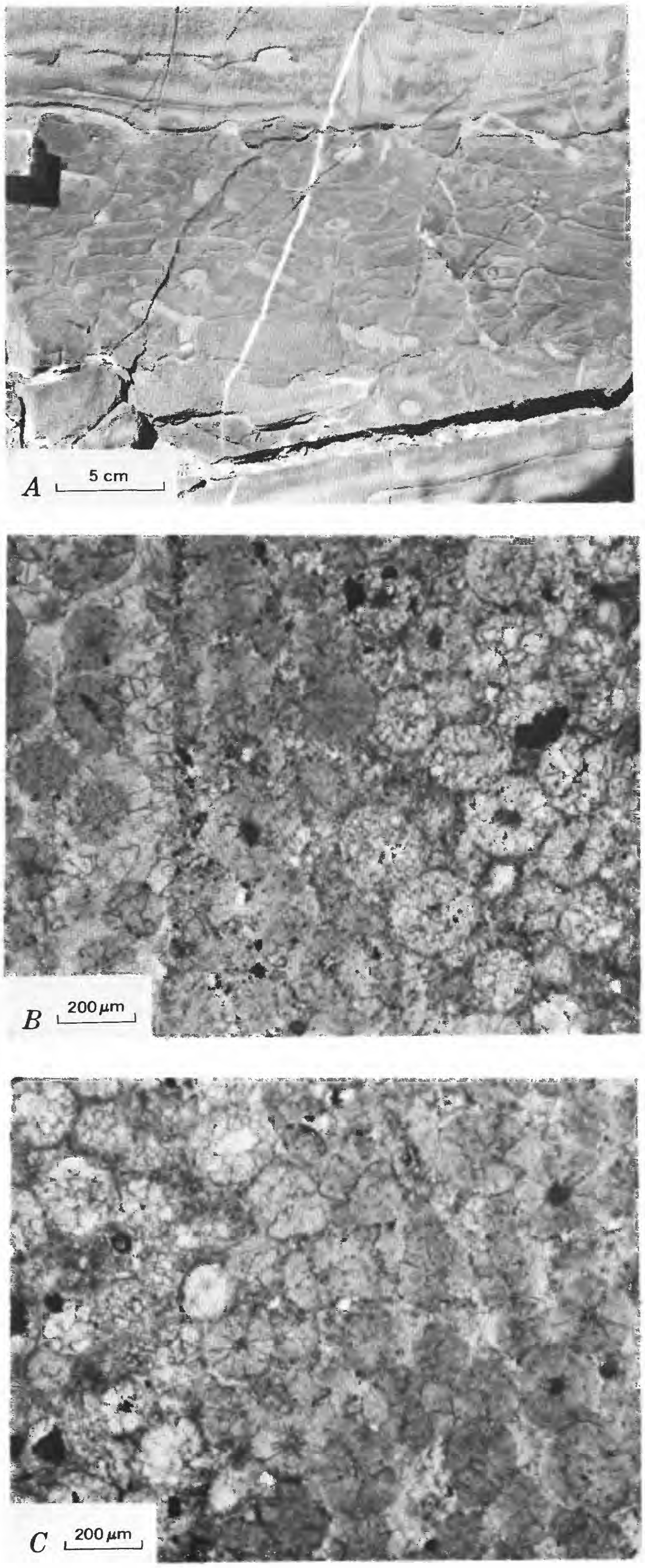


FIGURE 25.—Outcrop photo and photomicrographs of unusual oolite intraclast bed. *A*, Outcrop photo. The light outline of the clasts is a few millimeters within the clast. Jangle Limestone Member, Pahrump Hills section, Nevada. *B*, Photomicrograph of an intraclast margin. The intraclast-matrix boundary is the prominent vertical line in the left third of the photo. In the matrix, ooids are separated by blocky calcite cement; in the outermost wall of the clast, the ooids are similar to those in the matrix but are more closely packed; just inside this outermost wall, the ooids are recrystallized and the dark pigment in them is removed. These latter ooids form the light rim seen in the outcrop photo (*A*). *C*, Photomicrograph of the interior of an oolite clast illustrating the less recrystallized fabric of ooids in the clasts. The recrystallized ooids on the left form the light rim on the interior of the clast. Note that one ooid is replaced by a single crystal of calcite. ▶

graphic sections in the western part of the study area, it is possible that a narrow belt of oolite shoals could have existed near the western limit of the areas of shallow-water carbonate sediments. This belt, further suggested by the change in character of the oolite lithofacies in western sections, could have been the source for oolites that spread over the platform interior as a sand blanket.

The interpretation of most of the oolite lithofacies as a platform-interior sand blanket is supported by its geometry. The Holocene platform-interior sand blankets of the Bahama Platform described by Ball (1967) vary considerably in area from a minimum of 18,000 km^2 to a maximum of 240,000 km^2. The minimum area of a platform-interior sand blanket is considerably larger than the area covered by other types of sand bodies. The area covered by the oolite lithofacies of the Red Pass Limestone Member, about 40,000 km^2, is comparable with the areas covered by platform-interior sand blankets today. Width is also a distinguishing feature of these tabular sand bodies. Platform-interior sand blankets are usually much wider than other sand bodies which rarely exceed 50 km in width. With the exception of the Gold Ace Limestone Member, the oolite lithofacies of all other limestone members of the Carrara Formation exceed 50 km in width in the northwest-southeast direction.

Loreau and Purser (1973) stressed the point that the area of active ooid formation in the Persian Gulf is extremely small when compared with the area of ooid deposition. They suggest that in time a sheet of oolitic sand may develop whose geometry and magnitude will not reflect that of the ooid-forming environments. Such is believed to be the case for the major part of the oolite lithofacies of the Carrara Formation.

THE ALGAL-BOUNDSTONE LITHOFACIES

The algal-boundstone lithofacies is the most heterogeneous of the carbonate lithofacies of the Carrara Formation. The primary mineral composing this facies is low-magnesium calcite; however, dolomite is a much more important secondary mineral in this facies than in the mudstone or oolite facies. Other accessory minerals are clays, chlorite, feldspar, pyrite, and quartz.

As with the lime-mudstone lithofacies, the dominant grains of the algal-boundstone lithofacies are micrite, microspar calcite, and dolomite; pellets are the most common allochems. Other grain types frequently found in this facies are ooids, skeletal grains, lithoclasts, and oncolites. These larger grains are comparable to those described earlier for the lime-mudstone lithofacies, and there is no need to redescribe them here. Although composition of the limestone is important in the mudstone and oolite lithofacies, the fabric of the limestone is most important in the algal-boundstone lithofacies.

The most characteristic fabric of the algal-boundstone lithofacies is lamination, commonly found in medium and thick beds of limestone or dolomite. Individual laminae are usually horizontal or subhorizontal and vary in thickness from a minimum of 0.1 mm to a maximum of 1 cm but are usually about 1 mm in thickness. Successive laminae are produced by variations in color, grain size, clay content, or, where preserved, pellet size.

The laminated units form beds 10 cm–1 m thick. The laminations themselves may be relatively flat and even (figs. 26*C*, top 26*D*), may be wavy and appear rippled (fig. 26*B*), or may be uneven and crinkly (figs. 26*A*, 26*C* bottom). Small cut-and-drape structures are common. Occasionally, the drapes are vertical or even overhanging. Rarely, laminations are convex upward forming small stromatolites as much as 10 cm high and 20 cm in diameter. Presence of oversteepened laminations suggests that some sedimentary agent other than gravity influenced their accumulation. The most probable agent was algae. Some Holocene algae form mats which trap and bind sediment particles in successive layers on the surfaces with any attitude. Aitken (1967, p. 1164) has applied the term "cryptalgalaminates" to carbonate rocks possibly formed by such algal activity.

Dolomite cryptalgalaminates in the algal-boundstone lithofacies are quite different from the replacement dolomites of the lime-mudstone and oolite lithofacies. They are usually composed of micrite-sized grains of dolomite which are not stained with iron oxide. Dolomite rhombs are absent (fig. 26*D*). The color of these dolomites in a fresh surface is black, but they weather orange on exposed surfaces. Staining with potassium ferrocyanide (Evamy, 1963) shows that these are ferroan dolomites.

Cryptalgalaminates are interbedded with the other lithologies of the algal-boundstone lithofacies. Where the cryptalgalaminate is overlain by grainstones, a characteristic intraclast bed is formed (fig. 26*E*). Flat clasts of laminated limestone or dolomite, identical to the cryptalgalaminate lithology, are strewn throughout the overlying grainstone. The contact between the two lithologies is erosional, and close inspection reveals clasts in all stages of separation from the underlying bed.

A variety of epigenetic features disrupts cryptalgalaminates. Mudcracks are common. They are usually seen in vertical section as "stacked plates" whose upturned edges are the margins of mudcrack polygons (fig. 26*F*). Some thicker beds of limestone within intervals of mudcracked laminated sediment are probably storm deposits. Other features of laminated limestones are areas of calcite-spar cement believed to be void fill. These characterize a class of limestones called dismicrites by Folk (1959), "birdseye limestones" by Ham (1954), loferites by Fischer (1964), and laminoid fenestral fabrics by Tebbutt and others (1965). In outcrop these fenestral fabrics are commonly found in thick, generally light col-

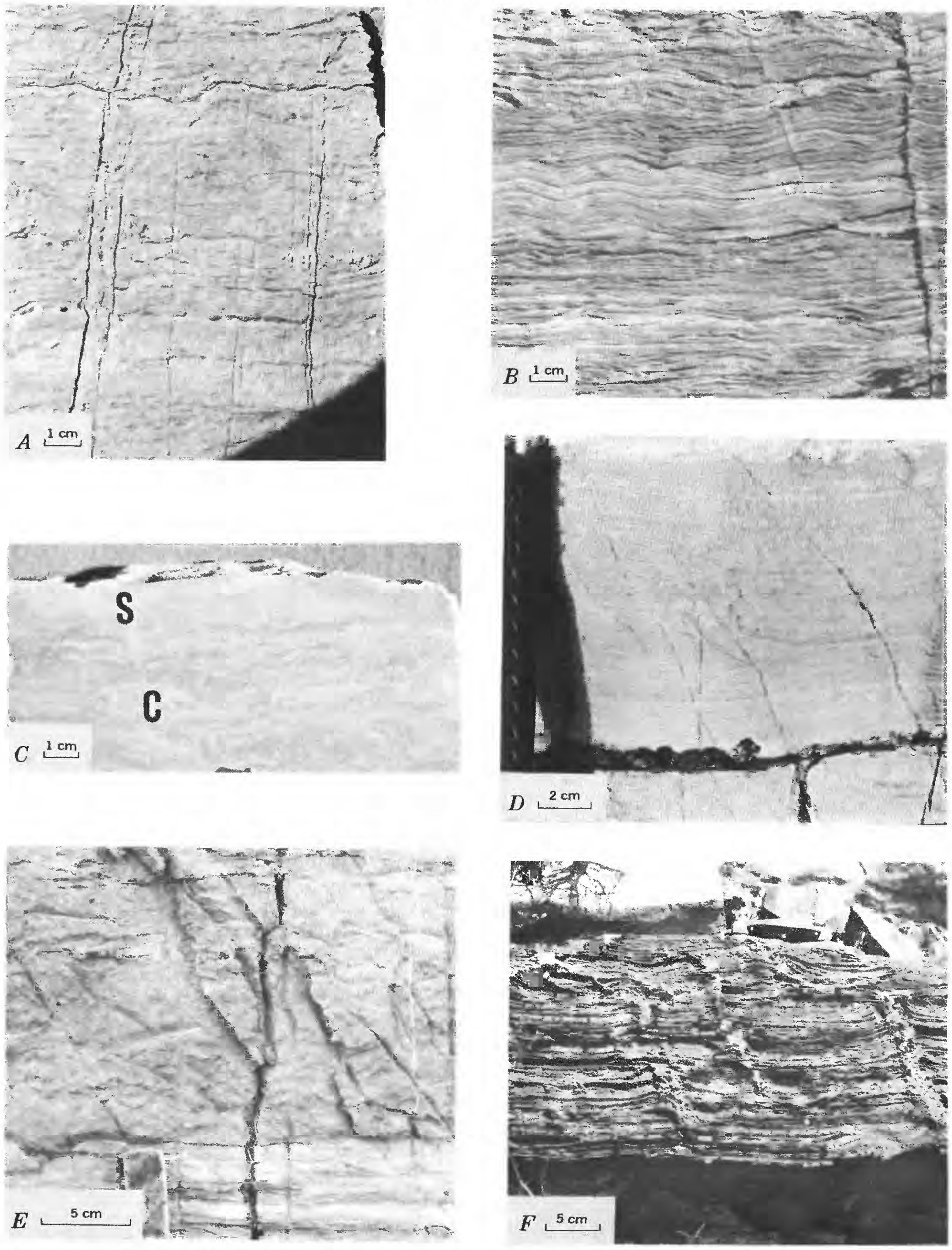


FIGURE 26.—Photographs of outcrops and vertical-cut surfaces of rocks of the algal-boundstone facies. *A,* Outcrop showing both wavy and irregular laminations in a cryptalgalaminate. Dark laminations contain more iron oxide and weather darker orange on the surface. Red Pass Limestone Member, southern Last Chance Range section, California. *B,* Outcrop showing both even and wavy laminations in a cryptalgalaminate. Pahrump Hills Shale Member, Striped Hills section, Nevada. *C,* Cut vertical surface of cryptalgalaminate illustrating sharp vertical break between crinkly laminations (C) in the lower ¼ of the sample and smooth laminations (S) in the upper ¼. Note oversteepened laminations in the crinkly laminated portions. Jangle Limestone Member, southern Last Chance Range section, California. *D,* Outcrop of cryptalgalaminate composed of dolomite. Note even lamination and small cut-and-drape structure. Pahrump Hills Shale Member, southern Last Chance Range section, California. *E,* Outcrop of cryptalgalaminate overlain by grainstone. Erosional contact between them is indicated by the small channel to the left of the hammerhead. Flat pebble intraclasts in the grainstone are identical to the underlying laminated bed. Jangle Limestone Member, Eagle Mountain section, California. *F,* Outcrop illustrating mudcracks in laminated limestone. Jangle Limestone Member, southern Last Chance Range, Calif.

ored, pink, cream, or white beds where the spar forms equant, irregular, or planar dark areas (fig. 27*A*). However, some units are black and the spar-filled voids are white (fig. 27*F*). Fischer (1964) called large planar spar-filled voids sheet cracks. In polished slabs and thin sections, some of these voids have irregularities in their ceilings that match irregularities in the floors, suggesting origin by desiccation shrinkage (figs. 27*B*, 27*C*). Some of the more irregular spar-filled voids have rather flat floors covered with silt-sized calcite grains termed "vadose crystal silt" by Dunham (1969) and "M_2" sediment by Fischer (1964) (figs. 27*B*, 27*C*). The matrix of these fenestral limestones is a pelleted micrite (fig. 27*D*). In some examples, laminae between fenestrae have been disrupted and appear broken and dislodged like clasts (fig. 27*E*). Such brittle movement, rather than bending, suggests a cemented crustlike layer.

In some fenestral limestones it is difficult to demonstrate that the sparry areas ever were voids; however, large sparry areas in an otherwise pelletal micrite, even when unsheltered, almost certainly must be void fill (fig. 28*A*). In plan view the filled voids also appear as discrete areas of calcite spar (fig. 28*C*). In many instances of recrystallization, the pelleted texture of the matrix is destroyed, but the sparry areas are still recognizable (fig. 28*B*).

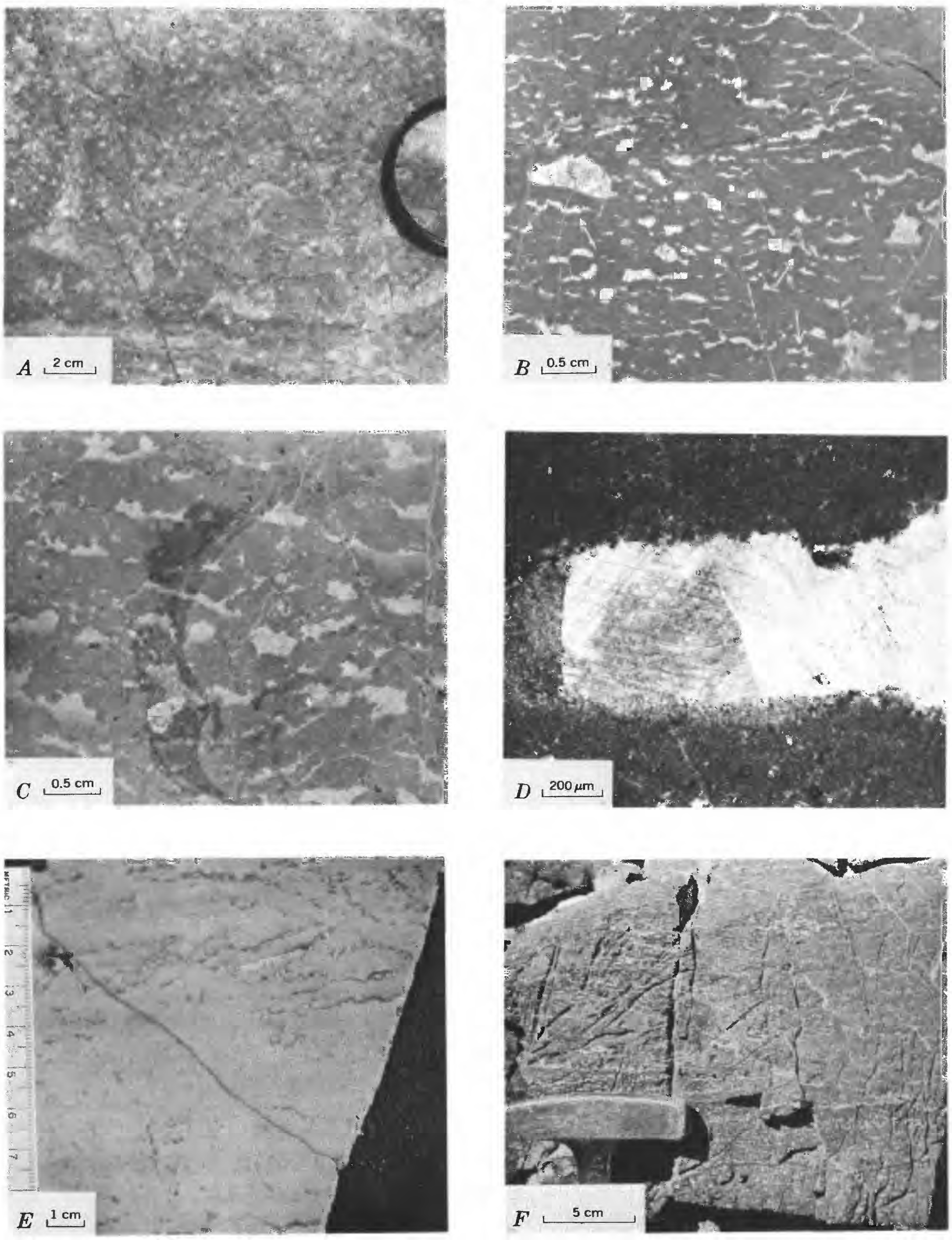
Many of the more irregular calcite-void fills are difficult to interpret as desiccation voids. Some have formed in discrete horizons within beds that show no other signs of desiccation (fig. 28*D*). Others are very large and irregular (fig. 28*E*), and in thin section they are characterized by rounded margins with many rounded protuberances projecting into the calcite spar (fig. 28*F*). Some fenestral limestones are characterized by spar-filled areas that are irregular, elongate, and subhorizontal, imparting a wavy spongy fabric to the limestone (figs. 29*A*—*C*). These fenestral limestones are most like the loferites of Fischer (1964) and characteristically have areas in which the spar and micrite contain a ramifying network of large tubes, perhaps very large algal filaments (fig. 29*D*). If these are algal tubes, however, they are an order of magnitude larger than *Girvanella* tubules.

Large stromatolites are rare in the algal-boundstone facies of the Carrara Formation. Their principal occurrence is in limestones at the base of the formation in the southern Last Chance Range. These stromatolites are poorly laminated and form biostromes, about 1 m in diameter and 0.5 m high, disrupting the surrounding thin-bedded grainstone (fig. 30*A*). The laminations are formed by alternations of micrite and microspar calcite or micrite and quartz silt (figs. 30*B*–*D*).

In addition to fenestral carbonates, mudcracked limestones, and cryptalgalaminates, the algal-boundstone lithofacies includes interbeds of grainstones, lime mudstones, oncolitic lime mudstones, and, occasionally, shales. There appears to be no pattern in either the detailed stratigraphic succession of these lithologies or their areal distribution. In the Jangle Limestone Member, their distribution approaches a facies mosaic (Laporte, 1967), perhaps reflecting relative sea level.

The distribution of the algal-boundstone lithofacies in each of the limestone members of the Carrara Formation, or correlative beds, is shown in figures 31 and 32. This lithofacies is characteristically light colored and forms distinct white bands in outcrops. Locally, the light coloration extends downward into the oolite lithofacies. In the Lower Cambrian members, this lithofacies is found only in their western correlatives—in the lower part of the Mule Spring Limestone at Cucomungo Canyon and in the lower and upper parts of the Mule Spring Limestone at Paymaster Canyon and in the Goldfield Hills. The western limit of the lithofacies in the Lower Cambrian is not known. In the Middle Cambrian members, this lithofacies is restricted to their upper and more oceanward parts. In the Red Pass and Jangle Limestone Members both the northwestern and southeastern margins of the algal-boundstone lithofacies may be roughly delineated. In both members the northwestern margin approximately corresponds to the area of transition be-

FIGURE 27 (facing page).—Photographs of outcrops, vertical-cut surfaces, and thin sections of rocks from the algal-boundstone lithofacies. *A*, Outcrop photo of fenestral limestone illustrating two geometries of spar-filled voids. The upper half of the photo is characterized by equant coarse sand and granule-size dark sparry areas, and the lower half, by elongate sheet cracks in a laminated lime mudstone. The white areas are abrasion features in the rock surface. Jangle Limestone Member, Eagle Mountain section, California. *B*, Photomicrograph of fenestral limestone illustrating some former voids (shown by arrows) with matching irregularities in their floors and ceilings although others are more irregular or equant and have flat geopedal floors lined with crystal silt. Jangle Limestone Member, Pyramid Peak section, California. *C*, Photomicrograph of fenestral limestone illustrating crystal silt partly infilling many of the voids. Note the dense pelletal nature of the matrix. Dark area in center is an imperfection in the thin section. Jangle Limestone Member, Pyramid Peak section, California. *D*, Photomicrograph of spar-filled void with a thin accumulation of crystal silt over its floor. Matrix is a very dense pelleted micrite. Jangle Limestone Member, Eagle Mountain section, California. *E*, Vertical-cut surface of fenestral limestone which is algally laminated and contains sheet cracks and more equant voids filled with calcite as well as some vertical burrows or gas-escape structures. The sharp truncation and rotated clast in the top center suggests consolidation, if not cementation, early in the history of this rock. Red Pass Limestone Member, Echo Canyon, Calif. *F*, Outcrop photo of fenestral fabric developed in a black dolomite. Top of the Mule Spring Limestone, Paymaster Canyon, Nev. ▶



tween the Carrara and Emigrant Formations although the actual transition between these formations is not exposed. The southeastern boundaries of this lithofacies in the two members differ only at Eagle Mountain where the algal-boundstone facies is present in the Jangle Limestone Member and absent in the Red Pass Limestone Member.

ENVIRONMENT OF DEPOSITION

The algal-boundstone facies is the most specifically interpretable lithofacies of the Carrara Formation in terms of recent carbonate depositional environments. In all studied major carbonate-mud-producing areas, the intertidal and supratidal zones display a very similar

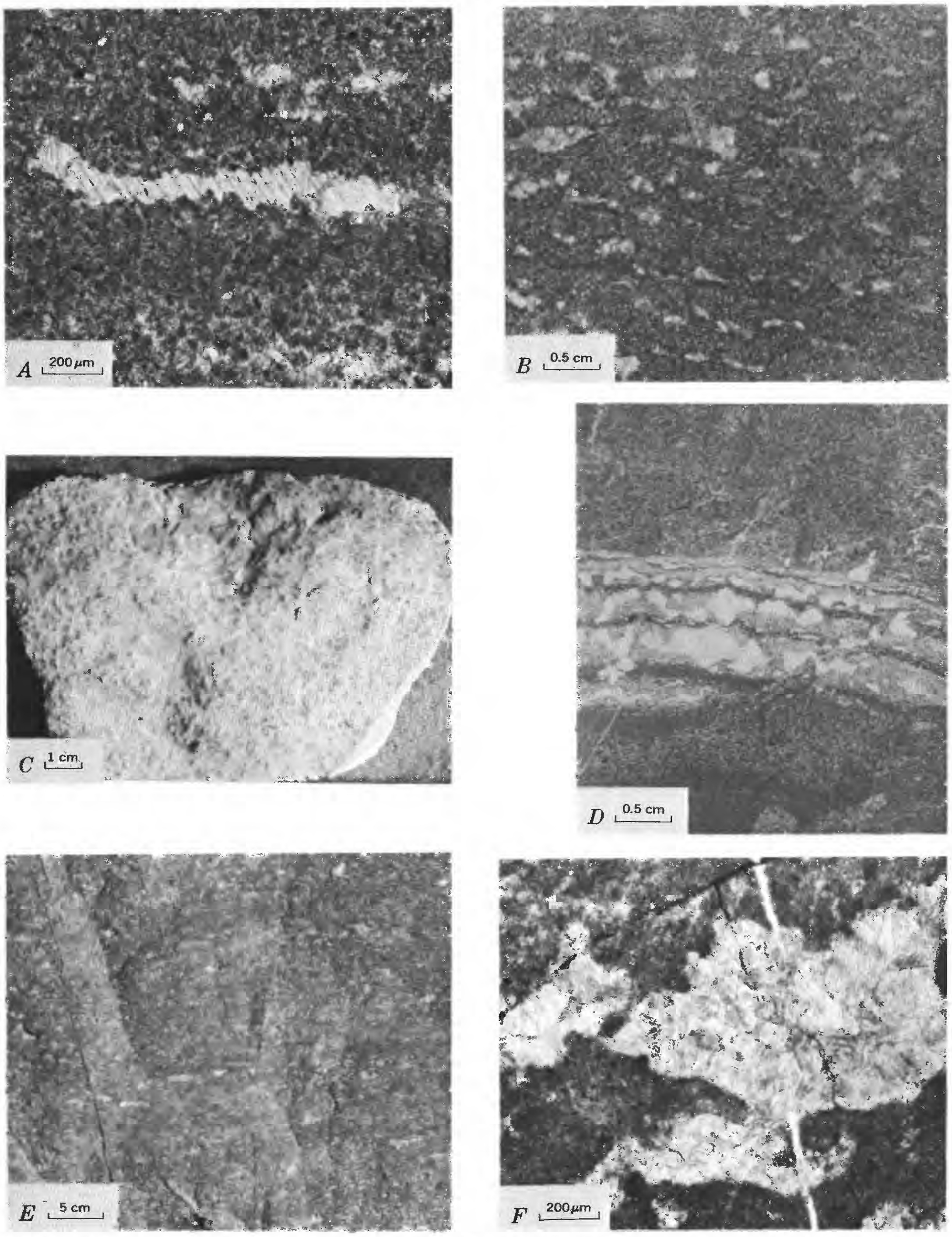


FIGURE 28.—Photographs of outcrops, float specimens and thin sections of rocks from the algal-boundstone lithofacies. *A*, Photomicrograph of unshadowed sparry area in pelletal lime mudstone, assumed to be primary void. Mule Spring Limestone, Paymaster Canyon section, Nevada. *B*, Photomicrograph of recrystallized fenestral limestone illustrating vague lamination although the sparry areas are still clearly visible. Mule Spring Limestone, Paymaster Canyon, Nev. *C*, Weathered surface of fenestral limestone illustrating the discrete nature of voids in plan view. Jangle Limestone Member, Echo Canyon section, California. *D*, Photomicrograph of isolated, irregular sparry areas of calcite in a laminated ferroan dolomite. Note the rounded edges of the sparry areas. These features are not clearly desiccation structures. Jangle Limestone Member, southern Last Chance Range section, California. *E*, Outcrop photo of large irregular sparry areas (light gray) developed in several localities immediately below more normal fenestral limestones. Red Pass Limestone Member, Titanothere Canyon section, California. *F*, Photomicrograph of a sparry area similar to those pictured in *E*. Note the well-rounded margins of the sparry area and the rounded protuberances of micritic matrix extending into the calcite spar. Jangle Limestone Member, Pyramid Peak section, California.

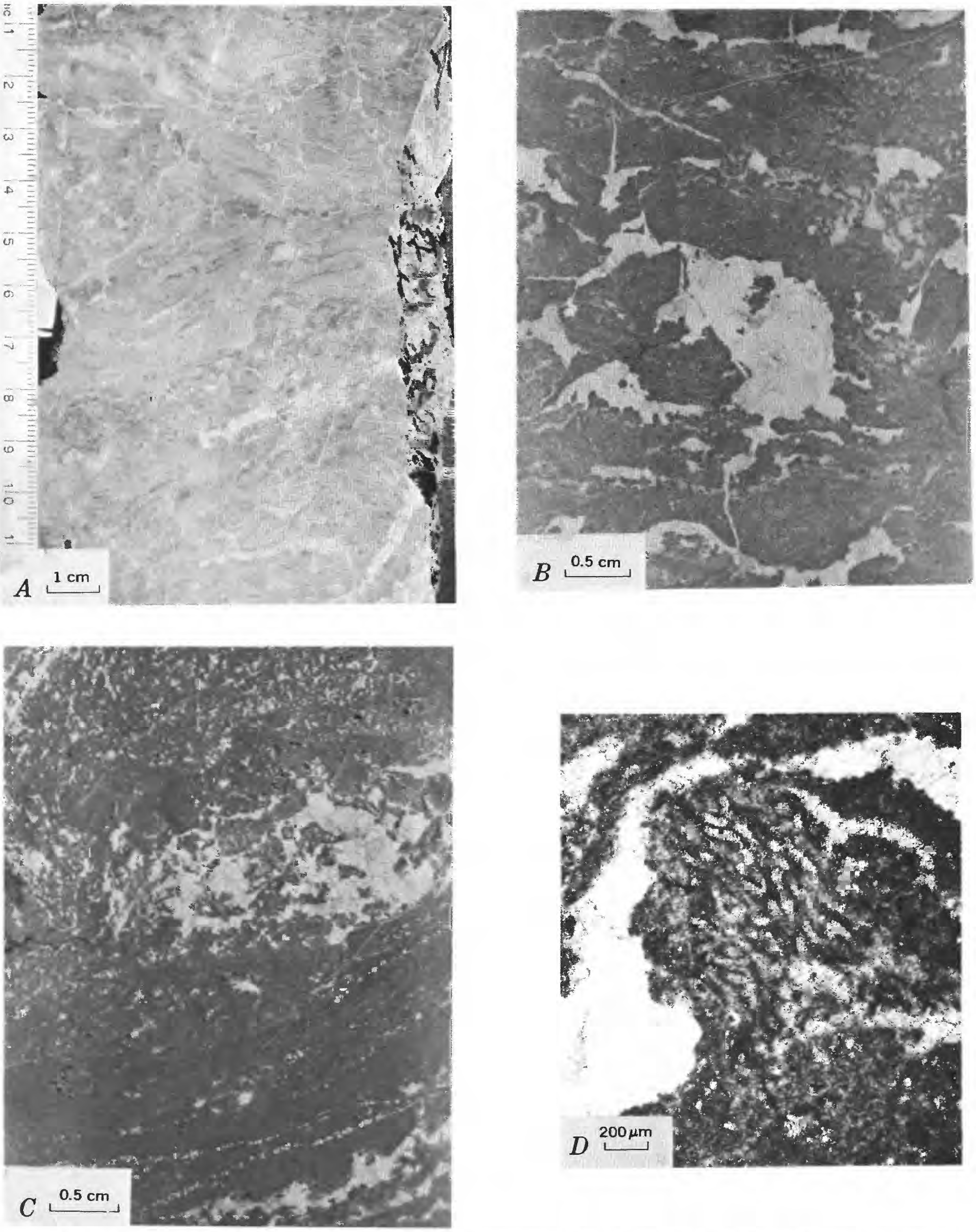


FIGURE 29.—Photographs of vertical-cut surfaces and thin sections of rocks from the algal-boundstone lithofacies. *A*, Vertical-cut surface of wavy fenestral limestone. Rock is irregularly laminated and contains numerous truncations of subhorizontal laminations. Dark laminations are calcite spar. Jangle Limestone Member, Eagle Mountain section, California. *B*, Photomicrograph of a thin section from specimen of *A* showing fine laminations in the micrite matrix between areas of massive calcite spar. *C*, Photomicrograph of a thin section from specimen of *A*. The laminations in the lower half of the photo are caused by stringers of quartz silt. The spongy appearance of the upper half of the photo is characteristic of this loferitelike lithology. *D*, Photomicrograph of an area of micrite matrix showing a ramifying network of probable algal-filament molds. These features have been found in many of the fenestral limestones and in some of the clasts of a beachrock-like conglomerate at the interface between the lime-mudstone and algal-boundstone lithofacies. Jangle Limestone Member, Eagle Mountain section, California.

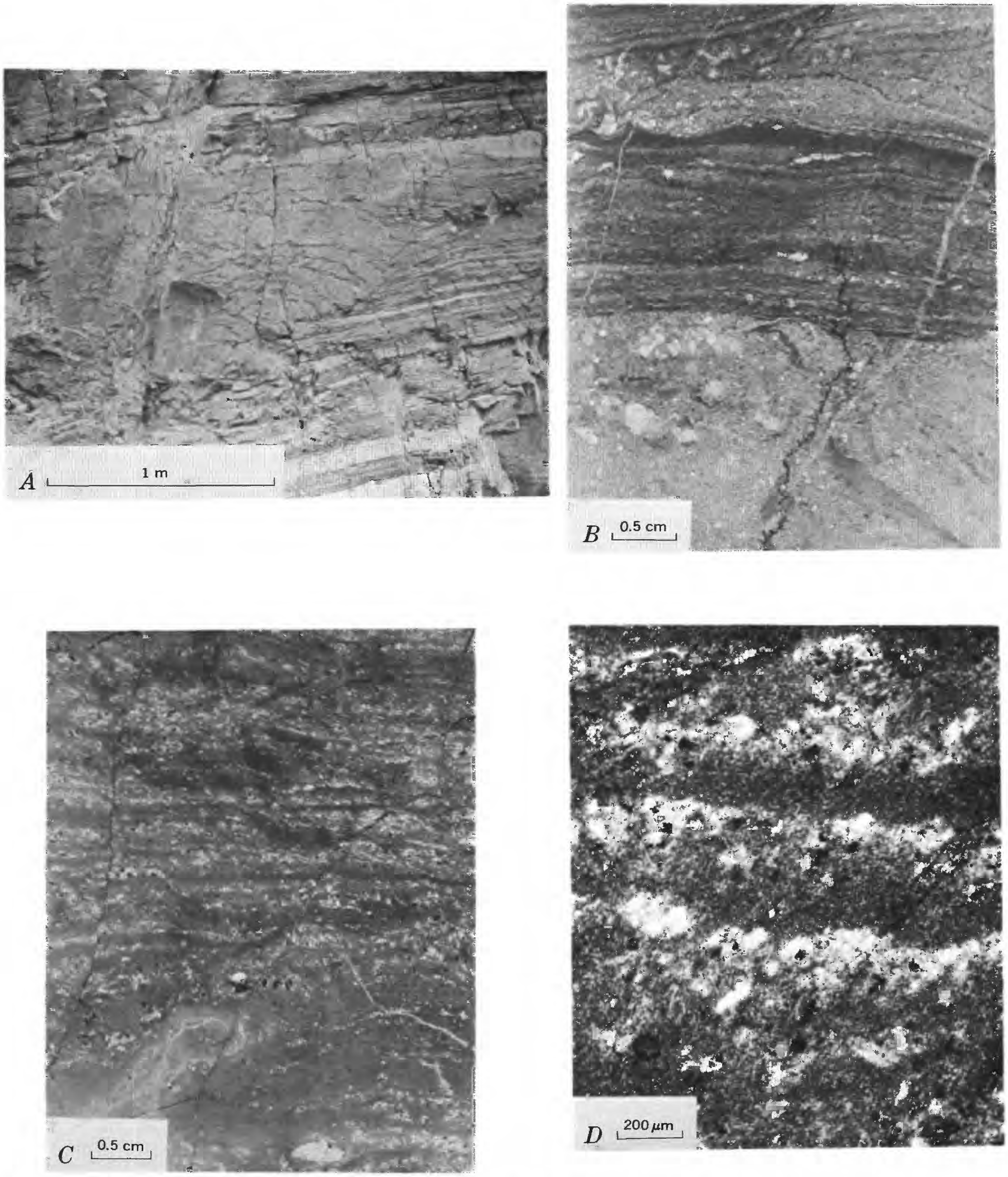


FIGURE 30.—Outcrop photo and photomicrographs of rocks from the algal-boundstone lithofacies. *A*, Outcrop photo of an algal biostrome in thin-bedded lime mudstone and grainstone. Eagle Mountain Shale Member, southern Last Chance Range section, California. *B*, Photomicrograph of algal laminations within a stromatolite illustrating the grain-size variation in successive laminations. Dark laminae are micrite; light laminae are microspar. Eagle Mountain Shale Member, southern Last Chance Range section, California. *C*, Photomicrograph of algal laminations within a stromatolite. These laminations are formed by successive alternations of micrite and quartz-silt laminae. The irregularity of the laminations leads to a poorly laminated structure. Eagle Mountain Shale Member, southern Last Chance Range section, California. *D*, Detail of *C* illustrating quartz-sand and micrite laminae.

array of sedimentologic criteria that identify these environments in ancient limestones. Often it is difficult to separate sediments deposited in the intertidal zone from those deposited in the supratidal zone and both are lumped together as peritidal deposits. Algally laminated pelletal mudstones, stromatolites, fenestral limestones, mudcracks, crusts, and flat-pebble conglomerates characterize the intertidal and supratidal zones of southern Florida (Ginsburg, 1957; Gebelein, 1971), Andros Island, Bahamas (Shinn and others, 1965, 1969; Gebelein, 1973), the Abu Dhabi area of the Persian Gulf (Kendall and Skipwith, 1968), and Shark Bay, Western Australia (Logan and others, 1970). In addition, the Persian Gulf and Shark Bay areas are in regions whose annual rainfall is less than 22 cm per year, and the peritidal deposits include well-developed evaporites.

The algal-boundstone lithofacies of the Carrara Formation and the peritidal deposits of south Florida and the Bahamas share all the common features of peritidal carbonates as well as the special textural features of their fenestral limestones. Molds of very large algal filaments resembling those in figure 29*D* have been recognized in fresh and brackish water algal marshes (Shinn and others, 1969, p. 1211; Monty, 1967, 1972). These features are restricted to humid areas of moderate rainfall where brackish and fresh water stand for long periods of time during the year.

In contrast, major differences exist between the algal-boundstone lithofacies of the Carrara Formation and the peritidal deposits of the Persian Gulf and Shark Bay. Although evidence for some evaporites (in the form of salt-crystal casts) exists in the Pahrump Hills Shale Member, no evidence was found for massive evaporite deposition. Furthermore, in the highly saline waters of Shark Bay, high-relief stromatolites are well developed (Logan, 1961; Logan and others, 1964). Although high-relief stromatolites are common in many Cambrian limestones, they are conspicuously rare in limestones of the Carrara Formation.

Thus, the near absence of evaporites and high-relief stromatolites and the presence of large algal-filament molds associated with the typical features of desiccation and exposure characteristic of Holocene peritidal environments strongly suggest that algal-boundstone lithofacies of the Carrara Formation accumulated as a peritidal deposit in a rather humid environment perhaps comparable to the Bahamas and south Florida where the annual rainfall is 100–150 cm.

The absence of peritidal features in the Emigrant and Monola Formations to the west—and in many of the eastern sections of the Carrara Formation—suggests that the peritidal deposits in the Carrara Formation formed as local low-carbonate islands on the western half of a carbonate platform.

SPATIAL RELATIONS OF THE CARBONATE LITHOFACIES

The limestone and shale members of the Carrara Formation reflect the dynamic interaction between predominantly western limestone lithosomes and predominantly eastern terrigenous clastic lithosomes. The key to understanding this interaction lies in the correct interpretation of the spatial relations of the depositional environments represented by the lime-mudstone, oolite, and algal-boundstone lithofacies. Although faunal control within the Carrara Formation is an adequate aid for identification and correlation of the members, it is insufficient for correlation of lithofacies within members. The consistent presence of trilobites of the *Olenellus multinodus* Zonule just above the top of the Gold Ace Limestone Member, and trilobites of the *Glossopleura* Zonule just above the top of the Jangle Limestone Member, together with the sharply defined stratigraphic tops to all the limestone members, suggests that the tops of the members are approximately synchronous throughout the study region. Thus, the regional distribution of the three carbonate lithofacies in the upper part of each of the limestone members probably reflects the real areal distribution of these lithofacies (fig. 31).

The lime-mudstone, oolite, and algal-boundstone lithofacies appear, respectively, to be deposits of a shallow protected subtidal carbonate platform, a subtidal platform-interior sand blanket (perhaps east of an oolite shoal), and peritidal zones around islands that formed on the western part of the carbonate platform. Although the three environments represented by the carbonate lithofacies did not coexist during all the time represented by the deposition of the Carrara Formation—or even of one limestone member—each of the environments coexisted with one or more of the others for significant periods of time.

Rocks of the algal-boundstone lithofacies are restricted both geographically and stratigraphically. They are found primarily in the western exposures of the limestone members or their western correlatives, and they are usually found only in the upper beds of these units. The algal-boundstone lithofacies certainly coexisted with the lime-mudstone lithofacies. Most of the sediment in the peritidal zone (algal-boundstone lithofacies) does not originate in this environment. The sediment originates as carbonate mud or pelleted mud in the adjacent subtidal areas and is transported to the peritidal zone catastrophically. Hardie and Ginsburg (1971) have shown that algally laminated sediments in the intertidal zone of An-

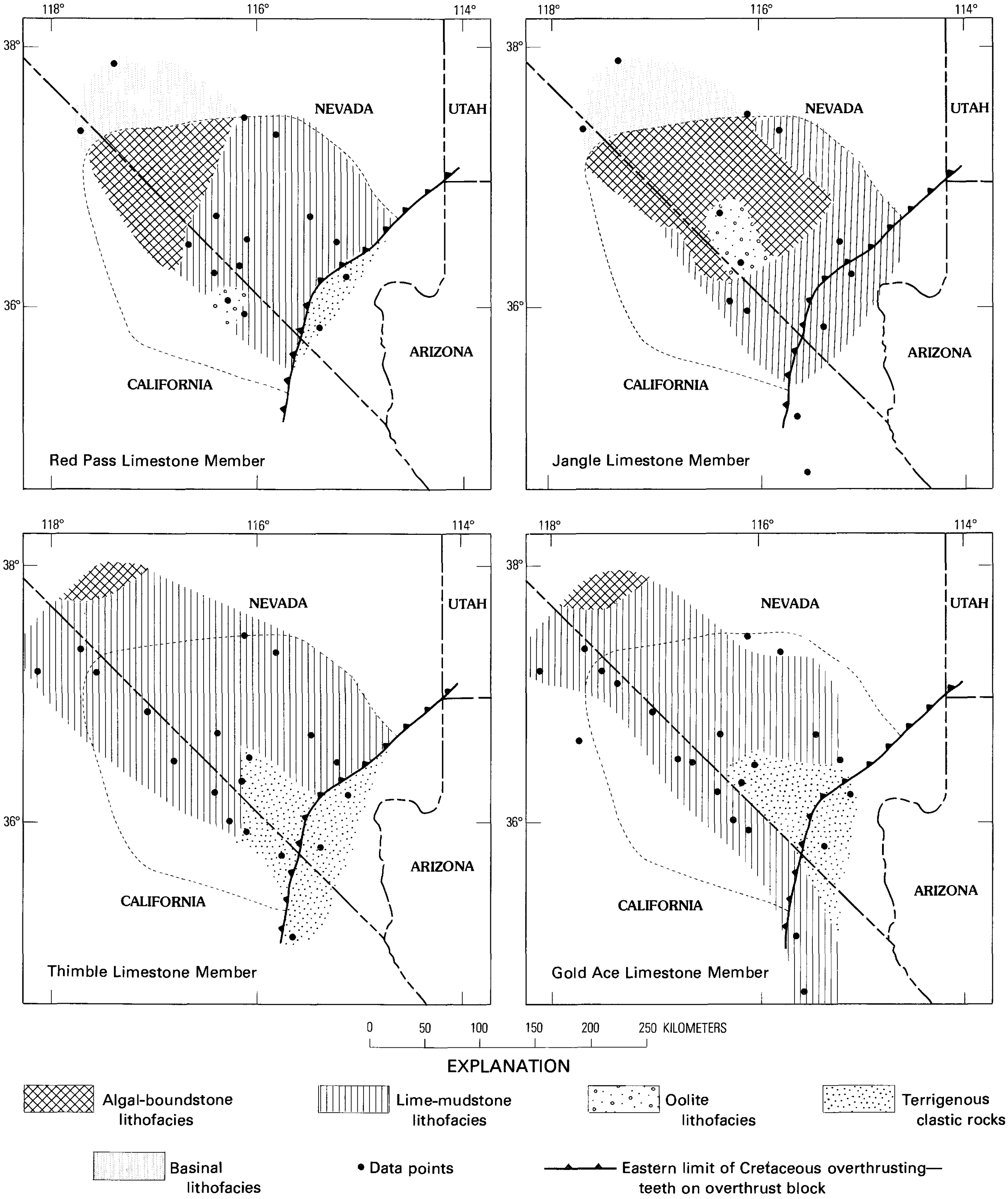


FIGURE 31.—Lithofacies distribution maps for the top of each limestone member of the Carrara Formation. Dotted line, limit of Carrara Formation.

dros Island are deposited only following major storms, perhaps as seldom as three times a year. Thus, any peritidal carbonate deposit requires a contemporaneous nearby subtidal carbonate-mud-producing area. The subtidal protected mud platform adjacent to Andros Island is the source of sediment for the Holocene tidal flats on its west side. By analogy with the Holocene, the sediments of the lime-mudstone facies of the Carrara Formation were the probable source materials for the peritidal algal-boundstone facies.

Proof of this relationship is found at Pyramid Peak in the Funeral Mountains, Calif. There, the algal-boundstone cap of the Red Pass Limestone Member consists of a fenestral limestone that grades laterally, over a distance of about 40 m, through a medium-bedded crossbedded rounded intraclast conglomerate into a thin-bedded lime mudstone (fig. 33). The intraclast conglomerate contains lithologies similar to those of the adjacent fenestral limestone. The intraclasts are surrounded by a well-developed zoned rim cement similar to that of many beach-rock cements (Moore, 1971, 1973; Taylor and Illing, 1971).

The stratigraphic distribution of the oolite and lime-mudstone lithofacies in the Red Pass Limestone Member at different localities strongly suggests that sediments of both these lithofacies coexisted at various times and that the oolite lithofacies predominated in the more westerly sections (fig. 32). A similar although less distinct areal relationship for these lithofacies existed for the other limestone members (fig. 32).

The oolite and algal-boundstone lithofacies are locally interbedded in the Jangle Limestone Member. The lithofacies probably coexisted locally. Exposures showing a lateral transition, comparable to that between the algal-boundstone and lime-mudstone lithofacies, have not been seen.

DEPOSITIONAL MODEL

The members of the Carrara Formation constitute four complete, and one partial, generalized asymmetrical sedimentary cycles composed of marine shale-limestone member-pairs. Each cycle begins with terrigenous clastics, shows a gradual upward change to increasingly cleaner carbonate sediments, and is terminated by an abrupt return to terrigenous clastic sedimentation. Such asymmetrical cycles on vertical scales of tens to hundreds of meters have been described as Grand Cycles in the Cambrian and Ordovician sequences of the southern Canadian Rocky Mountains (Aitken, 1966). The model proposed here for the genesis of the cycles in the Carrara Formation, which are comparable to the smaller Grand Cycles of Aitken, is probably applicable to other Cambrian and Ordovician Grand Cycles.

The key to the model is the pattern of lithofacies relationships that develops in the upper contact areas of each of the limestone members of the Carrara Formation. The abrupt appearance of peritidal deposits in the upper and western parts of the limestone members marks a striking contrast in style of deposition to the tens of meters of subtidal carbonates and terrigenous clastics deposited below. This event seems also to be correlated with a rapid westward spread of terrigenous clastic sediments. Both phenomena could be explained by invoking a marine regression caused by sea-level lowering or basinal uplift. However, some facts are inconsistent with this interpretation, and other evidence suggests that it is unlikely. In a region which must have undergone net crustal subsidence to accumulate hundreds of meters of shallow-marine sediments—and at a time when the paleogeographic history of western North America involved inundation of the continental interior—sea-level lowering or basinal uplift (both of which represent reversals of long-term trends) would be anomalies. Furthermore, both basinal uplift and sea-level lowering, unless they ceased as soon as carbonate islands and associated peritidal deposits formed, would have led to disconformities and to associated vadose sedimentary features or solution phenomena. These were searched for and not found within the Carrara Formation. The model proposed below for the production of the Grand Cycles of the Carrara Formation is based on variation in the rate of basin subsidence (or sea-level rise). This model explains more of the observed data than models invoking tectonic emergence or eustatic sea-level fall. It can be best understood if Holocene controls on the appearance, migration, and disappearance of depositional environments similar to those of the Carrara Formation are considered.

In all areas of Holocene peritidal carbonate-mud accumulation, the active area of carbonate-mud generation is only a few kilometers wide at most, and it is usually much less. Very wide accumulations of peritidal deposits develop through progradation—the seaward accretion of shorelines by continued sedimentation in the intertidal and supratidal zone. Only through progradation could the peritidal deposits of the Carrara Formation reach the areal extent illustrated by the distribution of the algal-boundstone lithofacies (fig. 31). The widespread development of a thin stratigraphic interval representing this lithofacies near the top of the Red Pass Limestone Member in the west, and its eastward interfingering with subtidal lime mudstone, suggests that it resulted from a single progradational event away from a carbonate island that developed near the western margin of the subtidal carbonate platform. Numerous interbeds of the algal-boundstone lithofacies and the lime-mudstone lithofacies in the more westerly exposures of the Jangle Limestone Member suggest that these peritidal deposits may have originated as a series of islands that appeared, coalesced, and disappeared or remained with subtidal channels and protected mud areas between them. Most of the sediment for the construction of these islands probably came from the broad shallow carbonate-mud-producing platform to the east of the islands, although some sediment may have been supplied initially from their westward side. If a complete barrier was established, all the sediment for eastward progradation must have come from the shallow subtidal carbonate-mud platform to the east.

The appearance and progradation of peritidal deposits over subtidal carbonates and clastics in the Carrara Formation is similar to Holocene sedimentary records resulting from progradation of peritidal sequences in the Persian Gulf and the Bahama Islands. In these areas progradation began after a rapid decrease in the rate of sea-level rise. The change in the rate of sea-level rise was almost an order of magnitude, from about 10 m per 1,000 years to 1–2 m per 1,000 years (Bloom, 1971). At Abu Dhabi in the Persian Gulf the progradation started about 4,000 years B.P. (Evans and others, 1969). On the west side of Andros Island in the Bahamas, the progradation may have started as much as 7,000 years B.P. (Gebelein, 1973).

The most recent change in rate of sea-level rise is related to melting of the Pleistocene ice cap. However, an apparent decrease in the rate of sea-level rise could also be caused by continuous sedimentation and a decrease in the rate of tectonic subsidence. Whatever the cause, decrease in the rate of sea-level rise does not drastically increase the absolute rate of sedimentation; it only increases the apparent rate of sediment supply by decreas-

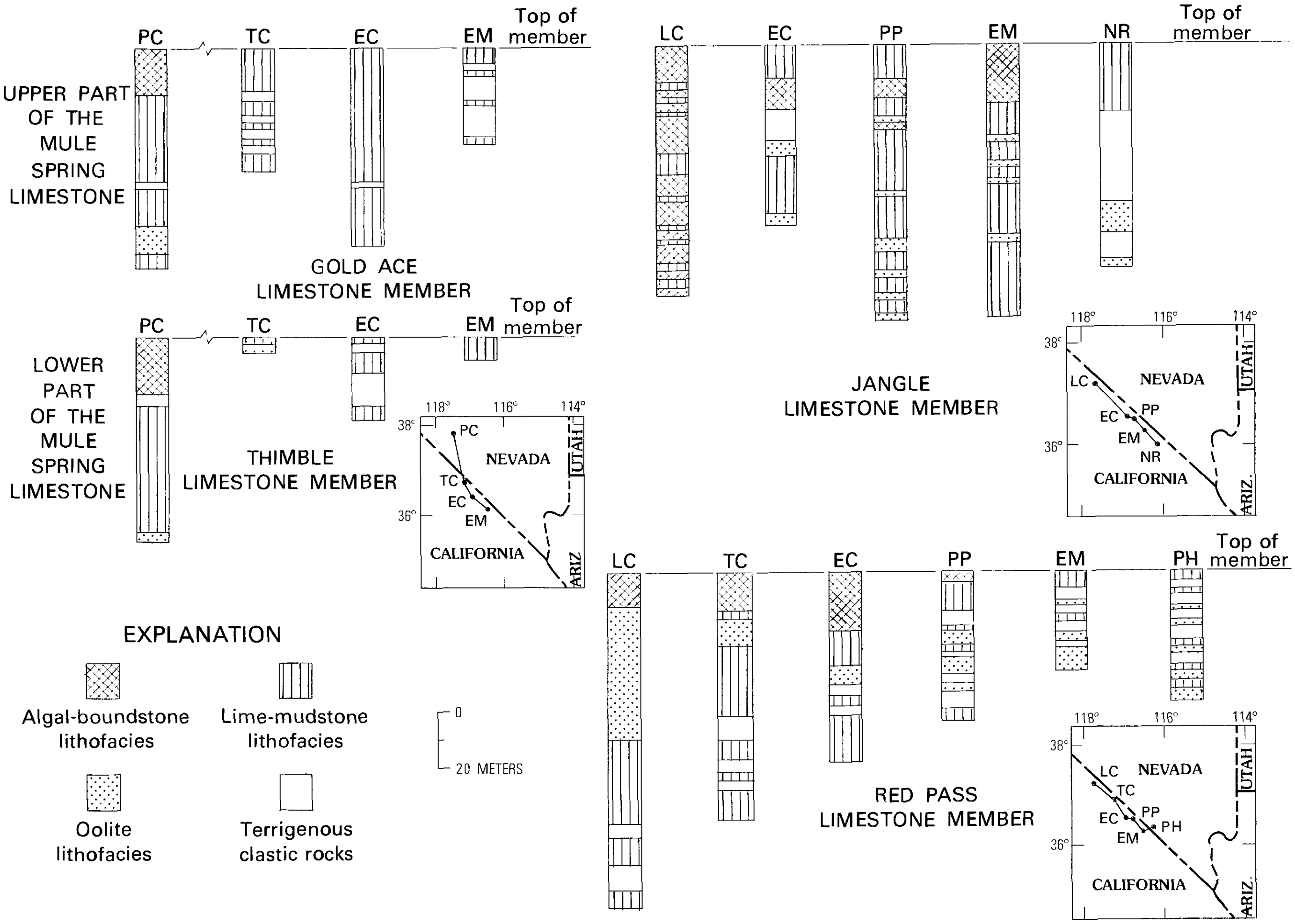


FIGURE 32.—Stratigraphic sections of Jangle, Red Pass, Gold Ace, and Thimble Limestone Members of Carrara Formation, showing details of lithofacies distribution and, for the Gold Ace and Thimble Limestone Members, relations to their western correlative, the Mule Spring Limestone. LC, Last Chance Range; EC, Echo Canyon; PP, Pyramid Peak; EM, Eagle Mountain; NR, Nopah Range; PC, Paymaster Canyon; TC, Titanothere Canyon.

ing the available space within which sediments can accumulate, thus forcing lateral spread of shoreline environments into the sea.

The absolute decrease in the rate of sea-level rise by about a factor of ten in the Holocene seems to have been sufficient to allow the belt of peritidal sediments to prograde seaward in the Persian Gulf and the Bahamas. A similar decrease in the rate of sea-level rise near the end of the time of deposition of each limestone member of the Carrara Formation could have caused the relative excess of carbonate mud required to initiate the peritidal deposition and the eastward progradation that has been observed.

A decrease in the rate of relative sea-level rise would also explain the westward spread of terrigenous clastics at about the same time as the eastward spread of peritidal carbonate rocks because both phenomena are sedimentologic responses to the same stimulus. During the time of deposition of the Gold Ace Limestone Member, clastic sedimentation predominated in the Pahrump Hills and Spring Mountains, and carbonate sedimentation predominated to the west (fig. 31). The abrupt upward change from limestone to shale at the top of the member and its western correlative, the Mule Spring Limestone, reflects a relatively rapid westward expansion of the area of terrigenous clastic deposition. Evidence for westward expansion of terrigenous clastics at this time includes the eastward and upward coarsening of the overlying Pyramid Shale Member. In addition, the upper part of the Mule Spring Limestone to the west is slightly younger than the top of the Gold Ace Limestone Member (Palmer, 1971), and it is composed of peritidal carbonate rocks.

Relations between the areas of shallow-shelf sedimentation and basinal sedimentation during Grand Cycle development provide important additional clues about the dynamics of Grand Cycle formation. Although the lateral westward transition from shallow marine carbonates to the basinal facies is nowhere exposed in the study area, vertical transitions are included within sections in the Groom Range, Belted Range, Paymaster Canyon, Cucomungo Canyon, and the Inyo Mountains. The first two sections involve the Red Pass Limestone Member of the Carrara Formation and the last three involve the Mule Spring Limestone. In each of the stratigraphic sections the prominent limestone is overlain by a shale or argillite which grades upward into thin and evenly bed-

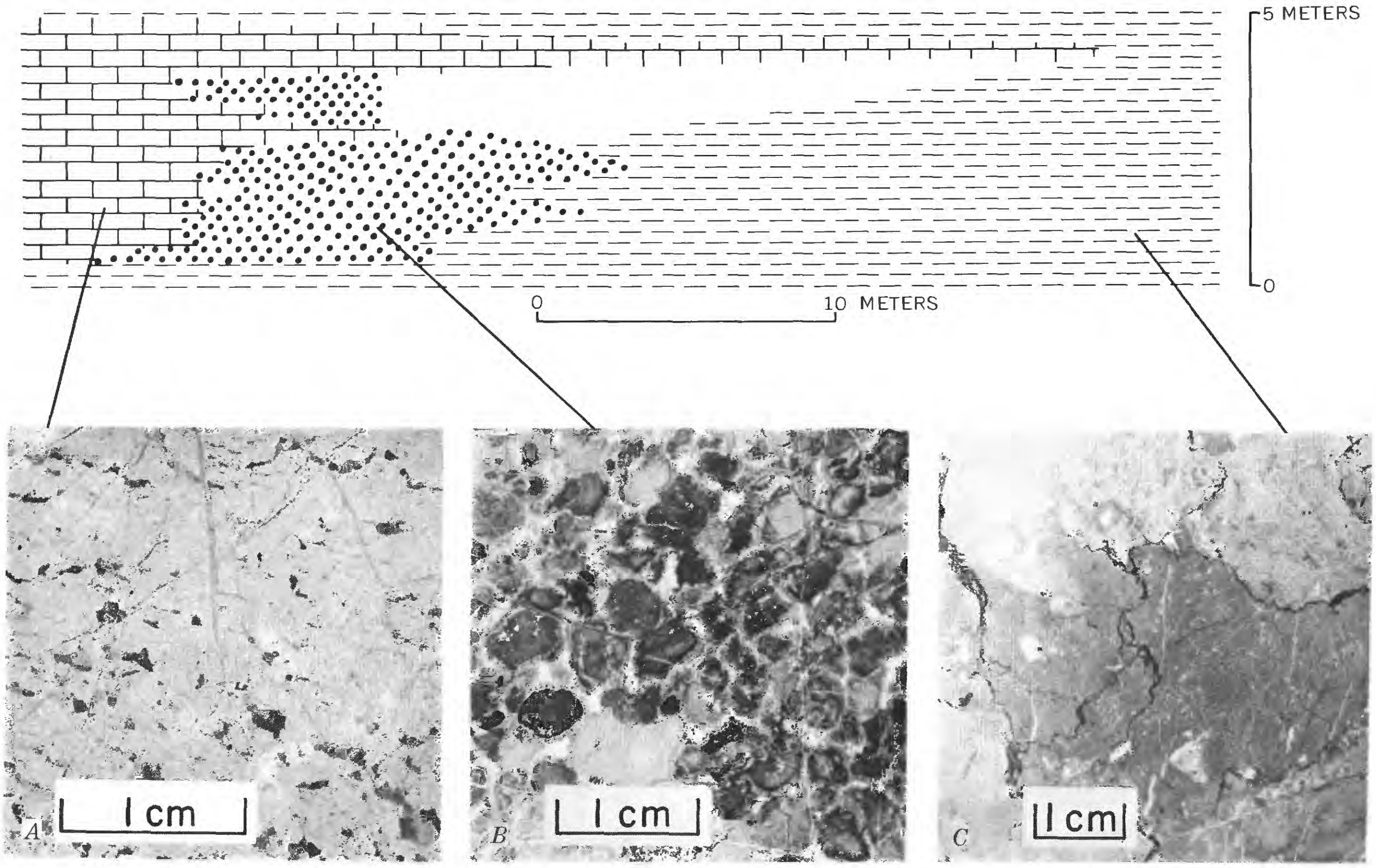


FIGURE 33.—Lateral relationships of peritidal and subtidal lithologies near Pyramid Peak, Funeral Mountains, Calif. *A*, Fenestral limestone. *B*, Intraformational conglomerate with rim cement suggestive of beach-rock cement. *C*, Subtidal lime mudstone.

ded often cherty dark-colored fine-grained limestones that contain no oncolites, few skeletal fragments, and no stromatolites, mudcracks, or other indications of shallow-water deposition.

The thickness of the Mule Spring Limestone and the Red Pass Limestone Member in these sections indicates that establishment of basinal sedimentation is not correlated with a westward thinning of the underlying shallow-water limestones. Such a thinning might be expected if the area of basinal deposition had gradually onlapped the area of shallow-water carbonates to the east. However, eastward migration of the areas of basinal deposition only occurred following termination of shallow-water carbonate deposition marking the end of a Grand Cycle. This observation strongly supports the suggestion that regional sedimentation patterns reflect differential rates of either basinal subsidence or sea-level rise. In either instance, the sea will get deeper in areas where carbonate sedimentation has been terminated, and this should be particularly noticeable on the seaward margins of former shallow-carbonate areas. Any models explaining cessation of shallow-water carbonate sedimentation by either basinal uplift or by lowering of sea level cannot simultaneously explain the abrupt appearance of deepwater sediments over shallow subtidal sediments.

In the light of evidence given, the sequence of events postulated for the development of an ideal Grand Cycle unit of the Carrara Formation is shown in figure 34, and the sequence is as follows:
(1) Shallow subtidal carbonate sedimentation is initiated on the subsiding outer part of the shelf and is represented by either oolite or lime-mudstone lithofacies; (2) these lithofacies spread gradually landward over areas of former terrigenous clastic sedimentation; (3) a decrease in the rate of subsidence or of sea-level rise triggers two simultaneous sedimentologic responses: supply of terrigenous clastics continues and the area of clastic sedimentation begins to spread seaward; at the same time, carbonate sediments build to sea level, low carbonate islands develop, and the peritidal areas prograde primarily landward toward the shallow subtidal part of the shelf which is the source of the carbonate sediment for progradation; (4) landward expansion of the peritidal facies and seaward expansion of the clastic facies decreases the area of shallow subtidal carbonate-mud production so that at some point the area becomes too small to supply mud for progradation and island growth stops; (5) the area of clastic deposition continues to expand seaward because its source continues to supply sediment, and it overrides part or all the remaining peritidal and subtidal carbonate areas, creating the sharp contact marking the base of a new Grand Cycle.

The extent to which the last event reaches completion is variable. For example, the clastic tongue of the Chisholm Shale and correlative clastics within the Desert Range Limestone Member of the Carrara Formation interfinger westward with shallow subtidal carbonate muds and do not completely cover the former carbonate platform. The clastic tongue of the Pahrump Hills Shale Member interfingers with shallow-water carbonates in the southern Last Chance Range but appears to have expanded completely across the carbonate platform in the Belted Range and Groom Range areas. The clastic tongue of the Pyramid Shale Member and its westward equivalents are not known to interfinger with shallow-water carbonate at any locality, which suggests that the clastic tongue completely engulfed the former carbonate platform. However, the western margin of this unit is not known, and it is possible that shallow-water carbonate sedimentation persisted farther to the west.

Incomplete clastic inundation indicates a waning of clastic deposition either because the distance to the clastic source was increased by sea-level rise, or because the relief of the source area was reduced by erosion, or because subsidence in the area of deposition increased thereby permitting clastic sedimentation nearer the source area. In any of these cases, areas of existing shallow-water carbonate sedimentation simply expand eastward again. However, if all areas of shallow-water carbonate sedimentation have been destroyed by the spread of terrigenous clastics, then a new initiation of oolite or lime-mudstone deposition becomes necessary. Although little information in the rocks relates to this problem, the bases of limestone units that are thought to be near the western margin of the area of carbonate sedimentation are commonly oolitic. Examples are the base of the Mule Spring Limestone at Paymaster Canyon and the base of the Red Pass Limestone Member in the Belted Range. This might indicate that at some point on a shelf floored by terrigenous clastics, carbonate deposition is initiated inorganically with the deposition of oolites.

Inherent in a model is its usefulness as a predictive tool. In the case of the Carrara Formation, the facies characteristics used to establish the mechanism of Grand Cycle sedimentation can be used to predict facies distributions in other areas. For example, if the Grand Cycles of the southern Canadian Rockies result from decreases in the rate of subsidence, then the upper parts of the carbonate half-cycles should contain intertidal and supratidal deposits which herald the oncoming regressive clastics. Aitken (1966) provided enough information to suggest that this prediction is correct. Stromatolites and cryptalgalaminates are commonly found at the top of six of the eight Grand Cycles he described (Aitken, 1966, p. 409,

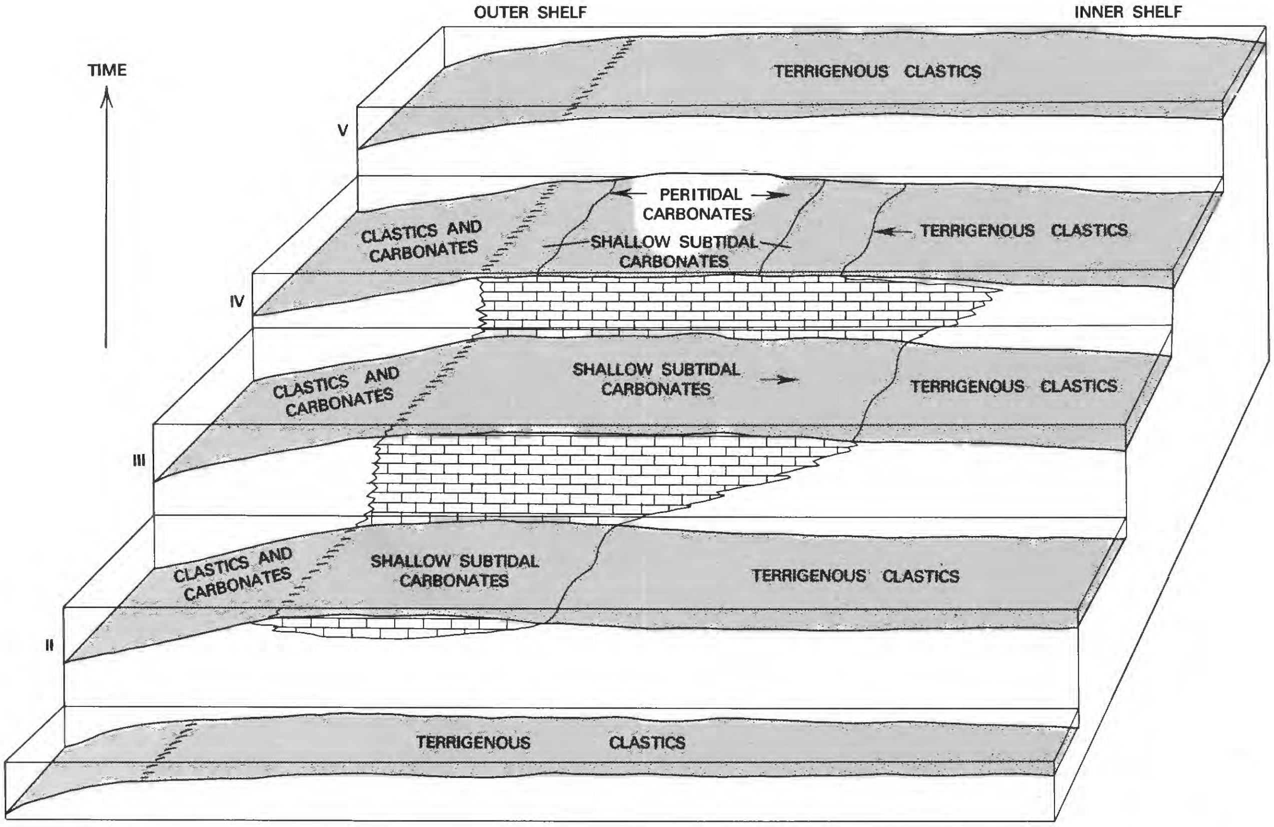


FIGURE 34.—Hypothetical model illustrating development of a limestone member of the Carrara Formation. I, Clastic phase of lower member of Grand Cycle; II, Development of subtidal oolite or lime mudstone near shelf margin; III, Subsidence and carbonate sedimentation keep pace, and area of subtidal carbonates expands predominantly across inner shelf; IV, Subsidence slows, carbonate sediments build to sea level and areas of peritidal carbonate prograde primarily towards inner shelf lagoon. Terrigenous clastic influx continues prograding seaward. Landward prograding peritidal carbonate areas and seaward prograding clastic areas eliminate area of subtidal carbonate production, terminating carbonate genesis. Continued seaward progradation of clastics across the slowly subsiding shelf caps former peritidal areas and begins stage V, the basal part of another Grand Cycle.

419). Furthermore, Aitken (1971, pp. 563–564) reported that the peritidal facies of the Eldon and Cathedral Formations is confined largely to western sections.

A second example of support for the model comes from a study of the Meagher Limestone of Montana by Lebauer (1965). The Meagher Limestone lies between two shales and might be the carbonate half of a Grand Cycle. The formation consists of a lower mudstone unit overlain by oolite and grainstone units. The model predicts that peritidal carbonates should occur in the upper and western areas of the Meagher Limestone or its correlative formations farther west. Although Lebauer reported no intertidal or supratidal lithologies from the Meagher Limestone, southwest and seaward there are mudcracked limestones and laminated dolomites that characterize the upper part of the correlative Blacksmith Limestone in northern Utah (Maxey, 1958, p. 656) and indicate intertidal or supratidal environments.

PALEONTOLOGIC ANALYSIS

BIOSTRATIGRAPHY

Analysis of the biostratigraphy of the Carrara Formation provides a good example of the limitations imposed by the geological record on our attempts to determine the meaning of the spatial distribution of fossilized animal remains.

We empirically observe the temporal changes in faunas in one stratigraphic section; we correlate sections by various means to obtain a composite summary of stratigraphic ranges of our taxa; and we then describe a succession of synthesized biostratigraphic units characterized by particular elements of our faunas. All too often we become obsessed by our generalizations and assume a sharp focus for our units that is not justified by our data. Furthermore, we often obscure discrete contemporary biofacies which are incorporated into our generalized biostratigraphic scheme. The data of plate 17 illustrate some of the opportunities, problems, pitfalls, and limitations of the "classical" first-approximation approach to biostratigraphy as it has been applied to North American rocks of late Early Cambrian and early Middle Cambrian age. Plate 18 shows the composite ranges of all the trilobite species described from the Carrara Formation.

Each of the stratigraphic sections studied has only a few fossiliferous beds. Inasmuch as several of these sections have been examined more than once without detecting significant new fossiliferous beds, the distribution of the fossiliferous beds shown on plate 17 is a reasonably good indication of the available faunal control on the biostratigraphy. This density of stratigraphic control is comparable to that reported earlier from Cordilleran sections in southern Canada (Rasetti, 1959), east-central Nevada (Fritz, 1968), and northwestern Mexico (Lochman, in Cooper and others, 1952). Data necessary for detailed evaluation of evolutionary relationships are lacking, and many questions regarding the nature of the boundaries between intervals of contrasting faunas cannot be answered. Nevertheless, biostratigraphic analysis of the faunas of the Carrara Formation has two main values: (1) It provides a guide to stratigraphic position in structurally disturbed areas where stratigraphically distinct but lithologically similar units might be miscorrelated on physical grounds, and (2) it points up some regional faunal differences between approximately contemporaneous intervals that may be reflecting the dynamics of animal-environment interactions in Cambrian time.

The published biostratigraphic framework for the part of the Cambrian represented by the Carrara Formation consists of four or five assemblage zones (Rasetti, 1951; Lochman and Wilson, 1958). These zones are generally useful interpretive biostratigraphic units of broad regional applicability. However, the data from the Carrara Formation show that the conventional method for graphical presentation which shows these zones in stratigraphic juxtaposition is really misleading for more detailed studies. Not only are contacts lacking between the zones, but also distinct faunules that have few or no common forms may be incorporated within one generalized zone, thus obscuring differences of possible biologic or paleoecologic significance.

Figure 35 illustrates the meaning of the biostratigraphic nomenclature as applied here. Four intervals represent the conventional regional-assemblage zones. They are separated by unfossiliferous sequences so that there is no precise local control on their boundaries. Furthermore, each of these intervals may contain one or more faunules. These faunules characterize descriptive biostratigraphic units designated as zonules which have validity only within the area of study. Within the Carrara Formation, these are the intervals that yield distinctive or widespread trilobite assemblages that can be used for local correlation. The intervals between zonules may or may not be fossiliferous. If they are fossiliferous, they contain generally inadequate material for precise biostratigraphy.

The value of the biostratigraphic scheme presented here is that units of local practical importance can be clearly designated. These are the building blocks for generalizations that can be applied on a regional scale. Thus, each region may have its own scheme of zonules, and at the same time, the local schemes can be integrated into useful conceptual units of regional scope.

OLENELLUS ZONE

The Lower Cambrian part of the Carrara Formation represents only the upper part of the youngest Early Cambrian *Bonnia-Olenellus* Zone (in the sense of Fritz, 1972). Older parts of this zone are represented by beds containing *Wanneria* (Palmer, 1964) in the Saline Valley Formation of the Inyo–White Mountain region, which together with still older *Olenellus*-bearing beds of the Harkless Formation are western time-equivalents of the Zabriskie Quartzite. The stratigraphic relations of beds with *Wanneria* to those with trilobites typical of the Carrara Formation are shown in the Cucomungo Canyon section of the northern Last Chance Range (pl. 17).

The *Olenellus* Zone in the Carrara Formation contains perhaps the greatest diversity of olenellid species of any part of the Early Cambrian, but very few associated non-olenellid trilobites. The principal fossiliferous intervals are the Eagle Mountain and Pyramid Shale Members and the Thimble Limestone Member. Within these members, three zonules can be distinguished and will be discussed. In addition, olenellid and ptychopariid trilobites, generally as indeterminate fragments, are scattered throughout the Gold Ace Limestone Member; but they are neither common enough nor well enough preserved to justify any subzonal biostratigraphic designation.

OLENELLUS ARCUATUS ZONULE

Immediately above the Zabriskie Quartzite, the basal few meters of the Eagle Mountain Shale Member have yielded *Olenellus arcuatus* n. sp. in the Grapevine and Funeral Mountains of California. *O. arcuatus* is associated with a less distinctive species, *O. cylindricus* n. sp. in the Grapevine Mountains. Although these trilobites are not widespread, they are quite distinct from the fauna of the next younger *Bristolia* Zonule and warrant separate recognition. *O. arcuatus* (pl. 2, fig. 11) has a glabellar structure most similar to that of *O. multinodus* n. sp. (pl. 4, fig.

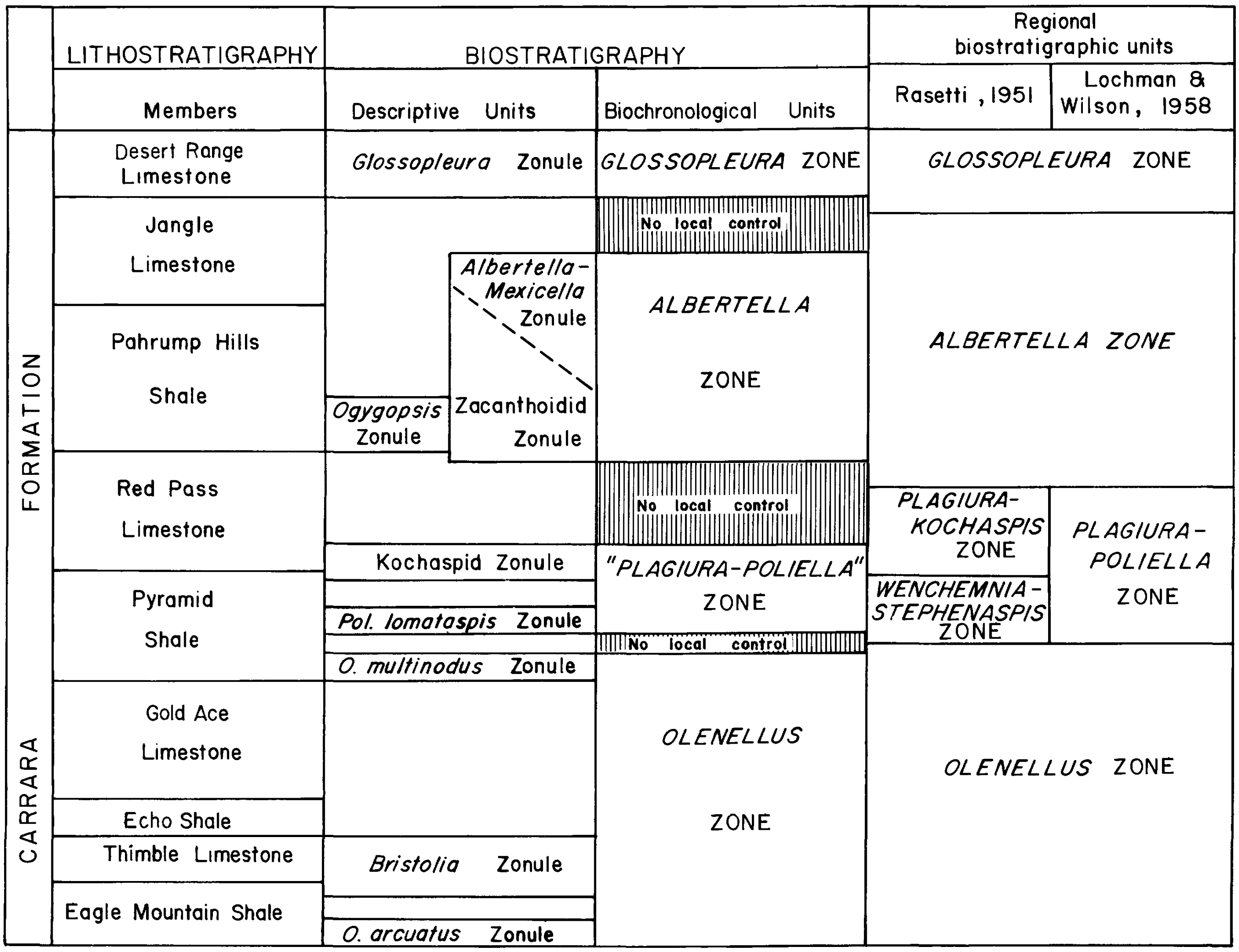


FIGURE 35.—Biostratigraphy of the Carrara Formation and its relation to the lithostratigraphy and to existing biostratigraphic schemes for the Cordilleran region of North America.

1) from the basal beds of the Pyramid Shale Member. However, the distinctive structure of the posterior part of the cephalon distinguishes *O. arcuatus* from all other olenellids in the Carrara Formation.

BRISTOLIA ZONULE

In almost every section of the Carrara Formation, thin often yellow bioclastic limestones or bedding planes of fine-grained limestones within or below the Thimble Limestone Member yield a diverse assemblage of olenellids. The most characteristic forms are species of *Bristolia*, an olenellid with unusually advanced genal spines, and *Peachella*, an olenellid with swollen genal spines. The other species are relatively less striking, but most are widespread throughout the area. The richest localities have yielded as many as 9 distinct olenellid species from a few meters of beds, and the total number of olenellid species from this interval is at least 11. The specimens in this interval are commonly broken, and often only the distinctive fishhook spines of *Bristolia* and the swollen genal spines of *Peachella*, which resemble large smooth ostracods, can be recognized. However, some samples from the Titanothere Canyon section in the Grapevine Mountains yielded excellent silicified specimens including the striking ontogenetic series of *Bristolia anteros* n. sp. shown on plate 1, figures 1–8.

Many elements of the *Bristolia* Zonule have been collected from the Latham Shale in the Marble Mountains southeast of the study area and from the lowest beds of the Pioche Shale in the Pioche and Eureka mining districts to the north. They are also present in the upper part of a thin-bedded zone within the Mule Spring Limestone, about 60 m above its base, in the Cucomungo Canyon section of the northern Last Chance Range (pl. 17) immediately to the west of the study area, where they demonstrate the dramatic westward increase in thickness of the Lower Cambrian carbonate facies as the Echo and Eagle Mountain Shale Members are replaced by limestone.

OLENELLUS MULTINODUS ZONULE

Clay shales in the lower 10 m of the Pyramid Shale Member throughout the area of study yield a diverse assemblage of olenellids, often partly articulated, and characterized by the distinctive small species, *O. multinodus* n. sp. The trilobites are commonly flattened and are frequently distorted slightly by postdiagenetic deformation of the less competent shales near the contact with the underlying Gold Ace Limestone Member. This is the youngest recognizable Early Cambrian zonule in Western United States. The occurrence of *O. multinodus* in the southern Canadian Rocky Mountains (Norford, 1962), in a comparable stratigraphic position, indicates that this species had wide distribution in the Cordilleran region.

In two sections in the Delamar Range, at Delamar, Nev., and west of Oak Spring Summit on U.S. Highway 93, north of the study area in Lincoln County, Nev., the *O. multinodus* fauna occurs within the Combined Metals Member of the Pioche Formation. The evidence from this area demonstrates that the top of the Combined Metals Member is distinctly younger than the top of the Gold Ace Member of the Carrara Formation, even though the two units occupy very similar homotaxial positions. In the Delamar Range, the *O. multinodus* fauna occurs in shales above a prominent ledge-forming limestone several meters thick that occupies the position of the Gold Ace Limestone Member and immediately below a thin limestone 10–20 cm thick. The thin limestone bed is immediately overlain by shales bearing only ptychopariid trilobites. Northward, in the type area of the Pioche Formation, the Combined Metals Member includes considerably more limestone and the ptychopariid-bearing shales immediately overlie several meters of olenellid-bearing limestone at the top of the member. The *O. multinodus* fauna, which seems to be confined to shales, has not been identified there, but the change from olenellid to non-olenellid-bearing beds indicates that the top of the member must be contemporaneous with the thin limestone overlying the *O. multinodus* fauna to the south and thus younger than the top of the Gold Ace Limestone Member.

O. multinodus has also been collected from a thin limestone bed immediately above the Chambless Limestone in its type area in the Marble Mountains of California southeast of the study area. The *Bristolia* fauna is found in the underlying Latham Shale in the same area, thus demonstrating unequivocally the correlation of the Chambless Limestone with the Gold Ace Limestone Member (fig. 3).

"*PLAGIURA-POLIELLA*" ZONE

The lowermost Middle Cambrian beds of the Carrara Formation, in the upper part of the Pyramid Shale Member and the lower part of the Red Pass Limestone Member, are the most poorly fossiliferous of the fossil-bearing parts of the Carrara Formation. This is also true for equivalent beds in other parts of the Cordilleran region and accounts for the principal contrasts in the biostratigraphic schemes of Rasetti (1951) and Lochman and Wilson (1958). Neither of their zonal schemes is really appropriate for the Carrara Formation although the correlations shown in figure 35 indicate approximate equivalence of the two faunal units within this interval to parts of Rasetti's zones in southern Canada. Because the existing zonal nomenclature is inappropriate and the fauna preservation is generally poor, this interval in the Carrara Formation is assigned to the "*Plagiura-Poliella*" Zone, which states its stratigraphic position without implying any common or characteristic genera.

POLIELLA LOMATASPIS ZONULE

A thin limestone unit in the Pyramid Shale Member of the Nevada Test Site, and an equivalent bed in the Belted Range in the northwestern part of the study area have yielded a small fauna characterized by *Poliella lomataspis* n. sp. and indeterminate kochaspid trilobites. This is the oldest Middle Cambrian faunule in the Carrara Formation, and it is isolated from the younger Kochaspid Zonule above by about 70 m of essentially unfossiliferous shales. It is also separated from the youngest olenellid-bearing beds below by at least 50 m of unfossiliferous shales. Thus, in the Carrara Formation, the nature of the Lower-Middle Cambrian boundary cannot be determined. The limestone containing trilobites of the *P. lomataspis* Zonule has a stratigraphic position similar to that of the Susan Duster Limestone Member of the Pioche Shale in the Pioche district, Nevada, and may correlate with that member.

In the Belted Range, the shales immediately above the *P. lomataspis* Zonule yield a small contrasting fauna consisting of an oryctocephalid, a pagetiid, and a smooth simple ptychopariid—all representatives of long-ranging groups within the early Middle Cambrian. This assemblage is of no apparent immediate biostratigraphic value.

KOCHASPID ZONULE

The lower part of the Red Pass Limestone Member locally yields small assemblages of trilobites generally characterized by one or more species of kochaspid trilobites. (Kochaspid trilobites defined on p. 99.) Such trilobites are not restricted to this interval, but they are most common here. In the Echo Canyon section of the Funeral Mountains, Calif., a single specimen of *Plagiura,* very possibly *P. cercops* (Walcott) (pl. 6, fig. 22), has been collected from beds within the Kochaspid Zonule. This strengthens the correlation of these beds with Rasetti's *Plagiura-Kochaspis* Zone in the southern Canadian Rocky Mountains. In the Groom Range and the Nevada Test Site, small trilobites representing a new species here referred to *Plagiura* are remarkably similar to an undescribed species shown to me by N. P. Suvorova of the Paleontological Institute, Academy of Sciences, Moscow, U.S.S.R., in 1968. Her specimens came from the Olekminskiy horizon of the Lena Stage along the Lena River in Siberia. According to a recent summary of Siberian biostratigraphy (Repina, 1974), the Olekminskiy beds are believed to correlate with the upper part of the *Olenellus* Zone in North America. Thus, the significance of these trilobites for intercontinental correlation is still to be resolved.

ALBERTELLA ZONE

This zone contains the richest and most diverse assemblages of trilobites in the Carrara Formation. It incorporates three different zonules (fig. 35) whose contrasts seem to reflect important biofacies differences. These units are in part spatially distinct but contemporaneous (*Ogygopsis* Zonule, Zacanthoidid Zonule) and in part only incompletely overlapping in time and space (Zacanthoidid Zonule, *Albertella-Mexicella* Zonule). (See also the section, "Paleoecology.")

OGYGOPSIS ZONULE

The most strikingly distinct faunal unit within the *Albertella* Zone is found in the 25 m of beds immediately above the Red Pass Limestone Member in the Belted Range, Nev. (pl. 17). This faunal unit is characterized by abundant specimens of *Ogygopsis,* some of the earliest agnostids known from western North America—oryctocephalid, pagetiid, and simple ptychopariid trilobites. One of the ptychopariids is a new species of *Elrathina* (pl. 15, figs. 1–3), a genus previously thought to characterize beds of the *Bathyuriscus-Elrathina* Zone, two zones higher in the regional Middle Cambrian biostratigraphy. Also notable in the *Ogygopsis* beds is the complete absence of any Zacanthoididae, which are common elements of contemporaneous beds to the east and southeast of the Belted Range. The biostratigraphic and physical correctness of the stratigraphic position of the *Ogygopsis* Zonule, however, is undoubted. Several of the agnostid, pagetiid, and oryctocephalid species from the *Ogygopsis* Zonule are found in *Albertella*-Zone faunas in eastern Nevada (Fritz, 1968) and the northern Utah–southeastern Idaho area (Resser, 1939b; Robison and Campbell, 1974). Comparison of the Belted Range section with the nearby sections of the Groom Range and the Nevada Test Site (pl. 17) shows the physical basis for correlation.

Every occurrence of *Ogygopsis* and associated trilobites, however, must be carefully examined before age determinations are made. In the spring of 1973, a visit was made to Cambrian exposures in the Narrows, near Currant, Nye County, Nev., north of the study area at the southern end of the White Pine Range. There, a unit with a rich assemblage of trilobites, including *Ogygopsis,* is found just above a prominent cliff-forming limestone. However, below this limestone we found shales bearing *Paralbertella,* a zacanthoidid trilobite typical of the *Albertella* Zone and the *lower part* of the Pahrump Hills–Jangle Grand Cycle. Thus, the cliff-forming limestone is probably the equivalent of either the Jangle or Lyndon Limestones, and the *Ogygopsis* beds there are probably contemporaneous with the basal beds of the *Glossopleura* Zone! *Ogygopsis* is also common in association with simple ptychopariids, oryctocephalids, and olenellids in beds slightly older than any of the fossiliferous invervals of the Carrara Formation, within the Saline Valley Formation to the west of the study area (Palmer, 1964).

In each of these instances, *Ogygopsis* and associated trilobites are found in black limestone or black limy beds within black shales or siltstones and often as complete individuals. This is also true in the Canadian Rocky Mountains where *Ogygopsis* characterizes beds within the western exposures of the Stephen Formation (Rasetti, 1951), within the Metaline Limestone in eastern Washington (McLaughlin and Enbysk, 1950), in the Kinzers Formation in southeastern Pennsylvania (Campbell, 1971), and in the Taconic region of eastern New York (Bird and Rasetti, 1968).

Each of these occurrences is near the ocean-facing side of the Carbonate Belt of North America. This suggests that the occurrence of *Ogygopsis,* typically associated with agnostids, pagetiids, oryctocephalids, and simple ptychopariids, represents a special habitat related to the carbonate platform edge. Assemblages with *Ogygopsis* can be used for precise correlation within the early half of the Middle Cambrian perhaps only at the species level.

ZACANTHOIDID ZONULE

The uppermost beds of the Red Pass Limestone Member, and a few beds in the upper part of the Pahrump Hills Shale Member, particularly in the western and northwestern parts of the study area, have yielded rich associations of trilobites with the greatest species diversity of any collections in the Carrara Formation. Most of these collections contain one or more species of Zacanthoididae, in contrast to their general absence in the contemporaneous and also highly diverse faunas of the *Ogygopsis* Zonule and in the low diversity faunas of the *Albertella-Mexicella* Zonule. Whereas the contrast with the *Ogygopsis* Zonule is reasonably clear cut, that with the *Albertella-Mexicella* Zonule is more qualitative. The qualitative difference is stressed here because it reflects a subtle biofacies difference that is of considerable importance for regional biostratigraphy (Palmer and Campbell, 1976).

The faunas of the Zacanthoidid Zonule contain a large number of species and genera in common with faunas of the *Albertella* Zone described from east-central Nevada (Fritz, 1968), northern Utah and southeastern Idaho (Resser, 1939b), and the southern Canadian Rockies (Rasetti, 1951).

ALBERTELLA-MEXICELLA ZONULE

The upper part of the Pahrump Hills Shale Member and the lower part of the overlying Jangle Limestone Member in the central and eastern parts of the study area yield small collections generally characterized by species of either or both *Albertella* (s.s.) and *Mexicella*. These faunas are much more comparable to the faunas of the *Albertella* Zone in the Caborca area of Mexico (Lochman, in Cooper and others, 1952), and the Grand Canyon region of Arizona (McKee and Resser, 1945), than they are to the *Albertella* Zone faunas containing Zacanthoididae that are cited just previously. Regional significance of these contrasts is discussed under "Paleoecology."

***GLOSSOPLEURA* ZONE AND ZONULE**

In almost every section of the Carrara Formation, one or more thin beds within the Desert Range Limestone Member will yield a coquina of trilobites dominated by a species of *Glossopleura*. Because the matrix of these beds is often very tight, few good specimens can be obtained unless the rocks are first heated and then chilled rapidly to loosen the matrix.

The diversity of the species assemblages in this interval is consistently low, suggesting, in line with the postulated biofacies relationships of the underlying *Albertella* Zone faunas (fig. 36), that the *Glossopleura* fauna of the Desert Range Limestone Member represents the restricted shelf biofacies of this time.

Evidence that the *Glossopleura*-bearing interval in the Carrara Formation is properly designated as the *Glossopleura* Zonule is provided by an important collection with specimens of *Glossopleura* from a thin-bedded silty unit about 150 m above the base of the Bonanza King Formation, which overlies the Carrara Formation, in the Striped Hills section, Nevada (pl. 17). The trilobites from this collection (7199-CO) are illustrated on plates 15 and 16. They demonstrate that the *Glossopleura*-bearing part of the Carrara Formation represents only the oldest part of the *Glossopleura* Zone and that this zone has a considerable stratigraphic thickness that is not generally apparent because few sections in the Great Basin region have fossiliferous horizons representing more than one restricted part of the zone.

The faunas of the *Glossopleura* Zone and Zonule in the southern Great Basin share practically no genera or species with the older parts of the Carrara Formation. Thus, the evolutionary significance of the *Glossopleura* fauna is uncertain. The fact that *Glossopleura* is a long-eyed corynexochid and that it is associated elsewhere with *Zacanthoides* provides a basis for relating the *Glossopleura* fauna to earlier corynexochid-rich Middle Cambrian faunas rather than later, corynexochid-poor faunas. If a consensus is ever reached about stage subdivision of the North American Middle Cambrian, the interval between the top of the *Olenellus* Zone and the top of the *Glossopleura* Zone, which characteristically yields collections with one or more long-eyed corynexochids, would be a likely candidate for the earliest Middle Cambrian stage.

PALEOECOLOGY

Even though the Carrara Formation is not richly fossiliferous, recognition of the spatial distribution of the principal physical environments permits a few observations of possible paleoecological significance. These concern the associations of particular trilobite assemblages with particular depositional environments.

The rocks of Early Cambrian age show a subtle contrast between the olenellids recovered from the oncolitic and burrowed lime mudstone of the Gold Ace Limestone Member and those from argillaceous limestones of the Thimble and shales of the Eagle Mountain and Pyramid which represent distinctly muddier and probably very slightly deeper environments. The species pair of *Olenellus gilberti* Meek and *O. clarki* (Resser) is present and is generally common in the *Bristolia* Zonule in the Eagle Mountain and Thimble Members and in the *O. multinodus* Zonule in the base of the Pyramid Member. However, in the stratigraphically intervening oncolitic and burrowed lime-mudstone environment of the Gold Ace Limestone

Member that spread eastward into the area of more terrigenous muds, a slightly different species pair is represented by *O. puertoblancoensis* (Lochman) and *O. howelli*(?) Meek. The differences between the two species pairs are most obvious in the relative length of the ocular lobes. The correlation between each species pair and its depositional environment is also apparent in the Pioche region to the north. There, shales within the Combined Metals Member bear the *O. multinodus* faunule which includes abundant specimens of *O. gilberti–O. clarki*; whereas oncolitic and burrowed lime mudstones within the member yield *O. puertoblancoensis–O. howelli*(?). Thus, distribution of at least some species of olenellids seems to be environmentally controlled and their regional biostratigraphic value is accordingly reduced.

A more dramatic example of environmental control on trilobite distribution is given by the faunules of the *Albertella* Zone. Within the Carrara Formation, there is both a vertical and an areal differentiation of these faunules. The vertical differentiation is reflected in the local sequence of zonules discussed previously. Areally, the *Ogygopsis* faunule is found only in the Belted Range, which is the northwesternmost section studied; the Zacanthoidid faunule is best developed in the region of the Nevada Test Site and the Groom Range adjacent to the Belted Range in the east and south; and the *Albertella-Mexicella* faunule is present predominantly in the central and southeastern sections. The *Ogygopsis* faunule occurs in dark-gray or black thin-bedded fine-grained limestone that represents sedimentation probably below local wave base; the Zacanthoidid faunule occurs in coarse bioclastic limestone in a shallower zone of moderate to high energy; and the *Albertella* faunule occurs in more argillaceous limestones suggestive of lower energy conditions. On the basis of the spatial distribution of these environments, the three faunules are interpreted here to represent outer shelf (*Ogygopsis* faunule), ocean-facing carbonate platform margin (Zacanthoidid faunule), and inner shelf (*Albertella-Mexicella* faunule) habitats (fig. 36).

Although the Zacanthoidid and *Ogygopsis* faunules share many common agnostids, pagetiids, and oryctocephalids, there is a complete absence of mixing of *Ogygopsis* and any members of the Zacanthoididae. Agnostids and pagetiids are believed to be pelagic and perhaps planktonic organisms (Jell, 1975), and their presence in both faunules reflects the presence of free access to open oceanic waters. The contrasts between the faunules most probably reflect strong benthic contrasts probably correlated with bathymetry. The presence of assemblages containing elements of both the *Albertella-Mexicella* and Zacanthoidid faunules in the Grapevine and Funeral Mountains (pl. 17) indicates probable faunal interchange between the inner and outer parts of the carbonate platform and shows that the contrasts between these two faunules are more geographic than bathymetric.

Work by Campbell (1974) in northern Utah and southeastern Idaho has demonstrated the presence in the *Albertella* Zone there of the same three faunules recognized in the Carrara Formation. They are also associated with rocks that represent the same depositional environments as those in the Carrara Formation. However, the stratigraphic sequence of the faunules is markedly different: The oldest faunule is the *Albertella-Mexicella* faunule, and the youngest faunule is the *Ogygopsis* faunule. This evidence demonstrates unequivocally that the time-space distribution of the faunules is environmentally controlled, and it emphasizes the extremely important point that the zonules characterized by each faunule are of only local stratigraphic value (Palmer and Campbell, 1976). Regionally, trilobite assemblages within the *Albertella* Zone may be assigned to particular faunules, but refinement of age within the zone will require careful physical stratigraphy as well as information about the location of faunas from the subjacent and superjacent zones.

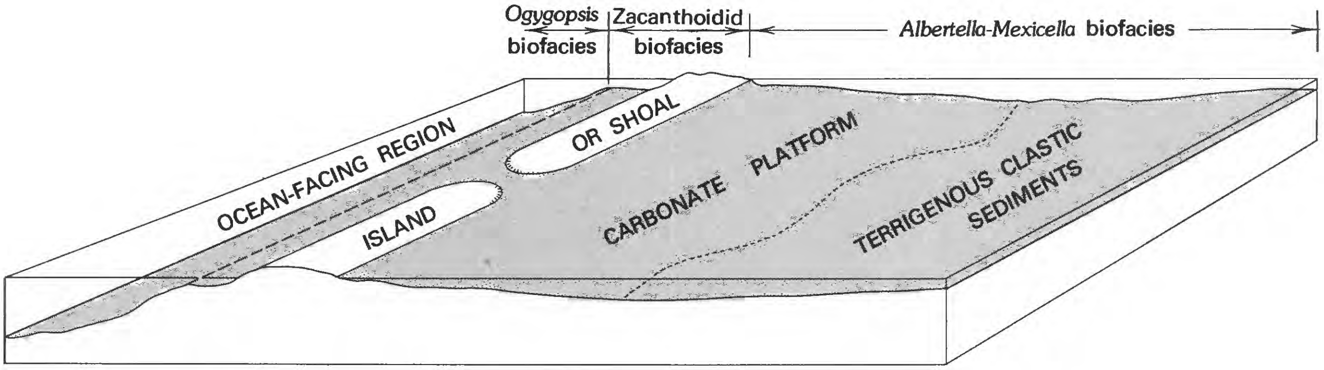


FIGURE 36—Suggested biofacies-lithofacies model for the *Albertella* Zone faunas of the Carrara Formation.

TABLE 1.—*Summary of classification of Early and Middle Cambrian trilobites of Carrara Formation*

Order	Superfamily	Family	Genus	Type
Olenellida		Olenellidae	*Bristolia* Harrington	*B. anteros* n. sp. *B. bristolensis* (Resser) *B. fragilis* n. sp.
			Olenellus Billings	*O. arcuatus* n. sp. *O. brachyomma* n. sp. *O. clarki* (Resser) *O. cylindricus* n. sp. *O. euryparia* n. sp. *O. fremonti* Walcott *O. gilberti* Meek *O. howelli*? Meek *O. multinodus* n. sp. *O. nevadensis* (Walcott) *O. puertoblancoensis* (Lochman) *Olenellus* sp. 1
			Peachella Walcott	*P. brevispina* n. sp. *P. iddingsi* (Walcott)
Miomera	Agnostoidea	Quadragnostidae	*Peronopsis* Corda	*P. bonnerensis* (Resser) *Peronopsis*? sp.
	Eodiscoidea	Eodiscidae	*Macannaia*	*M. maladensis* (Resser)
			Pagetia Walcott	*P. resseri* Kobayashi *P. rugosa* Rasetti *Pagetia* sp.
Corynexochida		Dolichometopidae	*Glossopleura* Poulsen	*G. tuta* Resser *G. lodensis* (Clark) *G. walcotti* C. Poulsen
			Poliella Walcott	*P. germana* (Resser) *P. lomataspis* n. sp. *P.* cf. *P. lomataspis* n. sp.
		Dorypygidae	*Bonnia* Walcott	*Bonnia* spp.
			Kootenia Walcott	*K. germana* Resser
			Ogygopsis Walcott	*O. typicalis* (Resser)
		Oryctocephalidae	*Oryctocephalina* Lermontova	*O.*? *maladensis* (Resser)
			Oryctocephalites Resser	*O. typicalis* Resser
			Oryctocephalus Walcott	*O. nyensis* n. sp.
			Thoracocare Robison and Campbell	*T. idahoensis* (Resser)

TABLE 1.—*Summary of classification of Early and Middle Cambrian trilobites of Carrara Formation*—Continued

Order	Superfamily	Family	Genus	Type
Corynexochida—Continued		Zacanthoididae	*Albertella* Walcott	*A. longwelli* n. sp. *A. schenki* Resser *A. spectrensis* n. sp.
			Albertellina n. gen.	*A. aspinosa* n. sp.
			Albertelloides Fritz	*A. mischi* Fritz *A. rectimarginatus* n. sp.
			Fieldaspis Rasetti	*Fieldaspis*? sp.
			Mexicaspis Lochman	*M. radiatus* n. sp.
			Paralbertella n. gen.	*P. bosworthi* (Walcott)
			Ptarmiganoides Rasetti	*P. crassaxis* n. sp. *P. hexacantha* n. sp.
			Zacanthoides Walcott	*Z. variacantha* n. sp. *Z.* cf. *Z. alatus* (Resser) *Zacanthoides*? sp.
				Corynexochid cranidium undet. 1 Corynexochid pygidium undet. 1 Corynexochid pygidium undet. 2
Ptychopariida			*Alokistocare* Lorenz	*Alokistocare* sp. 1 *Alokistocare* sp. 2
			Alokistocarella Resser	*A*? cf. *A. brighamensis* Resser *Alokistocarella*? sp.
			Caborcella Lochman	*C. pseudaulax* n. sp. *C. reducta* n. sp.
			Chancia Walcott	*C.*? *maladensis* (Resser) *C.* cf. *C. venusta* (Resser)
			Elrathina Resser	*E. antiqua* n. sp.
			Eoptychoparia Rasetti	*E. piochensis* n. sp.
			Kochaspis Resser	*K. augusta* (Walcott) *K. liliana*? (Walcott)
			Kochiellina n. gen.	*K. groomensis* n. sp. *K. janglensis* n. sp. Kochaspid sp. undet. 1 Kochaspid sp. undet. 2
			Mexicella Lochman	*M. mexicana* Lochman *M. grandoculus* n. sp. cf. *M.*? *stator* (Walcott)
			Nyella n. gen.	*N. clinolimbata* (Fritz) *N. granosa* (Resser) *N. immoderata* n. sp.
			Pachyaspis Resser	*P. gallagari* Fritz
			Plagiura Resser	*P. extensa* n. sp. *P. minor* n. sp. *P. retracta* n. sp. *P.* cf. *P. cercops* (Walcott)
			Schistometopus Resser	*Schistometopus* spp.
			Syspacephalus Resser	*S. longus* n. sp. *S. obscurus* n. sp.
			Volocephalina n. gen.	*V. connexa* n. sp. *V. contracta* n. sp.

TABLE 1.—*Summary of classification of Early and Middle Cambrian trilobites of Carrara Formation*—Continued

Order	Superfamily	Family	Genus	Type
Ptychopariida—Continued				Ptychopariid sp. undet. 1
				Ptychopariid sp. undet. 2
				Ptychopariid sp. undet. 3
				Ptychopariid sp. undet. 4
				Ptychopariid sp. undet. 5
				Ptychopariid sp. undet. 6
				Ptychopariid sp. undet. 7
				Ptychopariid sp. undet. 8
				Ptychopariid sp. undet. 9
				Ptychopariid sp. undet. 10
				Ptychopariid sp. undet. 11
				Ptychopariid sp. undet. 12
				Ptychopariid pygidium undet. 1
				Ptychopariid pygidium undet. 2

SYSTEMATIC PALEONTOLOGY

The classification of the Early and Middle Cambrian trilobites of the Carrara Formation is summarized in table 1. The taxa are listed in the order that they appear on the following pages. A diagnosis or description is provided for each species and for new genera. Lack of discussion of a supraspecific taxon indicates acceptance of this taxon as it is constituted in "Part O" of the "Treatise of Invertebrate Paleontology" (Harrington and others, 1959) unless otherwise indicated. Bergström (1973) has recently reviewed the suprageneric classification of trilobites and has made some valuable revisions at the ordinal level. In this paper, the orders are used in the sense of Bergström. Most descriptive terms used here were defined or illustrated in Harrington and others (1959, p. 42, 44, 46, 47, 117–126).

All illustrated specimens have been given U.S. National Museum catalog numbers and are deposited in the collections of that institution. The collection numbers are recorded in the Cambrian-Ordovician locality catalogs of the U.S. Geological Survey.

All figures on the plates show the exterior of the exoskeleton unless otherwise specified. All dimensions in the vertical plane that includes the axis of symmetry of the trilobite are sagittal dimensions, those in planes parallel to the sagittal plane are exsagittal dimensions, and those in a vertical plane at right angles to the sagittal plane are transverse dimensions. Particular dimensions on all parts were measured as straight-line distances between furrows or from margins to furrows as described earlier (Palmer, 1965, p. 23).

Order OLENELLIDA Resser
Family OLENELLIDAE Vogdes
Genus BRISTOLIA Harrington

Bristolia Harrington, 1956, p. 59; Poulsen, C., in Harrington and others, 1959, p. 192, Poulsen, V., 1964, p. 9.

Type species.—*Mesonacis bristolensis* Resser, 1928, p. 7, pl. 2, figs. 5–8.

Diagnosis.—Olenellidae with slender, elongate, hourglass-shaped glabella reaching to inner edge of anterior border. Anterior glabellar lobe hemispherical, about as wide as occipital ring, remaining lobes moderately to well defined by glabellar furrows. Occipital ring has median node at posterior margin. Ocular lobes elevated, generally unfurrowed, relatively short; line connecting posterior tips crosses glabella anterior to occipital ring. Genal spines moderately to very strongly advanced.

Discussion.—The hourglass-shaped glabella extended to the anterior border, the short ocular lobes and the advanced genal spines distinguish species of this genus from other late Early Cambrian olenellids. Some species of *Olenellus* may have slightly advanced genal spines, but the glabella generally does not reach the anterior border. If it does, it is neither as slender nor as constricted at its midlength as that of *Bristolia* species (pl. 1, figs. 13, 19; pl. 2, fig. 14).

Bristolia anteros n. sp.

Plate 1, figures 1–13

Olenellus gilberti Meek (part). Walcott, 1886, pl. 20, fig. 1f; 1891, pl. 86, fig. 1f; 1910, pl. 37, fig. 9; pl. 41, fig. 8.

Description.—Moderately small olenellids, width of largest observed cephalon about 17 mm exclusive of genal spines. Cephalon, without genal spines, subquadrate in outline; sagittal length about two-thirds width between intergenal angles at posterior margin; anterior margin gently curved forward in front of glabella. Genal spines of mature specimens slender, tapered, rounded in cross section, project laterally and slightly forward from anterolateral parts of cephalon, then curve strongly backward so that tips are subparallel to axis and posterior to posterior cephalic margin. Lateral margin of cephalon approximately perpendicular to posterior margin. Intergenal angle strongly rounded; lateral border just anterior to rounded intergenal angle has slight swelling representing vestige of immature intergenal spine. Cephalic border strongly convex in cross section, well defined around entire margin on mature specimens by deep furrow, interrupted at intergenal angle by intergenal ridge on larger immature specimens (pl. 1, figs. 8, 11).

Glabella long, extended to inner edge of anterior border, defined at sides by changes in exoskeletal slope.

Anterior glabellar lobe hemispherical, strongly elevated above extraocular region; width slightly greater than basal glabellar width and about one-third posterior cephalic width; posterior part continuous laterally with ocular lobes. Remainder of glabella indistinctly defined laterally, hourglass-shaped, width at middle glabellar segment (L2) slightly less than three-fourths basal glabellar width. Three glabellar furrows present, exclusive of occipital furrow; anterior furrow (S3) represented by dimples or transverse slots on glabella posterior to intersection of ocular lobe with anterior glabellar lobe; middle and preoccipital furrows (S2, S1) slotlike distally, shallow across top of glabella; middle furrow transverse; slots of preoccipital furrow directed posterolaterally from side of glabella. Occipital furrow slotlike at side of glabella, shallow across top. Occipital ring gently convex, with low median node adjacent to posterior margin.

Ocular lobe short, arcuate, unfurrowed, strongly elevated above cheek, top level with top of anterior glabellar lobe. Line connecting posterior tips of ocular lobes passes over occipital furrow (S1) or posterior part of middle glabellar lobe (L2). Tips separated from glabella by distance approximately equal to transverse width of ocular lobe. Although eye surfaces seem to be perfectly preserved on some small holaspids (pl. 1, fig. 12) individual facets are not discernible and the entire surface is smooth.

Extraocular cheeks gently downsloping; distance from ocular lobe to lateral margin about one-fourth width of cephalon on line through ocular lobes.

Thorax, pygidium, and hypostome unknown.

Ornamentation minimal, consists of fine bertillon markings (pl. 1, fig. 10) on top of glabella, anterior border, and genal spines, and extremely faint fine granulation on infraocular cheeks, observable only on delicately preserved specimens.

Ontogeny.—A small suite of silicified specimens representing the five developmental stages described for other olenellids (Palmer, 1957) is available for *B. anteros*. The first two stages, prior to the appearance of genal spines, are generally similar to those of *Olenellus*. They differ in having the glabella touching the anterior border and generally more prominent ocular lobes (pl. 1, figs. 1, 2). In the third stage, the genal spines of *B. anteros* appear slightly in advance of the intergenal spines rather than adjacent to them as in *Olenellus* (pl. 1, fig. 3). The succeeding stages show a gradual anterior progression of the genal spines to their full holaspid condition (pl. 1, figs. 4–9, 11). A strong intergenal ridge persists into the early holaspid stage separating the posterior and lateral border furrows; but in larger holaspids these furrows are joined at the intergenal angle, and the only vestige of the intergenal ridge and spine is a slight swelling of the lateral cephalic border. This series clearly demonstrates that the anterolateral cephalic spines of *Bristolia* are homologous with the genal spines of *Olenellus* and not an exaggerated development of the anterior border spines of the immature stages.

Discussion.—This species differs from all others in the genus in the mature holaspid position of the genal spines. In *B. insolens,* these spines are directed strongly forward analogous to antennae. In all other species, the genal spines are directed posterolaterally. The most similar species is *B. bristolensis* (Resser) which has consistently wider extraocular cheeks in addition to posterolaterally directed genal spines.

Occurrence.—Common (>40 cephala), upper part of *Bristolia* Zonule. California: 4144–CO, 7183–CO, Titanothere Canyon section, Grapevine Mountains; 4161–CO, 7180–CO, Cucomungo Canyon section, Last Chance Range. Nevada: 3101–CO, 4152–CO, Echo Canyon section, Funeral Mountains; 3694–CO, 3786–CO, Nevada Test Site; 6399–CO, Desert Range.

Bristolia bristolensis (Resser)

Plate 1, figures 14–19

Olenellus howelli Meek (part). Walcott, 1884, pl. 9, fig. 15; pl. 21, figs. 8, 9.
Olenellus gilberti Meek (part). Walcott, 1886, pl. 20, figs. 1a, 1k, 1l; 1891, pl. 86, figs. 1a, 1k, 1l; 1910, pl. 37, figs. 16, 18, 19.
Mesonacis bristolensis Resser, 1928, p. 7, pl. 2, figs. 5–8.
Olenellus bristolensis (Resser). Riccio, 1952, p. 30, pl. 7, figs. 1, 2, 5; pl. 8, figs. 1–11.
Bristolia bristolensis (Resser). Harrington, 1956, p. 59, text fig. 1D.

Description.—Moderately large olenellids, width of largest observed cephalon about 40 mm exclusive of genal spines. Cephalon, without genal spines, subpentagonal in outline; sagittal length equal to or slightly greater than one-half width between intergenal angles at posterior margin; anterior margin gently curved, curvature continued onto genal spine with no or only very slight deflection. Genal spine slender, tapered, oval in cross section, directed posterolaterally in broad curve from point about opposite glabellar midlength; posterior tip subparallel to axis and opposite anterior part of thorax. Lateral margin of cephalon generally perpendicular to posterior margin although angle may decrease laterally nearly to 45° on extreme variants (pl. 1, figs. 16, 18). Intergenal angles strongly rounded; short sharp intergenal spine may be retained just anterior to corner (pl. 1, fig. 17). Cephalic border extremely narrow in front of glabella, broadens laterally; well defined by broad shallow border furrow around entire cephalic margin.

Glabella long, extended to inner edge of anterior border. Anterior glabellar lobe hemispherical, strongly elevated above extraocular region; width about equal to basal glabellar width and about one-fourth of cephalic width between intergenal angles; posterior part connected to ocular lobes by slight change in slope. Remainder of glabella hourglass shaped, defined at sides by shallow axial furrows, narrowest at preoccipital furrow (S1). Three glabellar furrows present anterior to occipital furrow: anterior furrow (S3) slightly curved posteriorly, continuous across glabella between junctures with ocular lobes; middle furrow (S2) nearly straight across top of glabella, not connected to axial furrows; preoccipital furrow (S1) continuous across glabella in gentle posteriorly directed curve, deepest adjacent to axial furrows. Occipital furrow deep adjacent to axial furrows, barely apparent across top of glabella. Occipital ring has median node adjacent to posterior margin.

Ocular lobe short, arcuate, line connecting posterior tips passes over top of glabella at or just posterior to preoccipital furrow (S1). Upper surface rises slightly posteriorly relative to tip of glabella (pl. 1, fig. 15); posterior tips at same elevation as top of glabella. Very shallow longitudinal furrow barely apparent near and paralleling lateral margin of lobe. Posterior tips separated from sides of glabella by distance less than width of ocular lobe.

Extraocular cheeks gently downsloping; distance from ocular lobe to lateral margin about one-third width of cephalon at intergenal angles. Faint, narrow intergenal ridge apparent on some specimens.

Thorax, pygidium, and hypostome unknown.

Ornamentation minimal, consists of faint bertillon markings on tops of glabella and ocular lobes and caecal venation of the extraocular cheeks of some specimens.

Discussion.—All the specimens assigned to *B. bristolensis* from the limestones in the Carrara Formation have a slight deflection of the anterior margin at the base of the genal spine which is absent on specimens illustrated by Resser (1928) and Riccio (1952) from the Latham Shale in the Marble Mountains. The differences between specimens from the two lithotopes are considered here to be subspecific, possibly reflecting their different habitats.

B. bristolensis differs from *B. anteros* n. sp. and *B. insolens* (Resser) by lacking anterolaterally directed genal spines and by having relatively wider extraocular cheeks. The latter character as well as more anteriorly placed ocular lobes distinguish it from *B. groenlandicus* (Poulsen) and *B. kentensis* (Poulsen). Differences with *B. fragilis* n. sp. are discussed under that species.

Occurrence.—Moderately rare (20 cephala), lower part of *Bristolia* Zonule. California: 3673–CO, 3674–CO, Resting Springs Range; 3677–CO, 3678–CO, Eagle Mountain; 4144–CO, Titanothere Canyon section, Grapevine Mountains; 4153–CO, Echo Canyon section, Funeral Mountains; 7179–CO, Cucomungo Canyon section, Last Chance Range.

Bristolia fragilis n. sp.

Plate 2, figures 1–6

Description.—Moderate-sized olenellids, width of largest observed cephalon about 30 mm exclusive of genal spines. Cephalon, without genal spines, transversely subelliptical in outline, with straight posterior margin. Sagittal length about equal to width between intergenal angles at posterior margin; anterior margin broadly and evenly curved; very slightly deflected outward at base of genal spine. Genal spine directed posterolaterally in broad curve from point about opposite occipital furrow (S0) or preoccipital lobe (L1); tip slightly hooked. Lateral cephalic margin behind genal spines forms acute angle with lateral projection of posterior margin, joins posterior margin through broad curve at intergenal angle. Cephalic border narrow in front of glabella, well defined around entire margin by shallow border furrow.

Glabella long, extended to inner edge of anterior border. Anterior glabellar lobe hemispherical, strongly elevated above extraocular region; width about equal to basal glabellar width and about one-fourth width between intergenal angles; posterolateral part separated from ocular lobes by shallow, anterolaterally directed furrow. Remainder of glabella hourglass shaped, defined at sides by shallow axial furrows, narrowest at preoccipital furrow (S1). Three glabellar furrows present anterior to occipital furrow: anterior furrow (S3) represented by pits or short transverse slots adjacent to ocular lobes, connected across top of glabella by very shallow furrow; middle furrow (S2) not connected to axial furrows—on large mature specimens, represented by short transverse distal slots connected by shallow furrow; preoccipital furrow (S1) deep adjacent to axial furrows, posterolaterally directed, straight, barely apparent across top of glabella. Occipital furrow deep adjacent to axial furrows, barely apparent across top of glabella. Occipital ring has median node adjacent to posterior margin.

Ocular lobe moderately short, arcuate, unfurrowed; line connecting posterior tips passes over preoccipital segment (L1). Upper surface of lobe elevated above top of glabella, rises slightly posteriorly. Posterior tip close to glabella. Interocular cheek present only opposite posterior part of ocular lobe; anterior part of ocular lobe adjacent to laterally expanded glabellar segment (L3).

Extraocular cheeks gently downsloping often with well-developed radial caecal venation. Distance from ocular lobe to lateral border furrow at genal angle slightly more than one-third intergenal width of cephalon.

Ornamentation, except for radial caecae on extraocular cheeks not apparent.

Discussion.—This species differs from all others in the genus by the comparatively slight advance of the genal spines. The angularity of the intergenal angle is variable and some specimens are difficult to distinguish from variants of *B. bristolensis* which have an obtuse intergenal angle. Similar individuals of the two species can generally be separated on two characters: the anterior glabellar furrow (S3) of *B. bristolensis* is of more uniform depth than that of *B. fragilis*; and the intergenal angle of *B. bristolensis* is less smoothly curved. Generally, also, the interocular cheek of *B. fragilis* is more restricted than that of *B. bristolensis*. Although these differences are qualitative, the two species are generally easily distinguished by differences in their genal regions.

B. fragilis is a characteristic associate of *B. anteros* in the upper part of the *Bristolia* Zone in beds generally younger than those with *B. bristolensis*.

Occurrence.—Moderately common (>25 cephala), upper part of *Bristolia* Zonule. California: 4144–CO, 7183–CO, Titanothere Canyon section, Grapevine Mountains; 4152–CO, Echo Canyon section, Funeral Mountains. Nevada: 3694–CO, 3786–CO, Nevada Test Site; 6399–CO, Desert Range.

Genus OLENELLUS Billings

Olenellus Billings, 1861, p. 11; Walcott, 1910, p. 311 [synonymy to date]; Resser, 1928, p. 3; Bell, 1931, p. 1–22; Poulsen, 1932, p. 35; 1959, p. 192; Resser and Howell, 1938, p. 217; Lake, 1937, p. 236; Störmer, 1939, p. 242; Shimer and Shrock, 1944, p. 613; Kindle and Tasch, 1948, p. 135; Riccio, 1952, p. 29, 33; Hupé, 1953, p. 73; Shaw, 1955, p. 790; Raw, 1957, p. 149; Pokrovskaya, 1959, p. 157; Suvorova, N. P., in Chernysheva, 1960, p. 62; Fritz, 1972, p. 11; Robison and Hintze, 1972, p. 5.

Fremontia Raw, 1935, p. 243; Harrington, 1956, p. 57; Poulsen, 1959, p. 192.

Mesonacis Walcott, 1885, p. 328; 1910, p. 261 [synonymy to date]; Resser, 1928, p. 5; Bell, 1931, p. 1–22; Kobayashi, 1935, p. 117.

Paedeumias Walcott, 1910, p. 304; Raw, 1927, p. 137; 1935, p. 242; Raymond, 1928b, p. 169; Resser, 1928, p. 4; Bell, 1931, p. 1–22; Poulsen, 1932, p. 36; 1959, p. 192; Resser and Howell, 1938, p. 225; Shimer and Shrock, 1944, p. 615; Lermontova, 1951, p. 46; Riccio, 1952, p. 30; Best, 1952, p. 15; Palmer, 1957, p. 124, 126; Suvorova, N. P., in Chernysheva, 1960, p. 62; Öpik, 1961, p. 419; Cowie, 1968, p. 13.

Type species.—*Olenus thompsoni* Hall, 1859, p. 59, fig. 1.

Discussion.—Fritz (1972) has recently given a full description of *Olenellus* and has discussed its scope. He has regrouped into *Olenellus*, with good justification, species formerly segregated into *Paedeumias* and *Fremontia*, because the supposedly definitive characteristics of those genera intergrade among the large number of olenellid species now known, and consistent criteria for their recognition are not apparent. Synonymization of *Fremontia* with *Olenellus* was also suggested by Robison and Hintze (1972).

The diversity of forms now included within *Olenellus* is well illustrated by the olenellids from the Carrara Formation where 12 species are assigned to the genus. Species characteristics are based on combinations of cephalic features— particularly those of the glabella, ocular lobes, cephalic border, and genal regions. However, morphologic variability within these species is generally greater than variability within most nonolenellid species. This is most easily noted in details of cephalic outline, ocular lobe length, pattern of glabellar furrows, and form of the genal regions. Variability of the genal regions and in cephalic border width, and some of the variability in ocular lobe length, seem to be biologic, but some of the variability of specimens, particularly in shales, is related to diagenetic flattening or tectonic distortion. Because of these factors, small proportional differences are only considered to be valid discriminatory characteristics if they are consistently observed on a number of associated specimens.

In this report, the systematics within *Olenellus* are deliberately conservative. Although separation of the species described here into several genera might be possible, the present approach has been chosen because biologically meaningful or stratigraphically useful subsets of the species within the genus in the Carrara Formation are not apparent. This difficulty in supraspecific discrimination represents an important aspect of evolutionary systematics of trilobites that has perhaps not yet been fully appreciated.

Cambrian and Early Ordovician time appears to have been a time of gradual development of distinctness in intermediate-level (genus, family) supraspecific taxa. In the Early Cambrian, species can generally be satisfactorily discriminated, but genera and families are much disputed. In Middle Cambrian and early Late Cambrian time, genera are more distinct, but families are still disputed. Only by the later part of Late Cambrian time are family level taxa generally recognizable with some constancy. In post-Cambrian time, and particularly post-Early Ordovician time, taxa assigned the rank of superfamilies and orders become readily identifiable. This increase in effective taxonomic distance at increasingly higher taxonomic levels may reflect the gradual stabilization of shallow marine environments during Cambrian and Ordovician time.

A particularly difficult problem in taxonomy of the olenellids has been caused by differing interpretations of the value to be placed on minor but consistent differences in cephalic border width between generalized olenellids, such as those illustrated on plate 3. The specimens identified here as *Olenellus gilberti* Meek and *O. clarki* (Resser) are found together in most collections from shales of the Carrara Formation and their axial cephalic features are essentially identical. However, *O. clarki* is characterized by a narrower cephalic border than *O. gilberti*, which results also in a slightly longer preglabellar area. In addition, its genal spines are rarely advanced, and its intergenal spines, when observed, point directly posteriorly rather than posterolaterally.

Narrow- and broad-bordered olenellids are found associated not only in the Carrara Formation, but also in the Pioche Shale in Nevada (Palmer, 1957), the Parker Slate in Vermont (Walcott, 1910), and the Kinzers Formation in Pennsylvania (Fritz, 1972). Taxonomic placement of these narrow- and broad-bordered forms has ranged from separate genera (*Paedeumias* and *Olenellus*) (Resser and Howell, 1938; Lochman, Christina, in Cooper and others, 1952; Palmer, 1957) to variants of a single species (Fritz, 1972).

Although in the past I have supported separate recognition for *Paedeumias*, so much is now known about the variety of cephalic features of olenellids that it seems inappropriate to continue to assign so much taxonomic weight to the cephalic border. The more realistic and problematic taxonomic choice now is between interpreting narrow- and broad-bordered forms as congeneric species (often but not always as species pairs), or as subspecific, perhaps dimorphic, variants.

Dimorphism is favored by the common association of narrow- and broad-bordered forms which have indistinguishable axial characteristics as described above. It is strengthened by the fact that pairs of such forms from different stratigraphic levels or different sedimentary environments may have minor but consistent axial differences. For example, the species that I identified as *O. gilberti* and *O. clarki* from the Combined Metals Member of the Pioche Shale in Nevada (Palmer, 1957, pl. 19, figs. 19, 20) both have very long ocular lobes that reach nearly to the posterior border furrow. In specimens from the Carrara Formation that are assigned to these species, however (pl. 3, figs. 3, 8), posterior tips of the ocular lobes are clearly separated from the posterior border furrow and can usually be connected by a line that passes over the anterior half of the occipital ring. In addition, the shorter eyed forms identified here as *O. gilberti* and *O. clarki* are found both below and above the Gold Ace Limestone Member of the Carrara Formation, whereas long-eyed forms here identified as *O. puertoblancoensis* (Lochman) and *Olenellus howelli*? (Meek) are found in the intervening limestones of the Gold Ace Limestone Member, suggesting a possible environmental control of the associated pairs.

Several observations, however, provide counter arguments favoring recognition of broad- and narrow-bordered forms as separate species. Although morphologic pairs are common, they are not characteristic of all large species suites of *Olenellus*. For example, *O. euryparia* n. sp. and *O. multinodus* n. sp. have no similar associated species. Also, some distinctive and widespread narrow-bordered species, such as *O. nevadensis* (Walcott), have no broad-bordered associates. Perhaps the most significant evidence against dimorphism is provided by olenellid ontogenies.

On the basis of an earlier study of silicified ontogenetic suites of associated narrow- and broad-bordered forms from the Pioche region, Nevada (Palmer, 1957), arguments favoring dimorphism could have been made by interpreting the "*Paedeumias*"-type immatures (low cephalic relief; slender intergenal spines) and associated *Olenellus*-type immatures (strong cephalic relief; broad, ventrally open intergenal spines) as dimorphs. However, discovery of a sample with beautifully silicified immature olenellids in the northern Delamar Mountains, Nev., substantially weakens that interpretation. In that sample, forms typical of "*Paedeumias*" and *Olenellus* can be easily distinguished and all developmental stages described from the Pioche region can be recognized. However, all individuals in developmental stages I–III in the Pioche samples had procranidial spines; whereas a substantial number of specimens from stages I–III of both "*Paedeumias*" and *Olenellus* in the sample from the northern Delamar Mountains lack procranidial spines. Thus, the "dimorphs" seem to be dimorphic!

The evidence given in the preceding two paragraphs is considered sufficient to raise doubts about interpreting broad- and narrow-bordered species pairs as dimorphs. In this report they are recognized as separate species.

Olenellus arcuatus n. sp.

Plate 2, figures 11, 12

Description.—Small olenellids; width of cephalon of largest observed specimen about 15 mm. Cephalon subcrescentic in outline, both anterior and posterior margins curved forward. Genal angle acute, located posterior to transverse line through occipital ring, has short sharp posteriorly directed genal spine. Narrow cephalic border defined by shallow lateral and posterior border furrows. Intergenal spine not apparent.

Glabella elongate, separated from anterior border by narrow preglabellar area. Frontal lobe prominent, subhemispherical, well marked at sides by narrow axial furrows; width between one-third and one-half greater than width at occipital ring and slightly less than one-third greatest width of cephalon. Posterior part of glabella slender, slightly constricted at middle glabellar segment (L2). Three glabellar furrows present: anterior (S3) and middle (S2) furrows nearly straight, anterior furrow deepest at distal ends; preoccipital furrow (S1) directed inward in a gentle posteriorly directed curve from axial furrows. Occipital furrow apparent only adjacent to axial furrows. Occipital ring and at least glabellar segments L1 and L2 have low axial nodes.

Ocular lobes divergent, crescentic, short, well defined, posteriorly tapered. Ocular furrow not apparent. Line connecting tips of ocular lobes passes over anterior part of preoccipital segment. Intraocular cheek moderately to strongly convex transversely, wider than ocular lobe, forms distinct swollen areas adjacent to glabellar segments L1 and L2.

Extraocular cheek gently convex, has very faint vestige of intergenal ridge directed posterolaterally from tip of ocular lobe. Distance between ocular lobe and lateral margin between one-third and one-fourth maximum cephalic width.

Ornamentation, except for axial nodes, not apparent.

Discussion.—This species is distinguished from all other olenellids by the strongly curved posterior cephalic margin and short genal spines. The configuration of the glabella and ocular lobes is most similar to the younger species, *O. multinodus* n. sp., and both species have axial nodes on glabellar segments. The morphologic similarities and stratigraphic differences indicate that these species probably form a phyletic subgroup within *Olenellus*.

Occurrence.—Rare, *O. arcuatus* Zonule. California: 3148–CO (2 cephala), Echo Canyon section, Funeral Mountains; 4146–CO (5 cephala), Grapevine Mountains.

Olenellus brachyomma n. sp.

Plate 2, figures 7, 8

Description.—Small olenellids; width of largest observed cephalon about 15 mm. Cephalon semicircular in outline with marginal curvature continued into slender posterolaterally directed genal spines that originate at posterolateral cephalic corners. Posterior margin straight, directed slightly posterolaterally from occipital ring. Border narrow, defined by shallow border furrows that are deepest along anterior margin. Intergenal spine short, sharp, posterolaterally directed, close to base of genal spine.

Glabella elongate, extended nearly to anterior border furrow; preglabellar area extremely narrow. Frontal lobe subcircular in outline, not noticeably inflated, separated from extraocular cheeks by change in exoskeletal slope; top at same level as remainder of glabella; width about equal to transverse width of occipital ring. Remainder of glabella narrowest at middle glabellar segment (L2), poorly defined at sides by changes in exoskeletal slope. Three glabellar furrows present: anterior furrow (S3) shallow, curved slightly posteriorly, continuous between inner ends of ocular lobes; middle furrow (S2) represented only by isolated, slightly transverse pits on glabella; preoccipital furrow (S1) moderately deep at sides of glabella, very shallow across top, very slightly curved posteriorly. Occipital furrow deep at sides of glabella, shallow across top. Occipital ring has prominent median node adjacent to posterior margin.

Ocular lobe short, arcuate, unfurrowed, sloped inward, and not clearly differentiated from intraocular cheek; line connecting tips of ocular lobes passes over top of glabella at preoccipital furrow (S1).

Intraocular cheeks about as wide as ocular lobe.

Extraocular cheeks gently convex, downsloping; distance from ocular lobe to border furrow at genal angle slightly less than one-third width of cephalon between intergenal spines.

External surfaces of most parts of cephalon smooth; genal spines thickly covered with granules on well-preserved specimens (pl. 2, fig. 8).

Discussion.—The combination of a glabella not quite reaching the anterior border furrow, short unfurrowed ocular lobes, granular genal spines at the posterolateral corners of the cephalon, and pattern of glabellar furrows serves to distinguish this species from other olenellids. It is most similar to the larger species, *O. fremonti* Walcott, and differs principally by having a narrow preglabellar area and by having a less variable relationship between the genal and intergenal spines and the posterolateral corner of the cephalon.

Occurrence.—Locally common, *Olenellus* Zone, immediately above Gold Ace Limestone Member. Nevada: 3696–CO, 7194–CO (10 cephala), Desert Range.

Olenellus clarki (Resser)

Plate 3, figures 1–5

Paedeumias clarki Resser, 1928, p. 9, pl. 3, figs. 1, 2; Riccio, 1952, p. 33, pl. 9, figs. 1–4.

Olenellus gilberti Meek (Part). Walcott, 1884, pl. 21, fig. 14; 1886, pl. 20, fig. 4; 1891, pl. 85, fig. 1d.

Description.—Moderately large olenellids; width of largest observed cephalon about 50 mm. Cephalon semicircular in outline, nearly flat; marginal curvature continuous onto short slender genal spine located at or slightly in advance of posterolateral cephalic corner. Posterior margin nearly straight, slightly deflected forward distal to position of intergenal spines on some specimens. Intergenal spine usually not apparent on holaspid cephala. Cephalic border narrow, wirelike, well defined by border furrow around entire cephalic margin.

Glabella elongate, separated from frontal border by preglabellar area that is generally two to four times longer sagittally than the border. Frontal lobe subcircular to sagittally subovate in outline, not inflated; width about equal to width of occipital ring; separated from extraocular cheeks by change in exoskeletal slope. Remainder of glabella defined at sides by shallow axial furrows, narrowest at preoccipital furrow (S1). Three glabellar furrows present: anterior and middle furrows (S3 and S2) generally represented by isolated deep transverse slots not connected across top of glabella; preoccipital furrow (S1) and occipital furrow subparallel, deep at sides of glabella, not connected across top. Occipital ring has small axial node adjacent to posterior margin.

Ocular lobes slender, arcuate, elongate; line connecting tips passes over occipital furrow (S0) or adjacent parts of preoccipital or occipital segments (L1, L0). Shallow ocular furrow present, parallel to outer margin of ocular lobe for entire length of lobe. Intraocular cheek about as wide as ocular lobe opposite preoccipital furrow, narrows to about half this width between tip of ocular lobe and glabella.

Extraocular cheek broad, gently convex. Narrow preglabellar median ridge present on some specimens. Distance from ocular lobe to border furrow at genal angle about equal to, or slightly greater than, transverse width of occipital ring.

Ornamentation consists of faint bertillon markings on the glabella and extraocular cheeks of some specimens (pl. 3, fig. 5). Most specimens appear smooth.

Discussion.—This species is most similar to *O. gilberti* Meek with which it is often associated. It differs by having a somewhat greater sagittal length to the preglabellar area, a wirelike cephalic border, and generally less advanced genal spines. However, because of distortion of many specimens in shales, it is sometimes difficult to assign particular individuals to either species with confidence. The moderately long ocular lobes, clearly separated from both the axial and posterior border furrows at their tips, distinguish this species from other similar species of *Olenellus*.

Occurrence.—Rare to common throughout most of the *Olenellus* Zone, >50 cephala. California: 2304–CO, 3097–CO, 4152–CO, Echo Canyon section, Funeral Mountains; 3676–CO, Resting Springs Range; 3681–CO, Eagle Mountain; 3698–CO, 4144–CO, 7184a,b–CO, Titanothere Canyon section, Grapevine Mountains; 4168–CO, Salt Spring Hills; 4640–CO, Avwatz Pass. Nevada: 1034–CO, 1995–CO, 3694–CO, 3786–CO, 3787–CO, Nevada Test Site; 7192–CO, Desert Range.

Olenellus cylindricus n. sp.

Plate 2, figures 9, 10, 13, 14

Description.—Moderate to large olenellids; width of largest observed cephalon about 40 mm between intergenal angles. Cephalon semicircular in outline with marginal curvature continued into slender, posterolaterally directed, generally slightly advanced, genal spine. Lateral margin behind genal spine straight, makes an angle of 45° or less with lateral projection of straight posterior margin. Border well defined all around cephalon by shallow narrow border furrow. Intergenal spine short, sharp, laterally directed, poorly preserved on many specimens, located slightly anterior to intergenal angle.

Glabella elongate, not quite reaching anterior border, leaving narrow preglabellar area. Frontal lobe expanded, subcircular in outline, defined by shallow anterior axial furrows; width about one-third greater than width at occipital ring. Posterior part of glabella moderately defined by shallow axial furrows, sides subparallel or slightly convergent opposite occipital and preoccipital segments and only slightly divergent anterior to preoccipital segment. Three glabellar furrows present: anterior furrow (S3) shallow, sinuous, deepest adjacent to inner ends of ocular lobes; middle furrow (S2) not connected to axial furrows, represented by shallow transverse slots connected by shallower transglabellar furrow; preoccipital furrow (S1) deep adjacent to axial furrows, shallow across top of glabella. Occipital furrow similar in form and depth to preoccipital furrow. Occipital ring has axial node adjacent to posterior margin.

Ocular lobe crescentic, posteriorly tapered, upper surface not preserved on specimens studied. Intraocular cheek about as wide as ocular lobe. Line connecting posterior tips of ocular lobes passes over preoccipital segment (L1).

Extraocular cheeks gently convex; distance from ocular lobe to border furrow at base of genal spine about one-fourth width of cephalon between intergenal angles.

Ornamentation not preserved on specimens studied.

Discussion.—This species is most similar to *O. euryparia*, and its relations are discussed under that species. The relatively short ocular lobes well separated from the glabella, generally advanced genal spines, and narrow preglabellar area combine to distinguish this species from other similar olenellids.

Occurrence.—Common, *O. arcuatus* Zonule. California: 4146–CO (12 cephala), Grapevine Mountains.

Olenellus euryparia n. sp.

Plate 2, figures 15–18

Olenellus fremonti Walcott, 1910, pl. 37, figs. 1, 4, 5 (only).

Description.—Moderate to large olenellids; width of largest observed cephalon about 50 mm between intergenal angles. Cephalon transversely subpentagonal in outline, moderately rounded in front of glabella, gently curved laterally, with curve continuing along slender posteriorly directed genal spine. Lateral margin behind genal spine straight, makes angle of 45° or more with lateral projection of straight posterior margin. Border well defined by continuous anterior, lateral, and posterior border furrows. Intergenal spine short, sharp, laterally directed; present on even largest cephala; located at or slightly anterior to intergenal angle. Glabella elongate, anteriorly expanded, extended to inner edge of anterior border. Frontal lobe hemispherical, strongly elevated above adjacent extraocular cheeks, defined at sides by narrow shallow anterior axial furrows; transverse width about one-fourth more than transverse width of occipital ring. Remainder of glabella defined at sides by narrow, shallow axial furrows; narrowest at glabellar segment L2. Three glabellar furrows present anterior to occipital furrow: anterior furrow (S3) deep adjacent to inner end of ocular lobe, shallow across top of glabella; middle furrow (S2) nearly straight, deepest at distal ends, curved slightly backward laterally behind distally expanded glabellar lobe (L3); preoccipital furrow (S1) deep at sides of glabella, directed inward and backward, shallow across top. Occipital furrow nearly straight, deep distally, shallow across top of glabella. Occipital ring has moderately large axial node adjacent to posterior margin.

Ocular lobe slender, arcuate, separated from glabellar lobe L3 by shallow furrow. Ocular furrow apparent only near glabellar end of ocular lobe, connected to axial furrow so that only inner part of ocular lobe is connected to frontal glabellar lobe. Line connecting posterior tips of ocular lobes passes over anterior part of preoccipital glabellar segment (L2). Intraocular cheeks slightly narrower than ocular lobe, moderately to strongly convex transversely forming a ridge that merges posteriorly with extraocular cheek (pl. 2, fig. 18).

Extraocular cheek gently convex, downsloping; distance from ocular lobe to lateral border furrow at base of genal spine between one-third and one-fourth width of cephalon between intergenal spines.

Ornamentation consists of strong bertillon markings on glabella and weak bertillon markings on anterior border and genal spines; all other parts lack distinct ornamentation; surface of mold smooth.

Discussion.—This distinctive olenellid is distinguished from all other species by having advanced genal spines, laterally directed intergenal spines on specimens of all sizes, and a hemispherical frontal lobe on the glabella that reaches to the inner edge of the anterior border. The most similar species is *O. altifrontatus* Fritz (1972) from the upper part of the *Bonnia-Olenellus* Zone in the Sekwi Formation of the Mackenzie Mountains in the northwestern part of the Northwest Territories, Canada. However, *O. euryparia* has narrower and more convex intraocular cheeks, slightly shorter ocular lobes, less slotlike lateral parts to the glabellar furrows, and bertillon markings rather than granules on the external surface of the glabella. In addition, *O. altifrontatus* has axial nodes on several glabellar segments; whereas none are apparent on *O. euryparia*.

Among the Carrara faunas, *O. euryparia* is most similar to *O. cylindricus* n. sp., differing principally by having the glabella extended to the anterior border and more constricted at the middle segment (L2) and by having the middle glabellar furrow (S2) continuous across the entire glabella. *O. cylindricus* is also a slightly older species.

Occurrence.—Locally common, upper part of *Bristolia* Zonule (?). California: 3680-CO (> 20 cephala), Eagle Mountain.

Olenellus fremonti Walcott

Plate 3, figures 14–17

Olenellus fremonti Walcott, 1910, p. 320, pl. 37, fig. 2 (only); Riccio, 1952, p. 30, pl. 7, fig. 6.
Mesonacis fremonti (Walcott). Resser, 1928, p. 6, pl. 1, figs. 3–9; pl. 2, fig. 9; pl. 3, fig. 8.
?*Olenellus (Fremontia) fremonti* Walcott. Lochman, Christina, in Cooper and others, 1952, p. 91, pl. 18, figs 4–5.

Description.—Large olenellids; width of largest observed cephalon about 80 mm. Cephalon semicircular in outline, gently convex; marginal curvature continuous onto moderately long slightly advanced genal spine. Posterior margin nearly straight between rounded intergenal angles; deflected forward at varying angles to base of genal spine. Intergenal spine not apparent on holaspid specimens. Cephalic border flattened, well defined along lateral and anterior margins by continuous border furrow, less well defined along posterior margin.

Glabella elongate, extended to anterior border furrow. Frontal lobe subcircular to sagittally subovate in outline, not inflated; width slightly greater than width of occipital ring; separated from extraocular cheeks by change in exoskeletal slope. Remainder of glabella defined at sides by shallow axial furrows, slightly constricted at preoccipital furrow (S1). Three glabellar furrows present: anterior furrow (S3) curved backward, shallow, connected across top of glabella; middle furrow (S2) straight or slightly curved backward, shallow, not connected to axial furrows, but connected across top of glabella; preoccipital furrow (S1) directed inward and backward from axial furrows, connected across top of glabella. Occipital furrow nearly straight, deepest at sides of glabella, not clearly connected across top. Occipital ring has small axial node adjacent to posterior margin.

Ocular lobes short; ocular furrow barely apparent parallel to outer margin of lobe; line connecting tips of lobes passes over preoccipital furrow (S1) or middle glabellar segment (L2). Intraocular cheek about as wide as ocular lobe.

Extraocular cheek broad, gently convex. Distance from ocular lobe to border furrow at genal spine about one-third width of cephalon at intergenal angles.

Ornamentation consists of very faint bertillon markings on glabella and extraocular cheeks of some specimens. Most specimens appear smooth.

Discussion.—When Walcott, in 1910, described this species, he included it in a large number of previously illustrated specimens that had been identified as *O. gilberti* Meek or *O. howelli* Meek in earlier publications (Walcott, 1884, 1886, 1891). The type locality is given as locality 52, Prospect Mountain, Eureka, Nev. Resser (1928) placed *fremonti* in *Mesonacis* and restricted it to the specimen from locality 52 illustrated on plate 37, figure 2 by Walcott (1910) and a specimen from the Resting Springs Range (Walcott, 1910, pl. 37, fig. 1). By so revising the species, he automatically designated the specimen from locality 52 as the holotype, all other specimens from this locality being removed from the species. This specimen seems to be essentially the same as the much better preserved specimens from the Marble Mountains assigned by Resser to *Mesonacis fremonti.*

The species is similar to the associated *Bristolia bristolensis* from which it differs by having the glabella barely constricted at the preoccipital furrow and by having the genal spines less strongly advanced. It differs from other species of *Olenellus* by the following combined characteristics: glabella reaching the anterior border furrow, short ocular lobes whose tips are well separated from the glabella, and slightly advanced genal spines.

In October 1971 I located all but three of the specimens assigned by Walcott (1910, pl. 37) to *O. fremonti* in the collections of the U.S. National Museum and I reexamined them. In addition, specimens identified by Lochman (1952) as *O. (Fremontia) fremonti* were reexamined. Among Walcott's specimens, those he showed on plate 37, figures 1, 4, and 5 represent *O. euryparia* n. sp.; figure 2 is the holotype; figure 3 is a form lacking advanced genal spines and possibly represents *Wanneria,* although it is in a recrystallized limestone and its surface is not preserved; figures 6, 20, 21, and 22 are indeterminate parts; figure 7 is not well enough preserved to see critical cephalic characteristics and has genal spines more like those of *Bristolia fragilis* n. sp. than *O. fremonti;* figures 8, 10, and 11 represent an undescribed species related to *Bristolia anteros* n. sp.; figure 9, and figure 8, plate 41, are of a specimen of *Bristolia anteros* n. sp.; figure 14 represents another undescribed species with a glabellar and ocular lobe structure like that of *Bristolia anteros* but lacking advanced genal spines; figures 16, 18, and 19 represent *Bristolia bristolensis* (Resser); and figure 17 represents still a third undescribed species more closely resembling *O. euryparia* than *O. fremonti* and characterized by narrow extraocular cheeks. The specimens in figures 12, 13, and 15 could not be located.

Lochman (in Cooper and others, 1952) illustrated two specimens assigned to this species. One (Lochman, in Cooper and others, 1952, pl. 18, fig. 5) is too incomplete for specific identification, although it does have a short eye and the glabella reaches the border furrow. The other (Lochman, in Cooper and others, 1952; pl. 18, fig. 4) has much narrower extraocular cheeks than *O. fremonti* and also has a well-developed intergenal spine close to the genal spine.

Of the specimens assigned here to *O. fremonti,* the specimen from the Salt Spring Hills (pl. 3, fig. 17) agrees in all respects with the Marble Mountains and Eureka district specimens. The specimens from the Funeral Mountains are tectonically distorted but have no clear-cut features to distinguish them from *O. fremonti.*

Occurrence.—Rare throughout most of the *Olenellus* Zone (≈10 cephala). California: 2304–CO, Funeral Mountains; 3676–CO, Resting Springs Range; 4168–CO, Salt Spring Hills.

Olenellus gilberti Meek

Plate 3, figures 6–13

Olenellus gilberti Meek, 1874, in White, 1874, p. 7; White, 1877, p. 44, pl. 2, fig. 3a; (part) Walcott, 1886, p. 170, pl. 19, figs. 2, 2a, 2b; pl. 21, figs. 1, 1a; 1891, pl. 84, figs. 1, 1a; pl. 85, figs. 1b, 1c; 1910, p. 324, pl. 36, figs. 1, 2, 3, 6; Shimer and Shrock, 1944, pl. 253, figs. 2, 3.

?*Olenellus gilberti* Meek. Peach, 1894, p. 671, pl. 32, figs. 9, 10; Best, 1952, p. 17, pl. 1, figs. 13–17; Norford, 1962, p. 6, pl. 1, figs. 8, 9; Fritz, 1968, p. 193, pl. 36, figs. 26–28.

Olenellus truemani Walcott. Lochman, in Cooper and others, 1952, pl. 18, figs. 9, 10 (only).

Description.—Large olenellids; width of largest observed cephalon about 80 mm. Cephalon semicircular in outline, nearly flat; marginal curvature continuous onto short slender genal spine located slightly in advance of posterolateral cephalic corner. Posterior margin nearly straight from occipital ring to intergenal spine, then deflected slightly forward to base of genal spine. Intergenal spine short, sharp, laterally directed, present on specimens of all sizes. Cephalic border well defined around entire cephalic margin by moderately deep border furrow. Inner margins of anterior and lateral parts of border rise abruptly and steeply from border furrow; peripheral parts of border flattened.

Glabella elongate, separated from frontal border by preglabellar area as wide or wider than anterior border. Frontal lobe subcircular in outline, not inflated; width about equal to width of occipital ring; separated from extraocular cheeks by abrupt change in exoskeletal slope. Remainder of glabella defined at sides by shallow axial furrows narrowest at preoccipital furrow (S1). Three glabellar furrows present: anterior furrow (S3) deep, curved, not generally connected across top of glabella; preoccipital furrow (S1) deep at sides of glabella, directed inward and backward from axial furrow, generally not connected across top of glabella. Occipital furrow deep at sides of glabella, directed nearly straight inward from axial furrow, not connected across top of glabella. Occipital ring has small axial node adjacent to posterior margin.

Ocular lobes slender, arcuate, elongate; line connecting tips passes over occipital furrow (S0) or adjacent parts of preoccipital or occipital segments (L1, L0). Shallow ocular furrow present, parallel to outer margin of ocular lobe for entire length of lobe. Intraocular cheek about as wide as ocular lobe opposite preoccipital furrow, narrows to about half this width between tip of ocular lobe and glabella.

Extraocular cheek broad, gently convex. Narrow preglabellar median ridge present on some specimens. Distance from ocular lobe to border furrow at genal angle equal to or slightly more than transverse width of occipital ring.

Ornamentation consists of extremely faint bertillon markings on the glabella of some specimens. Most specimens appear smooth.

Discussion.—The original group of specimens identified by Meek as *O. gilberti* from a collection in the Pioche Hills, Nev., includes an association of *O. gilberti* and *O. clarki*. Specimens of both species were illustrated as *O. gilberti* by Walcott, who also included Meek's species *O. howelli* within his concept of *O. gilberti*. All available specimens assigned to *O. gilberti* by Walcott and earlier workers were reexamined, and the synonymy reflects my conclusions. *O. howelli* has long ocular lobes that reach nearly to the posterior border furrow; and it occurs in a crystalline limestone, which in the Pioche region can only be the Combined Metals Member of the Pioche Shale. This member is partly equivalent to the Gold Ace Limestone Member of the Carrara Formation. In both units, the olenellid species are characterized by long ocular lobes, and the constancy of those features suggests that they reflect real population differences, interpreted here to be of specific value.

O. gilberti is restricted to forms sharing the characteristics of the broad-bordered specimens of the type lot. It is distinguished from other species of *Olenellus* by the combined features of a narrow preglabellar field, by slightly advanced genal spines, by ocular lobes moderately long, but clearly terminating anterior to the posterior border furrow, and by a slightly flattened moderately broad border. It is most difficult to distinguish from the associated species, *O. clarki* (Resser). The difficulties of discrimination between forms assigned to these two species are mentioned in the opening discussion of the genus *Olenellus*.

In addition to the Nevada and California specimens assigned to *O. gilberti*, several of the specimens identified by Lochman (1952) as *O. truemani* have the characteristics of *O. gilberti* and are included here in its synonymy.

Occurrence.—Rare to common throughout most of the *Olenellus* Zone (>50 cephala). California: 2304–CO, 3097–CO, Funeral Mountains; 3676–CO, Resting Springs Range; 3681–CO, Eagle Mountain; 3698–CO, 4144–CO, 7184–CO, Titanothere Canyon section, Grapevine Mountains; ?3148–CO, 4152–CO, Echo Canyon section, Funeral Mountains; 4168–CO, Salt Spring Hills. Nevada: 1034–CO, 1995–CO, 3786–CO, 3787–CO, Nevada Test Site; 4433–CO, Belted Range.

Olenellus howelli? Meek

Plate 4, figure 16

Olenellus howelli Meek, 1874, in White, 1874, p. 8; White, 1877, p. 47, pl. 2, figs. 4a,b.

Olenellus gilberti Meek (part). Walcott, 1886, pl. 18, figs. 1, 1a; 1891, pl. 84, figs. 1b,c; 1910, pl. 36, figs. 4, 4a; Palmer, 1957, pl. 114, pl. 19, figs. 1–3, 6, 11, 12, 15, 16, 19.

Discussion.—A relatively small broad-bordered olenellid is associated with the narrow-bordered species *O. puertoblancoensis* (Lochman) and has all other features, including the distinctively long ocular lobes, essentially the same as that species. The basic morphologic characters are shared with the single large olenellid cephalon described as *Olenellus howelli* by Meek. The reasons for removing *O. howelli* from the synonymy of *O. gilberti* where it has been placed since 1886, have already been discussed in the section on *O. gilberti*. The differences between the holotype and the two specimens from the Carrara Formation may be due wholly to the size difference of the specimens. The frontal lobe of the glabella enlarges with increasing size in most olenellids, and the lesser gap between the front of the glabella and the border in the large specimen may be explained by this observation. However, without more specimens from either the type region or the Carrara Formation, the species identification of the Carrara specimens must remain tenuous.

Occurrence.—Rare, *Olenellus* Zone. California: 4145–CO (1 cephalon), Titanothere Canyon section, Grapevine Mountains.

Olenellus multinodus n. sp.

Plate 4, figures 1–9

Olenellid trilobite, undescribed, Norford, 1962, p. 6, pl. 1, fig. 3.

Description.—Small olenellids; width of largest observed cephalon about 20 mm. Cephalon semicircular in outline; anterior margin evenly curved with curvature continuing along short slender posterolaterally directed genal spine; posterior margin nearly straight to intergenal angle, then directed slightly anterolaterally to base of slightly advanced genal spine. Narrow border well defined by broad shallow border furrow along entire cephalic margin. Intergenal spine short, posterolaterally directed.

Glabella elongate, extended nearly to anterior border; preglabellar area very narrow. Frontal lobe prominent, subhemispherical, strongly elevated above extraocular cheeks, defined at sides by abrupt change in exoskeletal slope; width between one-third and one-half greater than transverse width of occipital ring and about one-third width of cephalon between intergenal spines. Posterior part of glabella slender, slightly constricted opposite middle glabellar furrow (S2), axial furrows present only opposite middle glabellar segment (L2). Three glabellar furrows present: anterior furrow (S3) marked only by pits adjacent to juncture of ocular lobe and frontal glabellar lobe; middle furrow (S2) deep at sides of glabella, very shallow across top; preoccipital furrow (S1) slightly curved posteriorly, deep at sides of glabella, shallow across top. Occipital furrow essentially the same as preoccipital furrow. Preoccipital segment merges laterally with intraocular cheek. Occipital ring has short axial spine at posterior margin. Single axial nodes decreasing in height from back to front are present on glabellar segments L1, L2, and L3.

Ocular lobes divergent, crescentic, short, prominent, without ocular furrows. Line connecting tips of ocular lobes passes over anterior part of preoccipital segment (L1) or preoccipital furrow (S1). Intraocular cheek wider than ocular lobes, on some specimens has two low swellings.

Extraocular cheeks gently convex; distance from ocular lobe to border furrow at genal angle slightly more than one-fourth width of cephalon between intergenal spines. Low narrow intergenal ridge present on some specimens extending from posterior tip of ocular lobe in sigmoid curve to border adjacent to intergenal spine.

Ornamentation consists of bertillon markings on glabella and ocular lobes, in addition to axial nodes on glabella.

Discussion.—This species is distinguished from all other olenellids by having strong glabellar relief and axial nodes on three glabellar segments; short divergent prominent unfurrowed ocular lobes; and slightly advanced, relatively short genal spines. Most samples collected show some evidence for tectonic deformation (pl. 4, figs 2, 3).

The most similar species is *O. arcuatus* n. sp. which differs by having a strongly curved posterior cephalic margin and much shorter genal spines.

A fragmentary partial thorax from the northern Delamar Range (pl. 4, figs. 7, 8) shows this species to have an extremely large macropleural third thoracic segment and a gradual transition from prothoracic to opisthothoracic segments. There is no indication of the axial spine usually found on the 15th thoracic segment, but this could be an artifact of imperfect preservation. The specimen has 17 opisthothoracic segments with no indication that the terminal segment is preserved. If additional specimens show similar thoracic peculiarities, *O. multinodus* and probably also *O. arcuatus* should be removed from *Olenellus* and placed in a new genus.

In addition to its occurrences in the Carrara Formation—always in the shales overlying the Gold Ace Limestone Member—*O. multinodus* has been collected in shales within the Combined Metals Member of the Pioche Shale in Nevada near Delamar and north of U.S. Highway 93 west of the Oak Spring Summit crossing of the Delamar Range (p. 58), and in a 2.5-cm limestone bed immediately above the Chambless Limestone in the Marble Mountains of southeastern California. A specimen assignable to this species (pl. 4, fig. 6) has been illustrated by Norford (1962) from a locality described by Mountjoy (1962) and 10 m above the top of the predominantly quartzitic Gog Group in Jasper Park, western Alberta, Canada.

Occurrence.—Common (>40 cephala), *O. multinodus* Zonule. California: 2304–CO, 3097–CO, Echo Canyon section, Funeral Mountains; 3676–CO, Resting Springs Range; 3681–CO, Eagle Mountain; 3698–CO, 7184–CO, Titanothere Canyon section, Grapevine Mountains. Nevada: 3696–CO, Desert Range; 7221–CO, 7224–CO, Delamar Range.

Olenellus nevadensis (Walcott)

Plate 4, figures 10, 13, 17

Olenellus gilberti Walcott (part). Walcott, 1884, pl. 9, fig. 16; 1886, pl. 19, fig. 2g; 1891, pl. 85, fig. 1e.
Callavia? nevadensis Walcott, 1910, p. 285, pl. 38, fig. 12.
Paedeumias nevadensis (Walcott). Resser, 1928, p. 9, pl. 3, figs. 3–7; Riccio, 1952, p. 33, pl. 9, figs. 5, 6.

Description.—Moderately large olenellids; width of largest observed cephalon about 65 mm. Cephalon semicircular in outline, nearly flat; marginal curvature continuous onto short slender genal spine at posterolateral corner. Posterior margin straight, deflected very slightly forward distal to short sharp intergenal spine that is located near genal spine. Narrow convex cephalic border well defined by narrow border furrow around entire cephalon.

Glabella tapered forward, relatively short, separated from anterior border by distance varying between one-sixth and one-half sagittal glabellar length. Frontal lobe subconical, defined by abrupt change in slope. Remainder of glabella widest at occipital ring, tapers very slightly forward to ocular lobes. Three glabellar furrows present: anterior furrow (S3) represented by moderately deep, elongate slots directed inward and backward from inner ends of ocular lobes, may or may not be connected across top of glabella by shallow furrow; middle furrow (S2) represented consistently by isolated deep transverse slots; preoccipital furrow (S1) deep at sides of glabella, directed backward and inward, either connected by shallow furrow or not connected across top of glabella. Occipital furrow deep at sides of glabella, not connected across top. Occipital ring has small median node adjacent to posterior margin.

Ocular lobes long, slender, arcuate, not furrowed; directed posterolaterally from posterolateral parts of frontal lobe; line connecting tips passes over occipital or preoccipital segment (L0, L1). Intraocular cheek about equal in width to ocular lobe.

Extraocular cheek broad, gently convex; distance from ocular lobe to lateral border furrow on line parallel to posterior border between one-third and one-fourth posterior width of cephalon. Very narrow preglabellar median ridge apparent on some specimens.

Discussion.—This species is distinguished from other species of *Olenellus* by its anteriorly tapered glabella well separated from the anterior border and by the configuration of its glabellar furrows. The statement by Walcott (1910) that the species is characterized by short ocular lobes resulted from an erroneous reconstruction of the type cephalon which added extra length. The ocular lobes reach nearly to the occipital furrow on most specimens and farther posteriorly on others.

Specimens possibly representing this species have been found associated with *O. multinodus* n. sp. in the northern Delamar Range, but they have a complete occipital furrow unlike the forms illustrated from the Death Valley region and in the Marble Mountains to the south. They are also significantly younger than the more characteristic specimens.

Occurrence.—Rare (≈5 cephala), *Bristolia* Zonule and underlying beds of the lowermost part of Carrara Formation. California: 3148–CO, Echo Canyon section, Funeral Mountains; 4144–CO, Titanothere Canyon section, Grapevine Mountains. Nevada: 7193–CO, Desert Range.

Olenellus puertoblancoensis (Lochman)

Plate 4, figures 11, 14

Paedeumias puertoblancoensis Lochman, in Cooper and others, 1952, p. 94, pl. 19, figs. 9–16.
Paedeumias clarki Resser. Palmer, 1957, pl. 19, figs. 4, 5, 10, 14, 17, 20.
Olenellus puertoblancoensis (Lochman). Fritz, 1972, pl. 17, figs. 1–7.

Discussion.—Two small collections from the Titanothere Canyon section in the Grapevine Mountains, Calif., have yielded a few cephala of a species-pair similar to *Olenellus gilberti–Olenellus clarki* except for long ocular lobes that extend to or nearly to the posterior border furrow adjacent to the occipital ring, isolating the intraocular cheek. The narrow-bordered forms agree in all essential details with specimens from the Buelna Formation near Caborca, Mexico, described by Lochman as *Paedeumias puertoblancoensis* and are assigned to that species. The broad-bordered forms are assigned to *O. howelli*? Meek discussed in a preceding section. A silicified ontogenetic sequence from the Highland Range (Palmer, 1957) that was assigned to *Paedeumias clarki* Resser represents a long-eyed form differing in this respect from *P.* (now *Olenellus*) *clarki*, and it should be assigned to *O. puertoblancoensis*. Both Lochman and Fritz gave full descriptions of this species.

Occurrence.—Rare, *Olenellus* Zone. California: 4144–CO, 4145–CO (3 cephala), Titanothere Canyon section, Grapevine Mountains.

Olenellus sp.

Plate 4, figures 12, 15

Discussion.—A single fragmentary cephalon represents an unusual olenellid characterized by well-developed granular ornamentation on the glabella, ocular lobes, and border. The ocular lobes are long; a line connecting their tips passes over the occipital ring. The anterior margin is broken but the front of the glabella is preserved, suggesting that a short preglabellar area was present. The nature of the genal spine is not known, but it was located at the posterolateral cephalic corner, and a well-developed laterally directed intergenal spine is adjacent to it.

No other olenellid has the granular ornamentation and long ocular lobes characterizing this species, but the sole specimen is too incomplete for formal naming.

Occurrence.—Rare, *Olenellus* Zone. California: 7184–CO (1 cephalon), Titanothere Canyon section, Grapevine Mountains.

Genus PEACHELLA Walcott

Peachella Walcott, 1910, p. 342; Shimer and Shrock, 1944, p. 615; Poulsen, C., 1932, p. 35; Poulsen, C., in Harrington and others, 1959, p. 192.

Type species.—*Olenellus iddingsi* Walcott, 1884, p. 28, pl. 9, fig. 12.

Diagnosis.—Olenellidae with generally effaced cephalic furrows. Cephalon semicircular in outline. Glabella elongate, extended to inner edge of anterior border. Ocular lobes short, close to glabella. Genal spines short, swollen.

Discussion.—This is the easiest of all olenellid genera to recognize because of the swollen genal spines and generally featureless cephalon. Good specimens are rare, but the swollen genal spines are moderately common (pl. 5, fig. 5) and permit specific identification of fragments in the absence of whole cephala.

Peachella brevispina n. sp.

Plate 5, figures 1–3

Description.—Moderately small olenellids, length of largest observed cephalon about 12 mm. Cephalon semicircular in outline with short, swollen, posterolaterally directed genal spines. Glabella long, extended to inner edge of anterior border, poorly defined by slight changes in exoskeletal slope, breadth nearly constant. Glabellar and occipital furrows not apparent. Ocular lobes short, unfurrowed, close to glabella, poorly differentiated from frontal lobe and intraocular cheek; line connecting posterior tips passes over glabella at point about two-thirds of glabellar length from anterior end of glabella. Occipital ring seems to lack distinct axial node adjacent to posterior margin. Extraocular cheeks gently downsloping to cephalic margin. Anterior and lateral borders poorly defined by shallow, narrow border furrow; lateral border furrow continues along inner base of genal spine to posterior margin. Posterior border furrow not clearly defined.

External surfaces of all parts of cephalon smooth.

Discussion.—This species differs from all other olenellids by its poor development of cephalic furrows, by short ocular lobes, and by short, swollen, and posterolaterally directed genal spines. The latter character distinguishes it from *P. iddingsi* (Walcott).

Occurrence.—Moderately rare (≈15 cephala), *Bristolia* Zonule. California: 3679–CO, Eagle Mountain; 4167–CO, Dublin Hills.

Peachella iddingsi (Walcott)

Plate 5, figures 4–9

Olenellus iddingsi Walcott, 1884, p. 28, pl. 9, fig. 12; Walcott, 1886, p. 170, pl. 19, fig. 1.

Peachella iddingsi (Walcott). Walcott, 1910, p. 343, pl. 40, figs. 17–19; Shimer and Shrock, 1944, pl. 254, fig. 17.

Description.—Moderately small olenellids, length of largest observed cephalon about 12 mm. Cephalon semicircular in outline with moderately short posteriorly directed sausage-shaped genal spines at posterolateral corners. Glabella long, extended to inner edge of anterior border, poorly defined by slight changes in exoskeletal slope, narrowest at about midlength. Glabellar and occipital furrows barely apparent even after whitening. Ocular lobes short, unfurrowed, close to glabella, poorly differentiated from frontal lobe of glabella and intraocular cheek; line connecting posterior tips passes over glabella slightly posterior to glabellar midlength and, where apparent, over middle glabellar segment (L2). Occipital ring has median node adjacent to posterior margin. Extraocular cheeks gently downsloping to shallow lateral border furrow. Posterior border furrow defined faintly only near genal angle. Anterior border narrow, begins to broaden posteriorly into swollen genal spine opposite anterior glabellar lobe. Posterior border wider than anterior border near genal angle at position of immature intergenal spine. Extremely faint intergenal ridge present on some specimens.

External surfaces of all parts of cephalon smooth.

Discussion.—This species is easily distinguished from all other olenellids by its short ocular lobes, posteriorly directed sausage-shaped genal spines, and poor development of cephalic furrows. The shape and direction of the genal spines distinguishes *P. iddingsi* from *P. brevispina* n. sp.

A small suite of silicified specimens from the Titanothere Canyon section includes immature cephala with a more distinctly defined glabella and glabellar furrows, and with a short intergenal spine adjacent to the genal spine (pl. 5, fig. 6).

Occurrence.—Moderately common (<20 cephala), *Bristolia* Zonule. California: 3675–CO, Resting Springs Range; 4144–CO, 7183–CO, Titanothere Canyon section, Grapevine Mountains; 4152–CO, Echo Canyon section, Funeral Mountains; 4290–CO, Funeral Mountains; 4161–CO, Cucomungo Canyon section, Last Change Range. Nevada: 3694—CO, 3786—CO, 3787—CO, Nevada Test Site; 7193—CO, Desert Range.

Order MIOMERA Jaekel
Superfamily AGNOSTOIDEA Salter
Family QUADRAGNOSTIDAE Howell

This family assignment is used here in the sense of Öpik (1961) and has been discussed by me earlier (Palmer, 1968, p. 23). The ordinal and superfamily designations, are those recommended by Jell (1975, p. 14).

Genus PERONOPSIS Corda

Peronopsis Corda in Hawle and Corda, 1847, p. 115; Palmer, 1968, p. 31 (for synonymy to date).

Type species.—*Battus integer* Beyrich, 1845, p. 44, pl. 1, fig. 19.

Discussion.—Robison (1964) presented a good recent diagnosis of this genus to which the specimens described below conform in all respects.

Peronopsis bonnerensis (Resser)

Plate 12, figures 11, 15

Agnostus bonnerensis Resser 1938b, p. 6, pl. 1, figs. 16, 17; Resser, 1939a, p. 8, pl. 2 figs. 24–26.
Agnostus lautus Resser, 1939b, p. 25, pl. 2, figs. 16–18.

Description.—Cephalon moderately convex transversely and longitudinally. Glabella well defined by narrow furrows. Anterior lobe bluntly rounded at front, separated from remainder of glabella by straight transverse furrow. A second glabellar furrow may be marked by shallow notches at the sides of the glabella. Basal lobes simple. Axial node indistinct. Border narrow, well defined, of constant breadth; sagittal length about one-third sagittal length of undivided preglabellar field.

Pygidium with axis well defined, bluntly pointed posteriorly, reaching nearly to inner part of border; postaxial furrow absent. First axial segment weakly defined by shallow transaxial furrow. Axial node situated in position of second segment which is only faintly outlined on exfoliated specimens. Border well defined, with short poorly developed posterolateral border spines.

Discussion.—Recent work by Campbell (1974) in southeastern Idaho demonstrated that the differences between *P. bonnerensis* (Resser) and *P. lautus* (Resser) are attributable to both preservation and to infraspecific variability; Campbell suggested that *P. lautus* be suppressed as a junior synonym of *P. bonnerensis*. The specimens from the Carrara Formation conform in all respects to specimens of this species described from southeastern Idaho.

P. bonnerensis (Resser) is most similar to *P. brighamensis* (Resser). It differs by having more weakly developed pygidial spines and a slightly longer pygidial axis, and by lacking a well-developed transverse furrow at the back of the second axial segment.

Occurrence.—Moderately rare, *Albertella* Zone. Zacanthoidid Zonule: Nevada: 3766–CO (3 cephala, 2 pygidia), Nevada Test Site. *Ogygopsis* Zonule: Nevada: 4437–CO (1 weathered complete individual, 3 cephala, 7 pygidia), 4438–CO (4 cephala, 4 pygidia), both from Belted Range.

Peronopsis? sp.

Plate 12, figure 7

Discussion.—A single agnostid pygidium, associated with *P. bonnerensis* (Resser), differs from that species by having an axis that is well defined and crossed by two deep complete transverse furrows. The posterior lobe is pointed posteriorly and is separated from the border by a distance slightly greater than the border width. There is no clear postaxial furrow. A large axial node on the second axial segment deflects the furrow outlining the posterior margin slightly backward on the axial line. The border has a slight angulation in the posterolateral area of the pygidium, but no clear border spine is present. The surface of the exoskeleton is smooth.

The axial structure of this species is like that of *Peronopsis brighamensis* (Resser), but it differs by lacking well-developed border spines. Without more material, a specific identification for this specimen is not possible. It has many characteristics of species of *Ptychagnostus*, and Robison (written commun., 1972) believed that *P. brighamensis* is a species transitional between the two genera. Without knowledge of the associated cephalon, specific and perhaps even generic identification of this pygidium is uncertain.

Occurrence.—Rare, *Albertella* Zone, *Ogygopsis* Zonule. Nevada: 4437–CO (1 pygidium), Belted Range.

Superfamily EODISCOIDEA Richter
Family EODISCIDAE Raymond
Genus MACANNAIA Jell

Macannaia Jell, 1975, p. 71.

Type species.—*Pagetia maladensis* Resser, 1939b, p. 25, pl. 2, figs. 4, 5.

Discussion.—This genus was recently proposed by Jell with *M. maladensis* (Resser) as its type. The material from the Carrara Formation conforms to the type species in all respects and contributes no new information about the genus. The superfamily and family designation are those recommended by Jell (1975, p. 14).

Macannaia maladensis (Resser)

Plate 12, figures 8, 12

Pagetia maladensis Resser, 1939b, part, p. 25, pl. 2, figs. 4 (cranidium in lower center, pygidium in upper center), 5 (cranidium in upper right); Rasetti, 1966a, p. 508, pl. 60, figs. 8–18; Fritz, 1968, p. 190, pl. 43, figs. 14–16.
Pagetia (Mesopagetia) maladensis Resser, Kobayashi, 1944, p.64, pl.2 fig. 4a (only).
Macannaia maladensis (Resser), Jell, 1975, p. 72

Discussion.—This distinctive species is characterized by a bulbous posterior part of the axial lobe of the pygidium, a subrectangular glabella, and a moderately deep preglabellar axial furrow. Only a few specimens have been found in the Carrara Formation, but they agree in all respects with the excellent description given by Rasetti (1966).

Occurrence.—Moderately common, *Albertella* Zone, *Ogygopsis* Zonule. Nevada: 4436–CO (>10 cranidia, 2 pygidia), 4437–CO (1 cranidium), both from the Belted Range.

Genus PAGETIA Walcott

Pagetia Walcott, 1916b, p. 407; Cobbold, 1931, p. 462; Lermontova, E. V., in Vologdin, 1940, p. 121; Richter and Richter, 1941, p. 17; Kobayashi, 1943, p. 40; Kobayashi, 1944, p. 63; Shimer and Shrock, 1944, p. 615; Rasetti, 1945, p. 315; Lermontova, 1951, p. 36; Howell, B. F., in Harrington and others, 1959, p. 189; Pokrovskaya, N. V., in Chernysheva, 1960, p. 55; Yegorova, 1961, p. 215; Yegorova, L. I., and others, in Khalfin, 1955, p. 104; Poletaeva, O.K., in Khalfin, 1960, p. 154; Repina and others, 1964, p. 253; Lazarenko, N.P., in Demodikov and Lazarenko, 1964, p. 176, Rasetti, 1966a, p. 503; Rasetti, 1967, p. 59; Palmer, 1968, p. 35; Jell, 1970, p. 304; Jell, 1975, p. 30.

Type species.—*Pagetia bootes* Walcott, 1916b, p. 408, pl. 67, figs. 1, 1a–f.

Discussion.—Jell (1975) thoroughly described and discussed the characteristics of this well-known genus, and the Carrara specimens conform in all observable features with the description given in his paper. The family and superfamily designations are also those recommended by Jell (1975, p. 14).

Pagetia resseri Kobayashi

Plate 12, figures 16–20, 23–26

Pagetia clytia Resser (not Walcott), 1939b, p. 25, pl. 2, figs. 6–8.

Pagetia (Eopagetia) resseri Kobayashi, 1944, p. 37.

Pagetia resseri Kobayashi, 1943, p. 40; Kobayashi, 1944, p. 64; Rasetti, 1966a, p. 509, pl. 60, figs. 19–25; Fritz, 1968, p. 192, pl. 38, figs. 8, 9.

Discussion.—Rasetti (1966) gave a thorough description of this species, with which the Carrara specimens agree in all respects. This species is easily distinguished from other North American species by having deep pleural furrows on the pygidium and by generally having pits rather than slots developed in the cranidial border.

One sample of this species has abundant silicified individuals of all growth stages and a rare example of the free cheek. Immature cranidia are characterized by prominent elongate swellings on the fixed cheeks, and the glabella is depressed between them. These are essentially comparable to some of the early forms of *P. ocellata* (Jell, 1970), which is the only other *Pagetia* for which the early stages have been described. The free cheek is a subrectangular plate divided into an outer border and inner ocular platform by a narrow nearly straight border furrow.

Occurrence.—Common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3547–CO (>20 silicified cranidia and pygidia, 1 free cheek), 3766–CO (>20 cranidia and pygidia preserved in limestone), both from Nevada Test Site.

Pagetia rugosa Rasetti

Plate 12, figures 9, 13

Pagetia maladensis Resser (part), 1939b, p. 25, pl. 2, figs. 4 (pygidium upper right corner), 5 (cranidia upper left, upper center, lower right).

Pagetia rugosa Rasetti, 1966 p. 509, pl. 60, figs. 1–7.

Pagetia arenosa Fritz, 1968, p. 189, pl. 43, figs. 10–11.

Discussion.—Rasetti recognized that Resser had included two species in his concept of *P. maladensis.* This species was characterized by its pitted and roughened ornamentation and by pygidia lacking a bulbous posterior part to the axis. Fritz, who completed his manuscript before Rasetti's paper appeared, acknowledged in a footnote that his species *arenosa* was a synonym for *P. rugosa*. The specimens from the Carrara Formation have the typical ornamentation and morphology of this species and add nothing to the excellent description given by Rasetti.

Occurrence.—Moderately common, *Albertella* Zone, *Ogygopsis* Zonule. Nevada: 4436-CO (5 cranidia, 6 pygidia), 4437–CO (4 cranidia, 2 pygidia), 4438–CO (12 cranidia, 7 pygidia), all from Belted Range.

Pagetia sp.

Plate 12, figures 10, 14

Discussion.—Associated with *P. resseri* Kobayashi is a second species of *Pagetia* represented by a few pygidia and possible associated cranidia. The pygidia have five distinctly defined axial rings, each with an axial node, and the pleural regions lack any trace of furrows. The cranidia, if properly associated, have the slots in the border typical of many species of *Pagetia* but have distinctly defined palpebral lobes. The combination of cranidial and pygidial features is unlike that of any other described North American species of *Pagetia.* However, without more material, the evidence for association of cranidia and pygidia is weak; and no name is proposed at this time.

Occurrence.—Rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (3 cranidia, 3 pygidia), Nevada Test Site.

Order CORYNEXOCHIDA Kobayashi

Although the Orders Corynexochida and Ptychopariida are used here is the sense of Bergström (1973), they seem to be taxa of lesser rank than the Olenellida and Miomera. Whereas the Olenellida and Miomera each have their own peculiar morphologies and their own distinctive ontogenetic development, the Corynexochida and Ptychopariida have essentially the same kind of ontogenetic development and lack consistently clear-cut morphologic differences. For example, oryctocephalid trilobites are as different from most corynexochids, such as *Albertella* or *Kootenia,* in cephalic and pygidial structure as they are from ptychopariids, but they are Included with the corynexochids in all major classifications. Without a comprehensive review of at least the Cambrian trilobites, which is far beyond the scope of this paper, I do not have a satisfactory alternative suggestion to offer regarding the suprageneric relationships of the nonagnostid and nonolenellid trilobites. Bergström (1973) has made an important contribution to this problem, but much more work remains to be done before a fully satisfactory classification of Cambrian trilobites above the generic level can be prepared.

Family DOLICHOMETOPIDAE Walcott
Genus GLOSSOPLEURA Poulsen

Glossopleura Poulsen, C., 1927, p. 268; Resser, 1935, p. 29; Kobayashi, 1942, p. 159; Palmer, 1954, p. 67; Poulsen, C., in Harrington and others, 1959, p. 224; Poulsen, V., 1964, p. 25.
Sonoraspis Stoyanow, in Cooper and others, 1952, p. 50.

Type species.—Dolichometopus boccar Walcott, 1916, p. 363, pl. 53, figs. 1, 1a–f.

Discussion.—This is a clear-cut genus that has been fully described earlier (Palmer, 1954) except for the hypostome. It is characterized by cranidia with long palpebral lobes and a glabella that reaches to the anterior margin and by semicircular to subovate generally broad bordered nonspinose relatively large pygidia. Several collections from the Carrara Formation that are rich in disarticulated specimens include a number of hypostomes that are as distinctive for the genus as the cranidia. The anterior body is anteriorly expanded as in many Corynexochida; but the distinctive and characteristic difference is that there is no differentiation of a separate rostral part, and the anterior margin is strongly deflected dorsally. When the cranidium is reassembled, the sagittal profile forms a continuous curve from the dorsal part of the anterior lobe to the ventral part of the hypostome without interruption by any marginal flange.

Glossopleura tuta Resser
Plate 16, figures 21–24

Glossopleura tuta Resser, in McKee and Resser, 1945, p. 196, pl. 26, figs. 5, 6.

Description.—A species of *Glossopleura* with glabella not clearly differentiated from anterior part of fixed cheek; only barely differentiated by broad shallow depression opposite posterior part of cheek. Occipital furrow broad, very shallow, poorly defined. Palpebral lobes well defined by abrupt change in slope of exoskeleton, situated below level of interocular area.

Free cheek has broad flat border as wide as or wider than the ocular platform. Lateral and posterior border furrows shallow, connected at genal angle. Genal spine flat, tapered; length more than twice length of posterior section of facial suture. Inner spine angle broad, evenly curved.

Pygidium semicircular in outline; anterior margin nearly straight. Axis lacks any indication of transverse furrows. Border broad, poorly defined, flat, downsloping; width slightly less than twice greatest width of pleural platform.

Discussion.—This species has been known previously only from a single pygidium from the Grand Canyon. Comparison of the specimens of *Glossopleura* from the southern Great Basin with those described from elsewhere in North America and housed in the collections of the U.S. National Museum showed essential identity between the specimen described by Resser as *Glossopleura tuta* and the specimens described above, which were obtained from the lowest bed of a thin-bedded silty limestone member overlying the basal 120-meter-thick massive limestone member of the Bonanza King Formation. This species is not really a part of the fauna of the Carrara Formation, but is illustrated here because it proves that the range zone of *Glossopleura* is represented only by its lower part within the Carrara Formation.

Occurrence.—Common, uppermost *Glossopleura* Zone. Nevada: 7199–CO (>10 pygidia, 1 free cheek, 1 cranidium, many fragments), Striped Hills.

Glossopleura lodensis (Clark)
Plate 16, figures 1–5, 9, 10

Bathyuriscus howelli lodensis Clark, 1921, p. 6.
Dolichometopus? *lodensis* (Clark). Resser, 1928, p. 10, pl. 3, fig. 9.
Glossopleura lodensis (Clark). Resser, 1935, p. 34.

Description.—Cranidium elongate, subrectangular in outline. Glabella long, low, slightly expanded anteriorly; sides partly defined by distinct change in slope of exoskeleton from occipital ring only as far forward as a pair of shallow pits situated slightly anterior to the anterior ends of the palpebral lobes; anterior end not differentiated from remainder of cranidium. Occipital furrow broad, shallow; occipital ring simple with low poorly defined axial node adjacent to posterior margin. Fixed cheeks narrow, gently convex; width, exclusive of palpebral lobes, slightly less than one-half basal glabellar width. Palpebral lobes long, arcuate, situated slightly below surface of cheek; anterior end close to glabella; line connecting posterior tips passes slightly anterior to occipital furrow. Posterior limbs not completely known.

Free cheek has broad flat border, slightly wider than pleural platform at anterior sutural margin. Lateral border furrow shallow, distinct, joined with broader and less distinct posterior border furrow at genal angle. Genal spine flat, broad-based, tapered to a sharp point; length slightly more than length of posterior section of facial suture. Inner spine angle very obtuse, gently curved.

Thorax consists of seven thoracic segments lacking axial nodes or spines. Pleural furrows well defined. Pleural tips sharp; spine of fifth segment seems slightly larger than others.

Pygidium semicircular in outline. Axis prominent, elevated above downsloping pleural regions, defined by change in slope of exoskeleton. Three or four obscure ring furrows observable in oblique lighting. Border poorly defined, downsloping, slightly concave; width slightly greater than greatest width of pleural platform. Pleural furrows obscure or absent; when present, extend onto border.

External surfaces of best preserved specimens show an extremely faintly shagreened surface. Most specimens appear smooth.

Discussion.—This species has never been adequately described. Its cranidium is characterized particularly by having relatively short palpebral lobes. The combined features described for the pygidium serve to distinguish this species from others in *Glossopleura.* The most similar described species is *Glossopleura mckeei* Resser, from the Grand Canyon, which has a smooth pygidium and slightly longer palpebral lobes.

Occurrence.—Common, *Glossopleura* Zonule. California: 3682–CO (2 pygidia, 3 fragmentary cranidia), Eagle Mountain. Nevada: ?3690–CO (1 fragmentary cranidium, 2 free cheeks, 5 fragmentary pygidia, many scraps), Striped Hills. California: 7198–CO (>10 cranidia, pygidia, free cheeks, abundant scraps), Eagle Mountain.

Glossopleura walcotti C. Poulsen

Plate 16, figures 6–8, 11–19

Glossopleura walcotti Poulsen, C., 1927, p. 268, pl. 16, figs. 20–30; V. Poulsen, 1964, p. 25, pl. 1, figs. 2–4.
Glossopleura expansa Poulsen, C., 1927, p. 269, pl. 16, figs. 31, 32.
Glossopleura sulcata Poulsen, C., 1927, p. 272, pl. 16, fig. 39.

Discussion.—This species has been well described by the Poulsens. It is characterized by cranidia with moderately well developed axial furrows and a distinctly expanded anterior end of the glabella. The associated pygidia have a moderately to poorly defined border about as wide as the widest part of the pleural platform, three or four shallow ring furrows and pleural furrows, and faint axial swellings on the anterior three to five axial rings. The pygidial shape varies from semicircular to elliptical. The external surface on well-preserved specimens may be smooth, faintly shagreened, or bear fine scattered pits. One pygidium in the Carrara fauna (pl. 16, fig. 15) has obscure low scattered granules on the pleural regions.

Pygidia of this species can be distinguished from those of other *Glossopleura* species by the combined presence of low axial swellings, shallow ring furrows and shallow pleural furrows, and a border about as wide as the widest part of the pleural platform.

Occurrence.—Common, *Glossopleura* Zonule. Nevada: 3544–CO (1 cranidium, 1 free cheek, 1 pygidium), Desert Range; 3545–CO (1 cranidium, 3 pygidia, 1 hypostome, numerous scraps), Nevada Test Site; 3767–CO (5 pygidia, 2 free cheeks), Nevada Test Site. California: 3684–CO (2 cranidia, 2 pygidia), Eagle Mountain; 4142–CO (>10 cranidia and pygidia, 6 free cheeks, 2 hypostomes), Titanothere Canyon section, Grapevine Mountains; 4155–CO (3 cranidia, 3 free cheeks, 2 pygidia, 1 hypostome, numerous scraps), Echo Canyon section, Funeral Mountains; 4156–CO (5 cranidia, 5 free cheeks, 19 pygidia, 1 hypostome, numerous scraps), Echo Canyon section, Funeral Mountains.

Genus POLIELLA Walcott

Bathyuriscus (Poliella) Walcott, 1916b, p. 349.
Poliella Walcott. Raymond, 1928a, p. 310; Resser, 1935, p. 43; Kobayashi, 1942, p. 153; Poulsen, C., in Harrington and others, 1959, p. 226; Fritz, 1968, p. 206.

Type species.—*Bathyuriscus (Poliella) anteros* Walcott, 1916b, p. 349, pl. 46, fig. 5.

Discussion.—The concept of *Poliella* as a long-eyed corynexochid characterized by a small poorly segmented pygidium seems to have been consistently applied by all authors who have assigned species to the genus. However, as pointed out by Fritz (1968), the genus includes, at present, species with, as well as, without axial spines on the occipital ring and thoracic segments. If it should become desirable to split the genus, those species with axial spines should be retained.

Poliella germana (Resser)

Plate 11, figures 1–8

Ptarmigania germana Resser, 1939b, pl. 7, figs. 16–20.
Poliella germana (Resser), Fritz, 1968, p. 207, pl. 37, figs. 1–9.
Dolichometopsis potens Resser, 1939b, p. 36, pl. 6, figs. 17–20 (only).
Dolichometopsis gravis Resser, 1939b, p. 36, pl. 7, figs. 6–9 (only).
Ptarmigania agrestis Resser, 1939b, p. 39, pl. 7, figs. 1, 2.
Ptarmigania altilis Resser, 1939b, p. 40, pl. 7, figs. 3, 4 (only).
Ptarmigania dignata Resser, 1939b, p. 41, pl. 8, figs. 1, 2, 4–7 (only).

Discussion.—Fritz (1968) gave a good description of this species and clarified the assignments of many of the specimens described and excessively split by Resser (1939b). In addition to the species placed in synonymy with *P. germana,* Fritz reassigned to *P. germana* nontype specimens of two other Resser species from the same report: *Dolichometopsis comis* (Resser, 1939b, pl. 4, left cranidium of fig. 24); and *Ptarmigania sobrina* (Resser, 1939b, pl. 7, fig. 13, pygidium only; figs. 14, 15). The cranidia described as *Dolichometopsis gravis* by Resser (1939b) should also be assigned to *P. germana*. This species is distinguished from all others in the genus by having a nondenticulate pygidial margin and by having two or three shallow pleural furrows continuing onto the inner edge of the pygidial border. It is distinguished, in addition, from the slightly older *P. lomataspis* n. sp. in the Carrara Formation by having a less well developed occipital spinule, a well-developed border furrow on the free cheek, a narrower pygidial border, and a less distinct pitted ornamentation.

Occurrence.—Common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3695–CO (>10 pygidia), Nevada Test Site; 4440–CO (>10 cranidia, 1 free cheek, >10 pygidia), Groom Range.

Poliella lomataspis n. sp.

Plate 6, figures 1–5, 12

Description.—Cranidium, exclusive of posterior limbs, elongate, subrectangular, moderately convex transversely and longitudinally; anterior margin gently curved; no anterior arch. Glabella elongate, expanded slightly forward, reaches nearly to anterior margin; sides nearly straight, defined by abrupt change in slope; anterior end bluntly rounded; anterolateral glabellar corners strongly rounded. Only posterior pair of glabellar furrows apparent, moderately deep, strongly oblique. Occipital furrow deep, straight. Occipital ring broad, nearly flat, with low axial keel terminating in short slender spine at posterior margin; sagittal length of occipital ring slightly more than one-fourth sagittal glabellar length. Frontal area consists only of narrow, flat, or slightly concave border about 0.1 length of glabella exclusive of occipital ring. Fixed cheeks gently convex, horizontal; palpebral lobe elongate, arcuate, well defined by palpebral furrow paralleling margin of lobe; width of palpebral lobe about 0.3 greatest width of palpebral area; width of palpebral area at anterior end of palpebral lobe about one-fourth width of glabella on line connecting anterior ends of palpebral lobes. Posterior limb short, abruptly deflected downward behind palpebral lobe; distal part slightly longer than proximal part. Posterior border furrow broad, shallow; posterior border has slight posterior expansion behind palpebral lobe. External surfaces of all parts except posterior limb and border covered with shallow coarse pits observable only on best preserved specimens.

Course of anterior section of facial suture slightly divergent forward from palpebral lobes to border, then curved inward to intersect anterior margin imperceptibly. Course of posterior section of facial suture gently convex outward from palpebral lobe to posterior margin.

Free cheek elongate, nearly flat; border not clearly defined. Lateral margin gently curved; curvature continued onto base of slender flattened genal spine situated at posterolateral cephalic corner. Length of spine at least twice length of posterior section of facial suture.

Pygidium broad, subovate in outline; sagittal length about 0.6 greatest width. Axis well defined, convex, tapered posteriorly, bluntly rounded, reaches to inner edge of broad concave poorly defined border; two shallow ring furrows present behind articulating furrow; anterior one or two segments may have low poorly defined axial node. Posterior margin straight or slightly indented behind axis. Pleural platforms gently convex, crossed by two widely spaced, gently curved, posterolaterally directed shallow pleural furrows. Extremely faint interpleural furrows on one specimen extend straight laterally, nearly forming the diagonal of a rectangle bounded by the pleural furrows, the axis, and the border. External surface of axis and pleural fields covered with shallow pitted ornamentation identical to that of the cranidium.

Discussion.—This species is most like *P. germana* (Resser). It differs by having a stronger pitted ornamentation, wider pygidial border and pleural furrows confined to the pleural platform. The free cheek also lacks a distinct border furrow. Poorly preserved tiny silicified specimens in the type collection are not distinguishable from the tiny individuals of *P.* cf. *P. lomataspis* described next.

Occurrence.—Common, *"Plagiura-Poliella"* Zone, *P. lomataspis* Zonule. Nevada: 4434–CO (>10 cranidia, 2 free cheeks, 5 pygidia), Belted Range.

Poliella cf. P. lomataspis n. sp.

Plate 6, figures 6–10

Discussion.—Abundant small silicified specimens of a species of *Poliella* are present in one collection. The largest cranidium is only 2 mm long, and other parts are comparably small. The cranidium has a narrow border in front of the glabella, a short occipital spine and short distal parts to the posterior limbs, which lack intergenal spines. The free cheek is narrow and lacks a well-defined border. The genal spine is about equal in length to the posterior section of the facial suture. Thoracic segments have deep pleural furrows and short or long axial spines. The pygidium is simple, has one well-defined axial ring, and a semicircular to subquadrate shape. The axis is prominent and wider than the pleural regions; it extends about two-thirds the sagittal length of the pygidium. A fine granular ornamentation is apparent on the axial region of the glabella, thoracic segments, and pygidium.

Despite the fact that this species is represented by many well-preserved parts, it is difficult to assess its characteristics relative to other species of *Poliella* because there are no larger holaspids. It seems to be most similar to *P. lomataspis* n. sp. from a correlative horizon. However, until larger holaspids can be found, an effective specific identification cannot be made.

Occurrence.—Common, "*Plagiura-Poliella*" Zone, *P. lomataspis* Zonule. Nevada: 3790–CO, (>20 cranidia, 3 free cheeks, 5 pygidia), Jangle Ridge area, Nevada Test Site.

Family DORYPYGIDAE Kobayashi

Synonym: OGYGOPSIDIDAE Rasetti, 1951, p. 190

In this report *Ogygopsis* is included in the Dorypygidae rather than separately assigned to its own monotypic family as has been done in the past. When Rasetti (1951) proposed the Ogygopsididae, he was reacting to an extremely unrealistic assignment of *Ogygopsis* to the Asaphidae by earlier authors. He stressed differences in hypostomal structure and the apparent uniqueness of the cephalic and pygidial combination as reasons for naming a new monotypic family. However, much new knowledge has been obtained about trilobite morphology, and the hypostomal structure among closely related genera seems to be quite variable. (Compare in this report pl. 9, figs. 6, 11 with pl. 10, figs. 5, 13, 20.) Also, species of *Ogygopsis* from the Lower Cambrian have a small number of pygidial segments, approaching those of typical Dorypygidae; and at least one undescribed species with a full complement of border spines similar to *Kootenia* is known from the Lower Cambrian of western Nevada. *Ogygopsis* also shares with other dorypygids a comparable nearly isopygous condition and consequently a thorax that barely diminishes in width backward. Its thorax also has a relatively small number (<10) of thoracic segments. Thus, the reasons for separately distinguishing *Ogygopsis* at the family level no longer seem compelling, and it is included here with *Bonnia* and *Kootenia* in the Dorypygidae.

Genus BONNIA Walcott

Corynexochus (*Bonnia*) Walcott, 1916b, p. 325

Bonnia Walcott. Raymond, 1928a, p. 309; Resser, 1936, p. 6; Resser, 1937b, p. 44; Lermontova, 1940, p. 142; Lochman, 1947, p. 68; Rasetti, 1948a, p. 14; Lermontova, 1951, p. 118; Pokrovskaya, 1959, p. 135; Poulsen, C., in Harrington and others, 1959, p. 217; Suvorova, N. P., in Chernysheva, 1960, p. 80; Yegorova, 1961, p. 225; Demokidov and Lazarenko, 1964, p. 207; Suvorova, 1964, p. 143; Repina, in Repina and others, 1964, p. 300; Palmer, 1964, p. 5; Rasetti, 1966b, p. 43; Palmer, 1968, p. 46 Fritz, 1972, p. 31.

Type species.—*Bathyurus parvulus* Billings, 1861.

Discussion.—This genus has been described or diagnosed many times and has elicited little difference of opinion about its characteristics. The specimens from the Carrara Formation contribute no new information about the genus.

Bonnia spp.

Plate 5, figures 10, 11

Discussion.—Two specimens of *Bonnia* have been identified in collections from the Carrara Formation, which attests to the rarity of this genus in the southern Great Basin. One of the specimens is an immature form (pl. 5, fig. 11) that is distorted but shows a strongly expanded glabella and moderately distinct posterior glabellar furrows. This does not resemble any other Cordilleran representatives of the genus, but it is too small to adequately compare with other forms. The other specimen (pl. 5, fig. 10) is very similar to *Bonnia columbensis* Resser in all cranidial proportions. However, it has extremely faint bertillon markings on the glabella and lacks any distinct granules which are said by Fritz (1972, p. 33) to characterize this species. In the absence of associated parts, an adequate specific designation cannot be given.

Occurrence.—Very rare (2 cranidia), *Bristolia* Zonule and Gold Ace Limestone Member. California: 7181–CO, Cucomungo Canyon section, Last Chance Range. Nevada: 3646–CO, Nevada Test Site.

Genus KOOTENIA Walcott

Bathyuriscus (*Kootenia*) Walcott, 1889, p. 446.

Kootenia Walcott, 1925, p. 92; Kobayashi, 1935, p. 156; Lermontova, E. V., in Vologdin, 1940, p. 139, Shimer and Shrock, 1944, p. 613; Rasetti, 1948b, p. 332; Thorslund, 1949, p. 4; Lermontova, 1951, p. 122; Palmer, 1954, p. 64; Hupé, 1955, p. 91; Ivshin, 1957, p. 37; Poulsen, C., in Harrington and others, 1959, p. 218; Suvorova, N. P., in Chernysheva, 1961, p. 126; Lazarenko, 1962, p. 60; Palmer, 1968, p. 47; Zhuravleva and others, 1970, p. 34; Palmer and Gatehouse, 1972, p. 18; Fritz, 1972, p. 35.

Notasaphus Gregory, 1903, p. 155; Whitehouse, 1939, p. 241.

Type species.—*Bathyuriscus* (*Kootenia*) *dawsoni* Walcott, 1889, p. 446.

Discussion.—The material from the Carrara Formation does not add any new information to the diagnosis and discussion of this widespread and well-known genus given earlier (Palmer, 1968).

Kootenia germana Resser

Plate 11, figures 22–24, 27–30

Kootenia germana Resser, 1939b, p. 49, pl. 9, figs. 19–24

Description.—Cranidium subquadrate in outline, gently to moderately convex transversely and longitudinally. Glabella prominent, sides subparallel, extended forward onto border. Glabellar furrows not apparent. Occipital furrow deep, straight, and deepest distally. Occipital ring convex, has short slender posteriorly directed axial spine. Frontal area barely apparent on axial line. Fixed cheeks gently convex, downsloping; width of palpebral area slightly less than one-half basal glabellar width. Palpebral lobe small, defined by shallow glabellar furrow, situated about opposite glabellar midlength, connected to anterolateral corner of glabella by barely discernable ocular ridge. Posterior limb subtriangular; transverse length about equal to basal glabellar width. External surface variably ornamented. Glabella has concentric "fingerprint" pattern of ridges either well defined or barely apparent even after whitening. Fixed cheeks may be obscurely pitted, distinctly granular, or roughened. There is no apparent correlation of intensity of ornamentation with size.

Thorax composed of seven segments. Each pleuron has deep pleural furrow that terminates near tip. Each segment bears short axial spine and short pleural spine.

Pygidium semicircular in outline, moderately convex transversely and longitudinally. Axis prominent, barely tapered posteriorly, extended to inner edge of moderately well defined border. Three distinct complete ring furrows and a faint incomplete fourth furrow present behind articulating furrow. No axial nodes or spines present. Pleural fields crossed by four straight shallow pleural furrows that terminate in slightly deeper areas of border furrow. Border nearly flat, bears six pairs of short slender border spines; posterior pair shorter than adjacent pair. Ornamentation consists of closely spaced fine granules that vary in intensity from moderately distinct to obscure; border spines generally retain distinct granular ornamentation.

Discussion.—This species is most similar to *K. brevispina* Resser which differs primarily by having shorter and more sawtoothlike border spines. The short closely spaced posterior pair of border spines seems to be particularly distinctive of *K. germana*, but a monographic review of the 107 species presently assigned to this genus will be needed to establish the ultimate validity of this observation. This is the only species of *Kootenia* so far obtained from the Carrara Formation.

Occurrence.—Common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3692–CO (>10 cranidia and pygidia, 3 articulated specimens), Groom Range; (>10 cranidia and pygidia), Nevada Test Site; 4440–CO (>10 cranidia and pygidia), Groom Range. Rare, 3547–CO (3 pygidia), Nevada Test Site.

Genus OGYGOPSIS Walcott

Ogygopsis Walcott, 1889, p. 446; Walcott, 1916b, p. 375; Raymond, 1912, p. 116; Shimer and Shrock, 1944, p. 613; Rasetti, 1951, p. 190; Rasetti, F., in Harrington and others, 1959, p. 219; Palmer, 1964, p. 6.

Taxioura Resser, 1939b, p. 62; Shimer and Shrock, 1944, p. 617; Romanenko, E. B., in Khalfin, 1960, p. 187.

Type species.—*Ogygia klotzi* Rominger, 1887, p. 12, pl. 1, fig. 1.

Discussion.—This genus has been described in detail earlier (Palmer, 1964), and the specimens from the Carrara Formation conform to this description in all respects.

Ogygopsis typicalis (Resser)

Plate 12, figures 1–4

Taxioura typicalis Resser, 1939b, p. 62, pl. 14, figs. 6–14; Shimer and Shrock, 1944, pl. 259, figs. 23, 24.

Description.—Cephalon semicircular in outline, gently to moderately convex transversely and longitudinally, bears moderately long slender posterolaterally directed genal spines. Cranidium subtrapezoidal in outline, anterior margin gently curved. Glabella long, well defined at sides and front by change in slope of exoskeleton; sides slightly bowed outward; anterior end strongly rounded, glabellar furrows not apparent. Occipital furrow straight, deep distally, shallow over axial line. Occipital ring gently convex, without node or spine. Frontal area consists only of flat border; sagittal length between one-seventh and one-eighth sagittal length of glabella exclusive of occipital ring. Fixed cheeks gently convex, horizontal; width of palpebral area about one-half basal glabellar width. Palpebral lobe gently curved, well defined by shallow palpebral furrow, situated slightly posterior to glabellar midlength; exsagittal length about one-third sagittal glabellar length exclusive of occipital ring. Ocular ridge narrow, low, extended inward and forward from palpebral lobe to anterolateral part of glabella. Posterior limb long, pointed; transverse length slightly greater than basal glabellar width. Course of anterior section of facial suture slightly divergent forward from palpebral lobe; course of posterior section evenly curved, directed strongly posterolaterally from palpebral lobe to posterior margin.

Hypostome moderately to strongly convex; posterior lobe and maculae poorly defined. Lateral and posterior margins have well-developed border that is flared ventrally opposite junction of anterior and posterior lobes. Anterior wings short, blunt.

Free cheek narrow, with border defined by lateral border furrow only anterior to base of slender genal spine; length of spine slightly greater than length of posterior section of facial suture.

Thorax composed of eight segments. Axis tapered backwards, but width of thorax remains nearly constant. Pleurae each bear broad deep pleural furrow and short slender posterolaterally directed pleural spine.

Pygidium semicircular in outline, gently convex transversely and longitudinally. Axis long, slender, slightly tapered, well defined by changes in slope of exoskeleton, reaches nearly to border and connected to it by short postaxial ridge; width of axis at anterior margin about one-fifth anterior pygidial width. Eight complete shallow ring furrows and a ninth partial ring furrow present behind articulating furrow. Pleural regions crossed by seven or eight deep gently curved pleural furrows that reach to inner edge of narrow well-defined slightly convex border. Very shallow poorly defined interpleural furrows present between most pleural furrows. Border bears distinct short slender anterolateral spines analogous to those of thoracic segments; nubs of one or two additional pairs of spines apparent on many specimens; posterior margin with slight median indentation.

Ornamentation consists of very delicate anastomosing ridges forming an irregular mesh on most surfaces, apparent only on well-preserved specimens after whitening.

Discussion.—This species is represented by numerous disarticulated specimens and several articulated individuals without free cheeks in several collections from the upper part of the Belted Range section. It agrees in all respects with the abundant material of this species from the upper part of the Naomi Peak Limestone Member of the Langston Formation of Maxey (1958) in northeastern Utah and southeastern Idaho. The presence of only one distinct anterolateral pair of pygidial spines, and seven or more pleural furrows, distinguishes this species from all others in the genus.

Occurrence.—Common, *Albertella* Zone, *Ogygopsis* Zonule. Nevada: 4436–CO (>10 cranidia and pygidia, 1 free cheek), 4437–CO (3 partly articulated individuals, >10 cranidia and pygidia), 4438–CO (5 partly articulated individuals, >20 cranidia and pygidia), all from Belted Range.

Family ORYCTOCEPHALIDAE Beecher

Genus ORYCTOCEPHALINA Lermontova

Oryctocephalina Lermontova, E. V., in Vologdin, 1940, p. 137; Chernysheva, 1960, p. 82; Yegorova, L. I., and others, in Khalfin, 1960, p. 198; Shergold, 1969, p. 47.

Type species.—*Oryctocephalina reticulata* Lermontova, in Vologdin, 1940, p. 137, pl. 42, figs. 3, 3a,b.

Discussion.—Chernysheva (1962) in her monograph of the Oryctocephalidae concluded that the type species of *Oryctocephalina*, represented only by cranidia, is a proper member of *Oryctocephalus*. Shergold (1969) revived this genus for oryctocephalids characterized particularly by few pygidial segments and by sinuous axial furrows outlining the glabella. However, the pygidium is only known for the Australian species, *O. lancastroides* Shergold. Until a comparable pygidium is found for *O. reticulata*, the content and character of this genus must remain uncertain.

Oryctocephalina? maladensis (Resser)

Plate 12, figures 21, 22, 27

Oryctocephalus maladensis Resser, 1939b, p. 45, pl. 3, figs. 7–9; Fritz, 1968, p. 202, pl. 41, figs. 25–27.

Discussion.—This species has been adequately described and figured by both Resser and Fritz. The Carrara specimens agree in all details with the specimens described earlier.

Shergold (1969, p. 47) placed this species unequivocally in *Oryctocephalina* because of the sinuous nature of the axial furrows on the cranidium. *Oryctocephalina* is characterized by having small poorly differentiated pygidia, which might explain why a pygidium has never been found for *O. maladensis*, although it is represented by many cranidia. Until the pygidium is identified, any generic assignment for this species within the Oryctocephalidae should be tentative.

Occurrence.—Moderately common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (>10 cranidia), Nevada Test Site.

Genus ORYCTOCEPHALITES Resser

Oryctocephalites Resser, 1939b, p. 44; Shimer and Shrock, 1944, p. 613; Rasetti, F., in Harrington and others, 1959, p. 220; Chernysheva, 1962, p. 24; Shergold, 1969, p. 28.

Type species.—*Oryctocephalites typicalis* Resser, 1939b, p. 45, pl. 3, figs. 1–6.

Discussion.—Resser and Rasetti have given good descriptions or diagnoses of this genus. The Carrara specimens are identical in all respects with the type species.

Shergold (1969, p. 17) made the ad hoc decision that the pygidium of the type species of *Oryctocephalus* should be in *Oryctocephalites* and that it is not congeneric with the associated cranidium, although he stated that the cranidium of *Oryctocephalites* is of "*Oryctocephalus*-type." Inasmuch as this statement could be reversed, he has by implication synonymized *Oryctocephalus* and *Oryctocephalites*. However, *Oryctocephalus* has at least two transglabellar furrows while *Oryctocephalites* has only one. No evidence from the type collection of *Oryctocephalus* exists to support the assumption that the pygidium and cranidium are not congeneric, and until such evidence is presented, their generic separation and the resulting implications do not seem justified.

Oryctocephalites typicalis Resser

Plate 13, figures 1–4

Oryctocephalites typicalis Resser, 1939b, p. 45, pl. 3, figs. 1–6; Shimer and Shrock, 1944, pl. 257, figs. 14, 15; Fritz, 1968, p. 202, pl. 41, figs. 9–11; Shergold, 1969, text figs. 9a–f.

Description.—Cranidium subtrapezoidal in outline, gently to moderately convex transversely and longitudinally, anterior margin moderately curved. Glabella elongate, subelliptical in outline, well defined by deep axial and preglabellar furrows, anterior end bluntly rounded, extended onto inner edge of flat narrow border. Three pairs of glabellar furrows present; posterior pair consists of pits separated from axial furrow, but connected across glabella; anterior two pairs represented only by pits or short transverse slots isolated from axial furrows. Occipital furrow straight, deep. Occipital ring miderately convex, bears small axial node adjacent to occipital furrow. Frontal area consists of narrow flat border; sagittal length about 0.1 sagittal length of glabella exclusive of occipital ring. Distal part of border defined by shallow border furrow that curves backward near anterolateral part of glabella. Fixed cheek moderately convex, horizontal; width of palpebral area about two-thirds or slightly more than two-thirds basal glabellar width. Palpebral lobe gently curved, well defined by palpebral furrow; line connecting posterior tips passes over preoccipital furrow; exsagittal length about 0.4 sagittal length of glabella exclusive of occipital ring. Ocular ridge barely apparent even after whitening. Posterior limb has straight deep posterior border furrow; distal part barely extended beyond palpebral lobe. Course of anterior section of facial suture nearly straight forward from palpebral lobe; course of posterior section slightly divergent posterolaterally behind palpebral lobe.

Pygidium, exclusive of border spines, semicircular in outline, gently convex transversely and longitudinally; sagittal length about one-half anterior width. Axis narrower than pleural regions, well defined, gently tapered backward to fourth axial segment and then more strongly tapered nearly to point at posterior margin. Three complete ring furrows present posterior to articulating furrow; an additional ring furrow less well defined. Pleural regions lack a defined border, crossed by four deep straight pleural furrows that extend nearly to margin. Shallow interpleural furrows present outlining posterior edge of macropleural segment. Other interpleural furrows very shallow or absent. Border bears five pairs of spines; anterior three pairs of equal length, short; fourth pair long, slender, posteriorly directed; fifth pair shortest, slightly convergent posteriorly.

External surfaces of all parts smooth.

Discussion.—This species is characterized by the relative sizes, orientation, and number of the pygidial border spines. The three anterior pairs of spines are shorter than those of the Australian species described by Shergold (1969), and the macropleural spines are slightly divergent rather than parallel or convergent; the interpleural furrows on the pygidium are not well developed as they are in *O. incertus* Chernysheva (1962) from Siberia; and *O. typicalis* has five rather than four border spines as in *O. resseri* Rasetti (1957).

One cranidium (pl. 13, fig. 1) shows much less well developed glabellar furrows than is typical for the species but agrees in all other details, and it is considered to illustrate the range of variability within this species.

Occurrence.—Common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (>10 cranidia and pygidia), Nevada Test Site.

Genus ORYCTOCEPHALUS Walcott

Oryctocephalus Walcott, 1886, p. 210; Reed, 1910, p. 10; Kobayashi, 1935, p. 146; Lermontova, E. V., in Vologdin, 1940, p. 136; Shimer and Shrock, 1944, p. 615; Palmer, 1954, p. 68; Rasetti, F., in Harrington and others, 1959, p. 220; Suvorova, N. P., and Chernysheva, N. E., in Chernysheva, 1960, p. 82; Yegorova, L. I., and others, in Khalfin, 1960, p. 198; Chernysheva, 1962, p. 11; Shergold, 1969, p. 15; Zhuravleva and others, 1970, p. 37.

Type species.—*Oryctocephalus primus* Walcott, 1886, p. 210, pl. 29, figs. 3, 3a.

Discussion.—Shergold (1969) has presented a good recent discussion of this genus and its species content. He restricted the genus to species with six pairs of pygidial spines and arbitrarily concluded that the five-spined pygidium associated with the cranidium of the type species should be assigned to *Oryctocephalites*. He also recognized two informal subgeneric groups, one with a macropleural fourth pair of pygidial spines and one lacking clear macropleural spine development. *O. nyensis* n. sp. belongs to the group lacking macropleural pygidial spines.

Oryctocephalus nyensis n. sp.

Plate 6, figures 13–15

Description.—Cranidium, exclusive of distal parts of posterior limbs, transversely subquadrate; anterior margin nearly straight; sagittal length about two-thirds width between palpebral lobes. Glabella well defined by deep narrow axial furrow, very slightly tapered forward, bluntly rounded, reaches to inner edge of narrow convex anterior border that is well defined laterally by deep border furrow; sides nearly straight; sagittal glabellar length slightly more than 1.5 times basal glabellar width. Occipital furrow represented by deep pits connected by shallow furrow. Occipital ring simple. Glabellar furrows represented by three pairs of deep pits isolated from axial furrows; two posterior pairs connected across glabella by shallow furrow. Additional faint furrows present adjacent to axial furrows at junction with ocular ridges. Frontal area consists only of narrow border. Fixed cheeks as wide as glabella, crossed by narrow well-defined ocular ridges that diverge only slightly laterally from parallelism with anterior margin. Palpebral lobes long, gently curved, and well defined by narrow palpebral furrow, midlength located slightly posterior to glabellar midlength; exsagittal length about 0.4 sagittal glabellar length exclusive of occipital ring. Posterior limb has well-developed border furrow; transverse length slightly greater than basal glabellar width.

Thorax composed of at least nine segments. Each segment has well-developed diagonal pleural furrow and long slender posterolaterally directed spine. Length of spine relative to transverse length of pleural region increases posteriorly.

Pygidium moderately large, transversely subovate in outline, has well-defined posteriorly tapered axis with at least four ring furrows posterior to articulating furrow. Pleural regions crossed by four deep pleural furrows reaching to posterior margin between marginal spines. Interpleural furrows present, shallow. Six pairs of slender tapered border spines present; anterior four pairs equal in length, fifth pair intermediate in length; sixth pair shortest.

Discussion.—This species differs most strikingly from all other *Oryctocephalus* species by having the pygidial spines long and slender and the fourth pair not modified. Evaluation of more subtle distinctions must await more material.

Occurrence.—Rare, "*Plagiura-Poliella*" Zone. Nevada: 4435–CO (1 cranidium, 2 pygidia, 1 thorax), Belted Range.

Genus THORACOCARE Robison and Campbell

Thoracocare, Robison and Campbell, 1974, p. 273.

Type species.—*Vistoia*? *minuta* Resser (Part), 1939a, p. 21, pl. 2, fig. 2 only.

Discussion.—This remarkable small corynexochid trilobite recently redescribed and clarified by Robison and Campbell is represented in the Carrara Formation only by pygidia. The distinctive small size, pygidial outline, short and tapered axis, and pleural furrows deepest near the margin easily distinguish this from all other associated trilobites.

Thoracocare idahoensis (Resser)

Plate 12, figure 5

Tonkinella idahoensis Resser, 1939b, p. 45, pl. 2, fig. 10.
Thoracocare idahoensis (Resser), Robison and Campbell, 1974, p. 279, figs. 3a–g.

Description.—Pygidium small, semicircular, gently convex transversely and longitudinally. Axis low, defined by shallow axial furrows, tapered backward, extending about two-thirds sagittal length of pygidium, consisting of four or five obscurely defined axial rings; greatest width about one-fourth greatest width of pygidium. Pleural regions have 12 pairs of poorly defined equally spaced radiating furrows best seen along pygidial margins. Posterior pleural furrows parallel to pygidial axis. Border smooth.

Discussion.—The tiny pygidia, less than 3 mm wide, that represent this species conform in all respects to a tiny form described by Resser (1939b) from southeastern Idaho as *Tonkinella idahoensis*. Although the pygidium has superficial resemblances to *Tonkinella*, it lacks the strong and regular development of pleural furrows and the distinctively scalloped pygidial margin of that genus. Robison and Campbell (1974) assigned this species to a remarkable tiny corynexochid genus *Thoracocare*. *T. idahoensis* differs from the only other species presently assigned to the genus, *T. minuta* (Resser), by having more clearly developed ring furrows on the axis and by having its width and length respectively one-fourth instead of one-third, and two-thirds instead of three-fourths, the width and length of the pygidium.

Occurrence.—Rare, *Albertella* Zone, *Ogygopsis* Zonule. Nevada: 4437–CO (2 pygidia), 4438–CO (1 pygidium), both from Belted Range.

Oryctocephalid sp. undet.

Plate 12, figure 6

Discussion.—A single weathered pygidium from the Belted Range represents an undescribed oryctocephalid species. The axis and pleural fields are too poorly preserved to see the development of the furrows and character of segmentation, but the outline is well preserved and shows seven pairs of border spines. The fourth spine is macropleural as in many oryctocephalids, but there are three pairs of spines behind the macropleural spines. All described oryctocephalids with the fourth spine macropleural have two or fewer posterior spines behind the macropleural segment. Formal naming of this species is deferred until better material is available.

Occurrence.—Rare, *Albertella* Zone, *Ogygopsis* Zonule. Nevada: 4438–CO (1 pygidium), Belted Range.

Family ZACANTHOIDIDAE Swinnerton

The Zacanthoididae, as constituted in the "Treatise on Invertebrate Paleontology" (Harrington and others, 1959, p. 227), includes a variety of corynexochid forms characterized by variously spinose pygidia and by a long, slender glabella that is slightly expanded anteriorly. The Dolichometopidae (Harrington and others, 1959, p. 220) contain many forms having cranidia similar to the Zacanthoididae but generally lacking spinose pygidia. One exception has been *Ptarmiganoides*, which has a strongly spinose pygidial margin. Restudy of specimens of *Ptarmiganoides* in the collections of the U.S. National Museum and new material from the Carrara Formation shows that *Ptarmiganoides* cranidia have posterior limbs with distinct intergenal spines (pl. 11, fig. 18) comparable to those of *Zacanthoides* and *Paralbertella* n. gen. and unlike any of the typical genera of the Dolichometopidae. On the basis of total morphology, *Ptarmiganoides* is here assigned to the Zacanthoididae.

In the future, perhaps the small-eyed genera, such as *Albertella* and *Vanuxemella*, that are now included in the Zacanthoididae should be removed to a separate family or subfamily, leaving the main body of the Zacanthoididae to be typified then also by long arcuate palpebral lobes. Such modification should be a part of a complete reevaluation of the entire Order Corynexochida that is beyond the scope of this report.

Genus ALBERTELLA Walcott

Albertella Walcott, 1908, p. 18: Resser, 1936, p. 1; Rasetti, 1951, p. 147; Rasetti, F., in Harrington, 1959, p. 227.

Type species.—*Albertella helena* Walcott, 1908, p. 19, pl. 2, figs. 1–4.

Description.—Small to medium-sized corynexochid trilobites; sagittal length probably not exceeding 50 mm. Cranidium subtrapezoidal in outline, gently convex transversely and longitudinally; anterior margin gently rounded. Glabella elongate, reaches nearly to anterior margin, well defined, sides subparallel or slightly expanded anteriorly, straight or concave. Four pairs of shallow glabellar furrows may be present. Occipital furrow straight, generally shallow. Occipital ring simple, axial node may be present at posterior margin. Frontal area extremely narrow, undivided. Fixed cheeks gently convex, horizontal, or slightly downsloping; width, including palpebral lobes, generally less than half basal glabellar width. Palpebral lobes generally small, well separated from glabella, situated opposite or slightly anterior to glabellar midlength. Ocular ridge poorly developed. Posterior limbs broad, triangular. Posterior border furrow shallow, straight. Course of anterior section of facial suture subparallel, slightly convergent, or slightly divergent anterior to eyes. Course of posterior section of facial suture gently convex.

Hypostome and rostral plate fused; rostral area usually not clearly differentiated.

Free cheek narrow, with moderately to poorly defined gently convex border and long slender cylindrical genal spine continuing curvature of cheek margin.

Thorax composed of seven segments. Third segment macropleural in all known species. Axis prominent, as wide as or wider than pleurae.

Pygidium subquadrate, width usually greater than length. Axis prominent, reaches to or nearly to posterior margin, composed of four or five variably defined segments and terminal part. Pleural regions with pleural or interpleural furrows defining three or four segments variably defined. Margin bears pair of long slender spines directed posterolaterally. Spines not clearly related to pleural segments. Posterior margin between spines curved posteriorly.

External surfaces of all parts smooth or covered with fine closely spaced granules.

Discussion.—Walcott included in *Albertella* two distinct kinds of trilobites that are now each represented by several species. One species group, typified by *A. helena* Walcott, has cranidia with small- to moderate-sized palpebral lobes well separated from the glabella, generally broad triangular posterior limbs, a third macropleural segment on the thorax, genal spines not strikingly advanced, the hypostome and rostral plate fused but not clearly differentiated, and pygidial border spines that are widely divergent and not clearly related to particular pleural segments of the pygidium. The second species group, typified by *A. bosworthi* Walcott, has cranidia with long palpebral lobes that have the anterior end close to the glabella, narrow posterior limbs, a fourth macropleural segment on the thorax of the one species known with articulated parts, free cheeks indicating advanced genal spines, hypostome and rostral plate fused but strongly differentiated, and a distinctive pygidial structure in which the anterior bands of the first three segments are accentuated as ridges and generally merge laterally with the pygidial border at the base of pygidial spines much less laterally divergent than in the first species group. Most species of the *bosworthi* group have axial nodes on the pygidial segments that are lacking or weakly developed on species of the *helena* group.

Rasetti (1951, p. 148) noted these differences but chose to retain both groups within *Albertella*. Fritz (1968) identified a third related group of species with cranidial characters much like the *bosworthi* group and with similar pygidial pleurae. However, in this group (*Albertelloides*), the pygidial spines are located much more posteriorly, there is consistent development of an occipital spine, and the free cheeks have large genal spines that are not advanced.

In order to be consistent in ranking the differences between the three groups of species, either *Albertelloides* should become a subgenus of *Albertella* because it is closer to the *bosworthi* group than the *bosworthi* group is to the *helena* group, or the three groups should be recognized as separate but related genera. Use of subgenera creates cumbersome nomenclature, and the range of morphology that would be included in the genus would be much greater than that of most other corynexochoid genera. Thus, in this report, the three groups are treated as related genera.

Albertella must be retained for the group of generally small-eyed forms with normal pygidial pleura that includes the type species. In addition to the species described in this report, this group includes the following species: *A. helena* Walcott (synonyms: *A. nitida* Resser, *A. sampsoni* Resser, *A. ressensis* Resser), *A. microps* Rasetti, *A. proveedora* Lochman, and *A. schenki* Resser. Of these species, only *A. helena*, which has longer eyes than the others, approaches the *bosworthi* group, here included in a new genus, *Paralbertella*, and then only in cranidial structure. The species included in *Paralbertella* are: *P. bosworthi* (Walcott) (synonym: *Albertella stenorhachis* Rasetti), *P. declivis* (Rasetti), *P. limbata* (Rasetti), *P. robsonensis* (Resser), *P. eiloitys* (Fritz), *P. lata* (Fritz), and *P. judithi* (Fritz). *Albertelloides* includes *A. mischi* Fritz, *A. pandispinata* Fritz, *A. maladensis* (Resser), *A. dispar* (Resser), and *A. rectimarginatus* n. sp. Although the three genera have approximately the same time range, species of *Albertella* s. s. are rarely found in association with either *Paralbertella* or *Albertelloides* and they seem to have a more landward distribution.

Albertella longwelli n. sp.

Plate 9, figures 1–3, 6, 7, 9, 10

Description.—Cranidium subtrapezoidal in outline, gently convex transversely and longitudinally, sagittal length about two-thirds width between tips of posterior limbs, anterior margin gently and evenly curved. Glabella low, elongate, expanded forward, reaches nearly to anterior margin, sides slightly concave; basal glabellar width about seven-eighths width at anterior end. Glabellar furrows barely apparent; posterior pair strongly oblique. Posterior end of glabella poorly defined by axial furrows. Occipital furrow shallow, straight. Occipital ring gently convex, without node or spine. Frontal area reduced to wirelike border in front of glabella. Fixed cheeks gently convex, downsloping; width exclusive of palpebral lobe slightly less than one-half basal glabellar width. Palpebral lobe small, situated slightly anterior to glabellar midlength; exsagittal length about one-fourth sagittal glabellar length exclusive of occipital ring. Palpebral furrow shallow. Ocular ridge barely apparent, strongly oblique to axial furrow. Posterior limb broad, triangular; transverse length slightly less than basal glabellar width. Course of anterior section of facial suture nearly straight forward in front of palpebral lobe and then curved evenly inward to intersect anterior margin near anterolateral cranidial corner. Course of posterior section of facial suture directed posterolaterally behind palpebral lobe and curved evenly backward to posterior margin.

Free cheek narrow; border gently convex, separated from ocular platform by shallow border furrow; width of border uniform, slightly less than length of anterior sutural margin of ocular platform; ocular platform expands posteriorly. Lateral margin gently curved, continuous with very long slender genal spine; length of spine about three times length of posterior sutural margin. Junction of posterior margin of cheek with inner margin of spine nearly a right angle.

Rostral plate and hypostome fused, not clearly differentiated.

Pygidium, exclusive of border spines, short, wide; sagittal length slightly more than one-half anterior width. Axis prominent, transversely convex, crest nearly flat, tapered very slightly posteriorly, rounded at tip, extended nearly to posterior margin. Two shallow straight complete ring furrows present posterior to articulating furrow; a partial third furrow barely apparent. Rings without nodes or spines. Pleural fields narrow, triangular, crossed by three broad shallow pleural furrows. Interpleural furrow between first and second segments barely apparent near axis. Border differentiated from pleural field by lack of furrows, produced posterolaterally into pair of very long slender border spines; length of spines more than three times sagittal length of axis. Posterior margin between spines curved posteriorly. Posterior part of border strongly depressed.

External surfaces of all parts covered with very fine, barely apparent, granules.

Discussion.—This species differs from all others in the genus except *A. microps* Rasetti by having only three ring furrows developed on the axis of the pygidium. It differs from *A. microps* by lacking any trace of axial nodes. Among the Carrara species, it is most like *A. schenki* Resser, but it consistently has fewer ring furrows and pleural furrows on the pygidium, the glabella is less well defined, and a narrow cranidial border is present.

Occurrence.—Moderately common, *Albertella* Zone, *Albertella-Mexicella* Zonule. Nevada: 1616–CO (>20 cranidia, 4 free cheeks, 5 pygidia), Spring Mountains. California: 4154–CO (1 cranidium, 2 free cheeks, 5 hypostome-rostral plates, 1 pygidium, all silicified), Echo Canyon section, Funeral Mountains; 4165–CO (3 cranidia, 1 hypostome-rostral plate, 2 free cheeks, 6 pygidia, all silicified), Eagle Mountain.

Albertella schenki Resser

Plate 9, figures 13–15, 17, 18

Albertella schenki Resser, in McKee and Resser, 1945, p. 195, pl. 20, fig. 18.

Description.—Cranidium subtrapezoidal in outline, gently convex tranversely and longitudinally, sagittal length about three-fourths width between tips of posterior limbs, anterior margin gently and evenly curved. Glabella low, elongate, expanded forward, sides concave, reaches nearly to anterior margin and merges with barely perceptible wirelike anterior border; basal glabellar width about three-fourths width at anterior end. Glabellar furrows barely apparent, posterior pair strongly oblique. Glabella well defined at sides by narrow shallow axial furrows. Occipital furrow straight, moderately deep across top of glabella, barely apparent distally. Occipital ring gently convex, without node or spine. Fixed cheeks gently convex, downsloping; width, exclusive of palpebral lobe, slightly less than one-half basal glabellar width. Palpebral lobe small, poorly defined, located slightly anterior to glabellar midlength; exsagittal length about one-fifth sagittal glabellar length exclusive of occipital ring. Ocular ridge barely apparent, strongly oblique to axial furrow. Posterior limb broad, triangular; transverse length about equal to basal glabellar width. Course of anterior section of facial suture nearly straight forward in front of palpebral lobe, curved inward to intersect anterior margin near anterolateral cranidial corner. Course of posterior section directed posterolaterally behind palpebral lobe and curved evenly backward to posterior margin.

Free cheek moderately wide, lateral margin and posterior sutural margin subparallel. Lateral and posterior borders gently convex, separated from gently convex ocular platform by broad shallow, continuous border furrow; width of border at anterior end about equal to length of anterior sutural margin of ocular platform. Ocular platform expands posteriorly. Lateral margin continuous with long slender genal spine; length of spine more than twice length of posterior section of facial suture. Angle between posterior margin of free cheek and inner spine margin slightly less than 90°.

Hypostome and rostral plate fused, not clearly differentiated.

Pygidium, exclusive of border spines, subquadrate; sagittal length about two-thirds anterior width. Axis prominent, transversely convex, crest nearly flat, tapered slightly posteriorly, rounded at tip, extended nearly to posterior margin. Three shallow straight complete ring furrows present posterior to articulating furrow; a partial fourth furrow barely apparent. Rings without nodes or spines. Pleural fields narrow, triangular, crossed by four subparallel broad shallow pleural furrows. Border differentiated from pleural field by lack of furrows, produced posterolaterally into pair of long slender border spines at least twice sagittal length of axis. Posterior margin between spines strongly curved backward, and concave in transverse cross section.

External surfaces of all parts smooth.

Discussion.—This species has been known previously only from a pygidium from the Grand Canyon section. The pygidia in the Carrara Formation are indistinguishable from the Grand Canyon specimen, and the associated cranidia, cheeks, and hypostome-rostral plates provide much additional information about the morphology of the species. The most similar species is *Albertella proveedora* Lochman (in Cooper and others, 1952) which differs by having one more axial segment on the pygidium and by having distinctly longer and more posteriorly placed palpebral lobes. If the free cheek of *A. proveedora* is correctly assigned, it has an obtuse rather than slightly acute angle between the inner spine margin and the posterior cheek margin. The most similar species in the Carrara Formation is *A. longwelli* which has a distinctly differentiated anterior border and one less axial segment on the pygidium.

Occurrence.—Common, *Albertella* Zone, *Albertella-Mexicella* Zonule. Nevada: 3543–CO (>20 cranidia, 5 hypostome-rostral plates, 5 free cheeks, 8 pygidia), Desert Range.

Albertolla spectrensis n. sp.

Plate 9, figures 4, 5, 8, 11, 12, 16

Description.—Cranidium subtrapezoidal in outline, moderately convex transversely and longitudinally, gently rounded anteriorly. Glabella moderately convex transversely, gently convex longitudinally, straight-sided, well defined by narrow axial and preglabellar furrows, slightly expanded forward, reaches to narrow upturned border. Glabellar furrows barely apparent. Occipital furrow straight, moderately deep. Occipital ring gently convex, has small axial node adjacent to posterior margin. Fixed cheek gently convex, horizontal; width, exclusive of palpebral lobe, slightly more than one-half basal glabellar width. Palpebral lobe moderately small, situated about opposite glabellar midlength; exsagittal length between one-third and one-fourth sagittal glabellar length exclusive of occipital ring. Ocular ridge moderately distinct, forms acute angle with axial furrow. Deep pit developed in axial furrow anterior to intersection of ocular ridge at anterolateral corner of glabella. Posterior limb triangular; transverse length about equal to basal glabellar width. Posterior border furrow straight, moderately deep. Course of anterior section of facial suture straight forward from palpebral lobe, strongly curved around anterolateral corner of cranidium. Course of posterior section divergent posterolaterally behind palpebral lobe and curved evenly to posterior margin.

Free cheek narrow. Lateral and posterior borders gently convex, well defined by shallow continuous border furrow; width of border at anterior end about equal to width of sutural margin of ocular platform. Ocular platform expanded slightly posteriorly. Lateral margin continuous with long slender genal spine. Angle between posterior margin and inner spine greater than 90°.

Hypostome and rostral plate fused; rostral part forms distinct angle with hypostomal part on axial line.

Pygidium, exclusive of border spines, subquadrate; sagittal length slightly less than anterior width. Axis prominent, transversely convex, nearly flat in profile, tapered slightly posteriorly; tip strongly rounded, reaches nearly to posterior margin. Three shallow straight complete ring furrows posterior to articulating furrow; a fourth incomplete ring furrow also present. Each of the first three or four segments has a low axial node. Pleural fields subtriangular, narrow, crossed by two or three weak pleural furrows. Border distinguished from pleural field by lack of furrows, produced laterally into long slender border spine more than three times sagittal length of axis. Posterior margin between border spines strongly curved posteriorly, slightly depressed.

All dorsal surfaces covered with fine granular ornamentation.

Discussion.—This species is not represented by material as well preserved or abundant as the other species from the Carrara Formation. Nevertheless, it differs from both *A. longwelli* n. sp. and *A. schenki* Resser by having a well-defined upturned cranidial border, slightly larger more posteriorly placed eyes, an occipital node, an obtuse angle between the posterior margin of the free cheek and the inner spine margin, a distinct differentiation of the junction between the hypostome and rostral plate, and axial nodes on the pygidial segments. The only other species of *Albertella* s. s. with axial nodes are *A. nitida* Resser and *A. microps* Rasetti. *A. nitida* has much larger palpebral lobes, narrower fixed cheeks and posterior limbs, advanced genal spines, and a more regular spacing of the pleural furrows on the pygidium. *A. microps* has deeper glabellar furrows and a smaller number of axial segments on the pygidium; the pleural furrows on the pygidium are unevenly spaced; and only the cranidium has granular ornamentation.

Occurrence.—Moderately common, fragmentary, *Albertella* Zone, *Albertella-Mexicella* Zonule. Nevada: 4169–CO (7 cranidia, 2 free cheeks, 3 hypostomes, >10 pygidia, mostly silicified), Spectre Range; 7195–CO (1 cranidium), Desert Range. California: 4159–CO (2 cranidia, 2 cheeks, 2 pygidia), Pyramid Peak section, Funeral Mountains.

Genus ALBERTELLINA n. gen.

Type species.—*Albertellina aspinosa* n. sp.

Description.—Moderately small corynexochid trilobites, length of largest known specimens probably about 30 mm. Cephalon subsemicircular in outline, with long flattened genal spines extending backward from posterolateral corners. Cranidium, excluding posterior limbs, elongate subrectangular in outline. Glabella long, low, narrow, straight sided, expanded forward, extended onto inner part of flat or slightly concave border; well defined at sides and anterior by changes in slope of exoskeleton; anterior end bluntly rounded. Four pairs of shallow glabellar furrows variably developed, generally obscure. Occipital furrow shallow, deepest distally. Occipital ring incomplete on all known specimens. Frontal area short, flat, or slightly concave, undivided; sagittal length slightly less than one-eighth sagittal length of glabella exclusive of occipital ring; outer part has zone of low coarse anastomosing ridges generally parallel to anterior margin. Palpebral area of fixed cheek gently convex, horizontal, greatest width more than half basal glabellar width. Palpebral lobe long, slender, curved, well defined by broad shallow palpebral furrow, continuous with low, poorly defined ocular ridge; situated opposite posterior half of glabella; exsagittal length between 0.4 and 0.5 sagittal length of glabella exclusive of occipital ring. Posterior limb moderately slender, spatulate; distal tip strongly rounded; transverse length about equal to basal glabellar width. Posterior border furrow broad, shallow. Anterior section of facial suture slightly divergent forward from palpebral lobe; posterior section divergent-sinuous. No intergenal spine.

Hypostome and rostral plate fused. Rostral part well defined by abrupt change in slope of exoskeleton.

Free cheek moderately narrow, gently convex, with broad flat border about equal to anterior width of ocular platform. Lateral border furrow shallow, not clearly continuous with deeper posterior border furrow which continues onto long flattened genal spine and extends nearly to tip. Genal spine not advanced.

Pygidium subtrapezoidal in outline, with sides slightly tapered posteriorly and with both anterolateral and posterolateral corners rounded. Posterior margin has slight median inbend. Axis prominent, tapered posteriorly, strongly rounded at rear, well defined by abrupt changes in slope of exoskeleton. Two or three very shallow ring furrows variably developed. Pleural regions crossed by variably developed raised anterior pleural bands of first three pleural segments that continue onto flattened border. No distinct border furrow. Lateral and posterior margins without spines.

Ornamentation consists of extremely fine granules on lateral and posterolateral parts of pygidial border. Other parts appear smooth.

Discussion.—This genus constitutes the third genus of a group including *Albertelloides* and *Paralbertella*. It differs from both of those genera most strikingly in lacking pygidial spines. It differs further from *Paralbertella* by the lack of advanced genal spines and from *Albertelloides* by the lack of a narrow furrow along the outer margin of the free cheek. The development of the anterior bands of the pygidial pleural segments is more variable and less strong than in either *Albertelloides* or *Paralbertella*.

Albertellina aspinosa n. sp.

Plate 10, figures 1–6

Discussion.—Because this is the only species at present in *Albertellina*, the generic description and discussion of affinities also suffice for the species.

Occurrence.—Moderately common, *Albertella* Zone, *Albertella-Mexicella* Zonule. Nevada: 4169–CO (2 pygidia), Spectre Range; 7195–CO (4 cranidia, 1 hypostome, 4 free cheeks, 8 pygidia), Desert Range.

Genus ALBERTELLOIDES Fritz

Albertelloides Fritz, 1968, p. 214.

Type species.—*Albertelloides mischi* Fritz, 1968, p. 215, pl. 38, figs. 1–7.

Description.—Moderate-sized corynexochids, length probably not exceeding 60 mm. Cephalon semicircular, with long broad-based flat curved genal spines extending backward from posterolateral corners. Glabella long, low, narrow, moderately well defined at sides and front by abrupt change in slope of exoskeleton; sides slightly concave; anterior end slightly wider than base. Four pairs of short lateral glabellar furrows present, posterior pair deepest and distinctly curved; others straight. Occipital furrow short, deep, slotlike at sides of glabella; shallow across axis. Occipital ring subtriangular, flat, extended into short slender occipital spine. Frontal area short, flat, undivided. Palpebral area of fixed cheek gently convex, horizontal, greatest width more than half basal glabellar width. Palpebral lobe long, slender, curved, well defined by palpebral furrow, situated opposite posterior half of glabella; anterior end connected to moderately distinct ocular ridge. Posterior limb slender, slightly expanded laterally; posterior margin nearly straight. Posterior border furrow well defined. Anterior section of facial suture slightly divergent anteriorly; posterior section strongly divergent, sinuous. Intergenal spine present on some small individuals, absent on cranidia longer than 5 mm.

Hypostome and rostral plate fused; rostral part distinctly defined by narrow furrow.

Free cheek narrow. Ocular platform gently convex, about as wide as flat border that is well defined by narrow lateral border furrow and continues into long flat curved genal spine. Posterior part of lateral margin and inner margin of spine bear narrow raised edges well defined by shallow furrows.

Thorax composed of eight segments; width of each pleural region, exclusive of spines, about equal to width of axis. Spines known only for last three segments; spines short, subequal in length, rounded in cross section.

Pygidium subquadrate in outline. Axis long, elevated, well defined, reaches nearly to posterior margin; bears two or three distinct ring furrows and one or two additional obscure furrows. Axial rings simple. Pleural regions triangular, crossed by three distinct broad pleural furrows and two narrow shallow interpleural furrows. Anterior bands of first three segments prominent, ridgelike. Border nearly flat; bears pair of slender posteriorly or posterolaterally directed border spines whose bases are about opposite end of axis.

Discussion.—The material representing this genus from the Carrara Formation adds information about the thorax, free cheek, and ventral morphology and proves the correctness of the association of cranidium and pygidium described by Fritz. The intergenal spines mentioned by Fritz as characteristic of the genus, are limited to small specimens, as in *Paralbertella* n. gen., and are not found on large specimens.

Albertelloides differs from *Albertella* by having long eyes, slender posterior limbs, eight rather than seven thoracic segments, ridgelike development of the anterior bands of the first three pleural segments on the pygidium, and pygidial border spines that are not strongly advanced. Differences from the more closely related genera *Paralbertella* n. gen. and *Albertellina* n. gen. are given in the discussions of those genera.

Albertelloides mischi Fritz

Plate 10, figures 7–13

Albertelloides mischi Fritz, 1968, p. 215, pl. 38, figs. 1–7.

Discussion.—Fritz has given a good description of the cranidium and pygidium of this species. The free cheek and hypostome-rostral plate are not distinguishable at present from *A. rectimarginatus* n. sp. and are described with that species. A partly preserved complete specimen that proves the association of cranidium and pygidium of this genus—whereas Resser (1939b) had assigned the pygidia to the ptychopariid genus *Kochaspis*—is questionably identified as *A. mischi*.

This species is characterized by having moderately long and slender pygidial spines directed nearly straight posteriorly, and the posterior margin between the spines is slightly convex posteriorly. The axis of most specimens has only one obscure ring furrow present behind the three distinct anterior ring furrows. The only distinct ornamentation on this species is on the pygidial spines, which are granular on smaller specimens and obscurely marked by anastomosing ridges on some larger specimens. The occipital furrow of uniform width and depth described by Fritz is found only on small cranidia. On most cranidia, the axial part of the furrow is quite shallow.

Occurrence.—Moderately common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (>10 cranidia, 2 free cheeks, 2 hypostome-rostral plates, >10 pygidia); 3484–CO (1 pygidium, one partially articulated specimen), both from Nevada Test Site.

Albertelloides rectimarginatus n. sp.

Plate 10, figures 14–20

Description.—Cranidium low, broad, gently convex transversely and longitudinally; width between palpebral lobes about equal to sagittal length exclusive of occipital spine. Glabella long, low, gently convex transversely and longitudinally, well defined at sides and front by abrupt changes in slope of exoskeleton; sides slightly concave; anterior end expanded; anterior width slightly greater than basal glabellar width. Four pairs of glabellar furrows present; posterior pair deep, short, strongly curved posteriorly, with shallow short anterior bifurcation; other pairs shallow, narrow, straight. Occipital furrow has deep distal slots and shallow axial part except on small specimens where depth is more uniform. Occipital ring has slender spine of unknown length. Frontal area flat, narrow, undivided; anterior margin has slight raised rim that is continuous with narrow lateral wirelike raised margin of free cheek. Sagittal length of frontal area generally between one-sixth and one-seventh sagittal glabellar length exclusive of occipital ring. Fixed cheeks have broad palpebral area and narrow part anterior to distinct ocular ridge. Transverse width of anterior part generally about one-third basal glabellar width. Palpebral area gently convex, nearly horizontal; greatest width, exclusive of palpebral lobe, about three-fourths basal glabellar width. Palpebral lobe long, narrow, arcuate, well defined by palpebral furrow, shaped like an inverted comma, situated opposite posterior half of glabella and at or slightly below level of palpebral area; line between posterior tips passes over or just anterior to axial part of occipital furrow; anterior end continuous with ocular ridge. Exsagittal length of palpebral lobe slightly more than one-half sagittal length of glabella exclusive of occipital ring. Posterior limb slender, posterior border furrow broad, deep, straight, approximately equally divided into distal and proximal parts by tip of palpebral lobe. Posterior border of limb widens distally. Course of anterior section of facial suture slightly divergent forward and then gently curved across frontal area to intersect margin near anterolateral cranidial corners. Posterior section of facial suture strongly divergent behind palpebral lobe, then directed posterolaterally to intersect cephalic margin near base of genal spine. External surface smooth.

Hypostome and rostral plate fused into single piece. Rostral plate gently convex in sagittal plane, well defined by anteriorly curved furrow at junction with strongly convex anterior body of hypostome. Posterior body small, low, well defined by transverse furrow. Maculae prominent on posterior part of anterior body.

Free cheek moderately narrow, with gently curved lateral margin continuous with margin of long nearly flat genal spine. Border nearly flat, about equal in width to ocular platform, defined by shallow lateral border furrow that is continuous with very short section of posterior border furrow at genal angle adjacent to posterior sutural margin. Genal spine has narrow, wirelike inner and outer margins defined by narrow furrows. External surface of spine is weakly ornamented with anastomosing venations and becomes increasingly granular towards tip. Length of spine nearly three times length of posterior sutural margin.

Pygidium subquadrate; sagittal length about three-fourths anterior width. Sides subparallel or slightly convergent posteriorly. Posterior border spines moderately short, sharp; length about equal to sagittal length of first two axial segments. Posterior margin between spines straight or curved slightly forward. Axis prominent, strongly convex transversely, sides subparallel, posterior end bluntly rounded, high, extended nearly to posterior margin. Axis bears three distinct ring furrows posterior to articulating furrow and generally two additional obscure furrows and a terminal piece. Axial rings without nodes or spines. External surface smooth except for granular ornamentation on surface of spines.

Discussion.—This species differs from all others assigned to the genus by having the pygidial spines short and directed nearly straight posteriorly and by having five axial segments. Pygidia are most like *A. maladensis* (Resser), which is the only other named species with the posterior margin straight or curved forward between the pygidial spines, but *A. rectimarginatus* consistently has one additional well-defined ring furrow on the axis. The cranidia are distinguished from those of *A. mischi* by having a sagittally longer frontal area and a wider anterior part to the fixed cheek. On *A. mischi* the sagittal length of the frontal area is about one-ninth the sagittal glabellar length exclusive of the occipital ring, and the width of the anterior part of the fixed cheek is only about one-fourth the basal glabellar width.

Occurrence.—Moderately common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3547–CO (>10 cranidia, 2 hypostome-rostral plates, 3 free cheeks, >10 pygidia); 3483–CO (1 pygidium, 2 cranidia); both from Nevada Test Site.

Genus FIELDASPIS Rasetti

Fieldaspis Rasetti, 1951, p. 159; in Harrington and others, 1959, p. 227.

Type species.—*Fieldaspis furcata* Rasetti, 1951, p. 159, pl. 15, figs. 1–8.

Discussion.—Rasetti (1951; Rasetti, in Harrington and others, 1959) presented good illustrations and discussions of the characteristics of this genus. Isolated cranidia are not generically separable from those of several other zacanthoidid genera, and the generic characteristic is in the pygidial structure which characteristically has a pair of posterolaterally directed spines or lobes. He also noted (Rasetti, 1957) the difficulty of distinguishing isolated pygidia of *Fieldaspis* from those of ptychopariids, such as *Kochaspis* and *Schistometopus*. Thus, without a large suite of associated parts, or an articulated specimen, a pygidium with paired spines that is not identical with one whose associations are already known cannot be generically identified.

Fieldaspis? sp.

Plate 6, figure 16

Discussion.—A single fragment of the left pleural region of a trilobite pygidium, viewed from below, may represent a species of *Fieldaspis*. The specimen has two pairs of well-developed pleural and interpleural furrows, of which the interpleural furrows are narrower and deeper, and a less well developed third set of pleural and interpleural furrows. The pygidium was subquadrate in outline with a broad nearly straight posterior margin between a pair of long slender posterolaterally directed spines. All these characteristics agree with those of *Fieldaspis superba* Rasetti from the *Plagiura-Kochaspis* Zone of the Canadian Rocky Mountains. However, the specimen is too incomplete to do more than suggest the possible presence of *Fieldaspis*, and perhaps *F. superba*, in the *Plagiura-Kochaspis* Zone of the southern Great Basin.

Occurrence.—Rare (1 specimen), "*Plagiura-Poliella*" Zone. California: 4139–CO, Titanothere Canyon section, Grapevine Mountains.

Genus MEXICASPIS Lochman

Mexicaspis Lochman, 1948, p. 455.

Type species.—*Mexicaspis stenopyge* Lochman, 1948, p. 455, pl. 69, figs. 1–11.

Diagnosis.—Small to moderate-sized corynexochid trilobites; maximum length probably not exceeding 30 mm. Cranidium gently convex transversely and longitudinally, anterior margin moderately and evenly rounded. Glabella low, poorly furrowed, slightly expanded forward, reaches nearly to anterior margin. Occipital ring gently convex, expanded backward, with or without axial spine. Fixed cheeks gently convex, moderately broad; width of palpebral area between one-half and three-fourths basal glabellar width. Palpebral lobes moderately long, situated slightly posterior to glabellar midlength. Posterior limbs short, blunt.

Free cheek has narrow pleural platform and large broad curved genal spine developed from posterolateral margin; spine at least five times length of posterior section of facial suture.

Pygidium moderately to strongly convex transversely. Axis prominent, sides subparallel; first segment well defined by deep ring furrow, usually has axial node. Remainder of axis long, obscurely furrowed; tip stands steeply above posterior margin. Pleural regions moderately to poorly defined. Border bears two or three pairs of border spines; posterior pair usually largest.

Discussion.—Lochman (1948) gave a good description of this genus based on the material of two very similar species from northern Mexico. The Carrara species described below has a cranidium that conforms fully to *Mexicaspis* and a pygidium with its axial structure essentially like that of the type species, but with a third pair of spines intercalated between the analogs of the spines of *M. stenopyge* Lochman. Free cheeks can also be associated with the Carrara specimens. The pygidial differences are not considered sufficient to justify generic separation of the species, and the diagnosis given above has been modified to accommodate the morphologic range shown by the pygidia and the new information about the free cheek.

Mexicaspis radiatus n. sp.

Plate 10, figures 22–25

Description.—Cranidium subquadrate in outline, gently convex transversely and longitudinally, moderately and evenly rounded at front. Glabella low, expanded anteriorly, reaches nearly to anterior margin, well defined by abrupt changes in slope of exoskeleton. Glabellar furrows poorly developed; only posterior oblique pair moderately distinct. Occipital ring broad, gently convex; sagittal length about one-third sagittal length of remainder of glabella. Occipital furrow moderately deep, straight. Fixed cheeks gently convex, slightly downsloping; width of palpebral area about 0.6 basal glabellar width. Palpebral lobe moderately long, narrow, curved, well defined by palpebral furrow, situated slightly posterior to glabellar midlength and well separated from glabella; exsagittal length between 0.4 and 0.5 sagittal glabellar length exclusive of occipital ring. Posterior limb short, blunt; transverse length about equal to basal glabellar width; length of distal part less than half length of proximal part. Posterior border furrow broad, shallow, straight.

Free cheek consists of small ocular platform separated by moderately deep border furrow from broader gently convex border that continues backward into large curved genal spine. Length of spine slightly more than five times length of posterior section of facial suture; angle between posterior margin of cheek and inner margin of spine moderately obtuse.

Pygidium, exclusive of border spines, subsemicircular in outline; sagittal length slightly less than anterior width. Axis prominent, sides subparallel; end strongly rounded, overhangs posterior margin. First axial segment well defined by deep ring furrow, bears small axial node of variable prominence. Two additional very shallow ring furrows present anterior to long terminal part. Pleural fields subtriangular; greatest width less than that of axis. Two shallow pleural furrows present extending to inner edge of moderately well defined border. Border bears three pairs of broad-based border spines; anterior pair laterally directed, relatively small; middle pair posterolaterally directed, intermediate in size; posterior pair largest, directed nearly straight posteriorly; spacing of spines nearly uniform around margin.

External surfaces of all parts have obscure finely granular ornamentation visible only after whitening of best preserved specimens.

Discussion.—This species is easily distinguished from all others in the genus by having three pairs of pygidial border spines. The massive genal spines and axial node on the first axial segment of the pygidium suggest a relationship between this species and species of *Ptarmiganoides*. However, the pygidial border spines of all species of *Ptarmiganoides* are slender rather than broad-based, and the genal spine is advanced rather than at the posterolateral cephalic corners.

Occurrence.—Common, *Albertella* Zone, *Albertella-Mexicella* Zonule(?). California: 4141–CO (10 cranidia, 3 free cheeks, 10 pygidia), Titanothere Canyon section, Grapevine Mountains; 7197–CO (>10 cranidia, 1 free cheek, >10 pygidia), Eagle Mountain.

Genus PARALBERTELLA n. gen.

Type species.—*Albertella bosworthi* Walcott, 1908, p. 22, pl. 1, figs. 4–6 (only).

Description.—Moderate-sized corynexochid trilobites, length probably not exceeding 60 mm. Cephalon transversely subpentagonal in outline, anterior margin straight or gently rounded, genal spines distinctly advanced from posterior margin. Cranidium elongate, gently convex transversely and longitudinally. Glabella long, well defined at sides and front by axial and preglabellar furrows, moderately convex transversely, gently convex longitudinally, sides subparallel, anterior end bluntly rounded. Four pairs of shallow lateral furrows present, posterior pair generally deepest and strongly oblique to axial furrow. Occipital furrow straight, occipital ring has small axial node adjacent to posterior margin. Frontal area short, flat. Fixed cheek gently convex, horizontal; width of palpebral area about one-half or slightly more than one-half basal glabellar width. Palpebral lobe long, arcuate, situated opposite posterior half of glabella, well defined by palpebral furrow that is continuous along ocular ridge to axial furrow. Anterior end of palpebral lobe near glabella; posterior end opposite or posterior to occipital furrow. Posterior limb long, slender, posterior border expands distally; specimens less than 5 mm long show vestiges of intergenal spines. Course of anterior section of facial suture moderately to strongly divergent forward from palpebral lobes; course of posterior section directed nearly straight laterally.

Free cheek crescentic in outline with well-defined border furrow and long genal spine projecting posterolaterally from posterior margin.

Hypostome and rostral plate fused.

Thorax composed of seven segments. Axis prominent, usually wider than pleurae. Fourth segment macropleural.

Pygidium elongate, semielliptical in outline exclusive of pair of advanced lateral border spines. Axis prominent, tapered posteriorly, reaches nearly to inner edge of narrow pygidial border, connected to border by narrow postaxial ridge. Five to seven distinct ring furrows present posterior to articulating furrow; most segments have low axial nodes. Pleural regions flat or gently convex, characterized by prominent ridgelike development of anterior bands of first three pleural segments. The ridges generally converge laterally to merge with pygidial border at base of border spine. Posterior margin behind lateral spines strongly curved posteriorly, usually downsloping.

Discussion.—This genus includes those species formerly assigned to *Albertella* that have long eyes, slender posterior limbs, anteriorly divergent facial sutures, a fourth macropleural segment on the thorax, strongly advanced lateral border spines on the pygidium, a narrow and well-defined posterior pygidial border, and the anterior bands of the first three pygidial segments developed as ridges and merged laterally with the border at the base of the pygidial spine. The most similar genus is

Albertelloides, which differs by having a strong occipital spine, broad genal spines that are not advanced, eight instead of seven thoracic segments, fewer axial segments on the pygidium, a less well defined posterior pygidial border, and pygidial spines that are not strongly advanced.

Paralbertolla besworthi (Walcott)

Plate 9, figures 19–25

Albertella bosworthi Walcott, 1908, p. 22, pl. 1, figs. 4–6 (only); Burling, 1916, p. 470, fig. 2a; Walcott, 1917, p. 38, pl. 7, figs. 3–3c (only); Rasetti, 1951, p. 149, pl. 17, figs. 1–9.
Albertella similaris Resser, 1936, p. 2.
?*Albertella stenorhachis* Rasetti, 1951, p. 155, pl. 18, figs. 18–21.

Discussion.—This species has been well illustrated and has been discussed by Rasetti. The Carrara material is well preserved in limestone and seems to differ in no important respects from the shale and limestone material from British Columbia. The species differs from others in the genus by having the anterior margin curved and the frontal area slightly upturned on the cranidium, by having commonly five axial segments and pleural furrows on the pygidium together with a pleural region only slightly narrower than the axis, and by having long curved pygidial border spines. The examples of fused hypostomes and rostral plates in the sample from the Carrara Formation provide the first information about this structure for *P. bosworthi*. The rostral area is strongly distinguished from the hypostomal area by a deep curved furrow and by its ornamentation of terrace lines. The anterior lobe is strongly distinguished from the posterior lobe by a deep transverse furrow.

Study of the type collections of the U.S. National Museum suggests that *A. stenorhachis* Rasetti may be no more than an extreme variant of *A. bosworthi*. I could not find consistent criteria for discrimination of these forms.

Occurrence.—Moderately common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (>10 cranidia, 2 hypostome-rostral plates, >10 pygidia), Nevada Test Site.

Genus PTARMIGANOIDES Rasetti

Ptarmiganoides Rasetti, 1951, p. 178; Poulsen, C., in Harrington and others, 1959, p. 226.

Type species.—*Ptarmiganoides bowensis* Rasetti, 1951, p. 179, pl. 20, figs. 1–8.

Description.—Moderate- to large-sized corynexochid trilobites; maximum length probably not exceeding 90 mm. Cephalon semicircular in outline with well-developed long genal spines, sometimes advanced in front of genal angle. Cranidium elongate, gently to moderately convex transversely and longitudinally; anterior margin gently rounded. Glabella long, low, expanded slightly forward, extended nearly to anterior margin. Glabellar furrows shallow; four pairs usually present. Occipital ring with or without long axial spine. Fixed cheek gently to moderately convex, horizontal; width, exclusive of palpebral lobes, between 0.3 and 0.6 basal-glabellar width. Palpebral lobe long, slender, anterior end near glabella, posterior end about opposite or slightly anterior to occipital furrow. Posterior limb long, slender, bears distinct intergenal spine on posterolateral part of tip. Course of anterior section of facial suture slightly divergent forward in front of palpebral lobe. Course of posterior section strongly divergent behind palpebral lobe.

Free cheek always has distinct border furrow, other features variable. Genal spine at or anterior to posterolateral corner of cephalon, slender or broad, generally long.

Pygidium, exclusive of border spines, semicircular in outline. Axis prominent, as wide as or wider than pleural fields, always has strong vertical axial spine on first segment; other segments may have axial spines or nodes. Pleural regions crossed by one to three shallow pleural furrows that continue onto inner part of border and have a broad pit at inner margin of border. Border bears three to five pairs of long slender border spines.

External surfaces of most species show some degree of granular ornamentation.

Discussion.—Although the description of this genus by Rasetti (1951) is adequate, a new description has been presented because additional information is now available concerning the posterior limbs, free cheeks, and structure of the pygidial margin. Rasetti (1951) proposed the genus *Ptarmiganoides* for the species from the Naomi Peak Limestone Member of the Langston Formation that Resser (1939b) assigned to *Dolichometopsis*, and included a new species from the Canadian Rocky Mountains. Both Rasetti (1951) and Lochman (in Cooper and others, 1952) concluded that Resser had misunderstood the relation of the Langston species of "*Dolichometopsis*" to the specimens described as *Dolichometopsis* by C. Poulsen (1927) from Lower Cambrian rocks of Greenland, although Lochman considered Resser's species all to belong to *Ptarmigania*. Ivshin (1957) reviewed the published material of Resser, Rasetti, and Lochman and concluded that there was insufficient reason to separate *Ptarmiganoides* from *Ptarmigania*. However, C. Poulsen (in Harrington and others, 1959) recognized both genera, and Fritz (1968) referred several species to *Ptarmiganoides* without comment about the problem of generic distinction. He did, however, note that some of Resser's specimens of "*Dolichometopsis*" were referable to *Poliella* rather than *Ptarmiganoides*.

In this report, *Ptarmiganoides* is considered as a genus distinct from *Ptarmigania* primarily because it has three or more pairs of slender pygidial border spines. Cranidia and free cheeks of both genera are not consistently distinguishable, nor can they be separated from those of *Paralbertella* n. gen. and some other long-eyed corynexochids without knowledge of associated pygidia. When the whole trilobite is known, pygidia typical for *Ptarmigania* have one pair of anterolateral border spines and only nubs of one or two additional spines and can be easily distinguished from the multispinose pygidia of *Ptarmiganoides*. At the present time, grouping of corynexochid species into genera based only on cephalic features, as proposed by Ivshin, would seem to obscure important differences between species groups.

Because of the great confusion caused by excessive splitting of species in the Langston Formation by Resser (1939b), and inadequate evaluation of their morphology, the current generic assignment for the holotype of each species of *Ptarmigania* and *Dolichometopsis* in that paper is presented here.

Present Name	Name in Resser (1939b)
Ptarmiganoides propinqua (Resser)	*Dolichometopsis propinqua* *comis* *communis* *gregalis* *lepida* *mansfieldi* *media* *poulseni* *stella* *Ptarmigania sobrina* *aurita*
Ptarmigania exigua Resser	*Ptarmigania exigua* *ornata* *natalis*
Poliella germana (Resser)	*Ptarmigania germana* *altilis* *agrestis* *dignata* *Dolichometopsis potens* *gravis*

As noted in the discussion of *Poliella germana*, not all paratypes of Resser's "species" were conspecific with their holotypes. Instead of 21 species assigned to 2 genera, there are now considered to be 3 species of 3 genera. The three species are: *Poliella germana* (Resser), already revised by Fritz (1968); *Ptarmiganoides propinqua* (Resser), chosen from 11 names because its syntype series contains the most representative specimens for the species; and *Ptarmigania exigua* Resser. *P. germana* has smooth or pitted ornamentation, lacks fixigenal spines and has a pygidium that lacks border spines; *P. propinqua* has a weakly granular ornamentation and four pairs of slender pygidial spines; and *P. exigua* has a well-developed granular ornamentation and only one pair of short pygidial spines and several nubs of additional spines. With this reduction in names, *Ptarmiganoides* now includes six species: *P. bowensis* Rasetti, *P. propinqua* (Resser), *P. bispinosa* (Lochman), *P. araneicauda* Fritz, and the two new species from the Carrara Formation described later in this report.

Ptarmiganoides crassaxis n. sp.

Plate 11, figures 12, 13, 17, 18

Description.—Cranidium questionably assigned to this species elongate, moderately convex transversely and longitudinally, gently to moderately rounded at front; width between palpebral lobes equal to or greater than sagittal length exclusive of occipital spine. Glabella long, moderately convex transversely, expanded slightly forward, reaches nearly to anterior margin, moderately to strongly rounded at front, well defined by abrupt changes in exoskeletal slope along sides and by narrow preglabellar furrow. Glabellar furrows shallow; posterior two pairs best developed; posterior pair strongly oblique to glabellar margin. Occipital furrow straight, of uniform depth on small forms, shallowest on axial line of large forms. Occipital ring gently convex, produced posteriorly into slender occipital spine; length, including spine, about three-fourths sagittal length of glabella. Frontal area very narrow, about one-tenth sagittal length of glabella exclusive of occipital ring. Fixed cheeks gently convex, horizontal; width of palpebral area slightly more than one-half basal glabellar width. Palpebral lobe long, arcuate, well defined by palpebral furrow, situated opposite posterior half of glabella, connected to glabella by oblique, moderately well defined ocular ridge; exsagittal length greater than one-half sagittal glabellar length on small specimens, slightly less than one-half sagittal glabellar length on large specimens; width of cheek opposite anterior end between one-third and one-fourth basal glabellar width. Posterior limb slender, bears well-developed posterolateral fixigenal spine. Course of anterior section of facial suture nearly straight forward from palpebral lobe. Course of posterior section strongly divergent behind palpebral lobe.

Free cheek has broad nearly flat border that expands slightly posteriorly and is separated from the ocular platform by a shallow furrow of uniform depth that is curved and continuous with the posterior border furrow. Genal spine long, slender, flattened, slightly advanced so that inner spine angle is slightly acute; length about five times length of short posterior section of facial suture. Surfaces of ocular platform and border covered with moderately coarse granules. Lateral margin also has oblique terrace lines which form anteriorly directed V-shapes in anterior part.

Pygidium, exclusive of border spines, subsemicircular in outline; sagittal length slightly greater than one-half anterior width. Axis large, strongly convex transversely, reaches nearly to posterior margin, two ring furrows present. Anterior axial ring well defined by deep first ring furrow, bears large axial spine. Second ring furrow relatively shallow; second axial ring without node or spine. Width of axis almost three times width of narrow triangular pleural field. Pleural field crossed by only one distinct pleural furrow. Inner margin of border has broad shallow depressions between bases of border spines. Four moderately long slender posteriorly directed border spines present.

External surfaces of cranidium covered with strongly developed granular ornamentation. Granular ornamentation on pygidium obscure.

Discussion.—This species is represented by only a few specimens, and the correctness of the association of cranidia and pygidia is not certain. For that reason, the pygidium is the designated holotype. The cranidia are very similar to that of *Ptarmigania exigua* Resser, although the largest specimen has a much more strongly rounded anterior margin. The pygidium has all the characteristics of *Ptarmiganoides* and differs from all other species in the genus by having a very broad axis and poor development of pleural furrows.

Occurrence.—Moderately rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (5 cranidia, 1 free cheek, 2 pygidia), Nevada Test Site.

Ptarmiganoides hexacantha n. sp.

Plate 11, figures 9–11, 14–16

Description.—Cranidium elongate, gently convex transversely and longitudinally, anterior margin gently rounded. Glabella long, low, very slightly expanded anteriorly, bluntly rounded at front, well defined by axial and preglabellar furrows. Only posterior pair of oblique lateral glabellar furrows distinctly developed. Occipital furrow deep distally, shallow across axial line. Occipital ring flat, with position of occipital node marked by four tiny pits; no occipital spine. Frontal area undivided, flat, short; sagittal length between one-seventh and one-tenth sagittal length of glabella exclusive of occipital ring. Fixed cheeks gently convex, horizontal; width of palpebral area about 0.6 basal glabellar width. Palpebral lobe slender, arcuate, well defined by narrow palpebral furrow that continues across cheek to glabellar furrow outlining posterior edge of oblique ocular ridge; width of cheek at anterior end of palpebral lobe about one-third basal glabellar width. Posterior limb slender, transverse length about equal to basal glabellar width; border furrow deep, straight; distinct intergenal spine directed posterolaterally from tip.

Free cheek has narrow crescentic ocular platform of more or less constant breadth separated from broad gently convex border by well-defined evenly curved border furrow. Border produced into broad-based long curved genal spine that originates opposite midlength of eye. Angle between posterior cheek margin and inner spine margin acute. Length of spine more than five times length of posterior section of facial suture.

Pygidium, exclusive of border spines, semicircular in outline; sagittal length about one-half greatest width. Axis broad, strongly convex transversely, strongly rounded posteriorly, reaching to inner edge of poorly defined gently convex border. First axial ring well defined by first ring furrow and bears large subvertical axial spine; a second shallow ring furrow may be present. Pleural regions downsloping, subtriangular, about as wide as axis at anterior margin, crossed by two shallow pleural furrows that continue onto border and a third pleural furrow represented only by broad pit in position of poorly defined inner margin of border. Border bears three pairs of short pointed spines; posterior pair separated by gap slightly wider than axis.

Ornamentation consists of scattered very faint granules on glabella and palpebral lobes, and either granules or pits on fixed cheeks; genal spine has closely spaced granules; pygidium obscurely ornamented with faint granules on axis and border spines.

Discussion.—This species is distinguished from all others in the genus by having only three pairs of border spines on the pygidium. It differs, in addition, from *P. propinqua* (Resser) and *P. araneicauda* Fritz by lacking an occipital spine on the cranidium. The distinctive free cheek is similar to that of *P. araneicauda* and also to that of *Ptarmigania rossensis* (Walcott), the type species of *Ptarmigania*, and it emphasizes the close relationship of *Ptarmigania* and *Ptarmiganoides*.

Occurrence.—Moderately common, *Albertella* Zone, *Albertella-Mexicella* Zonule(?). California: 4141–CO (6 cranidia, 5 free cheeks, 7 pygidia), Titanothere Canyon section, Grapevine Mountains. Rare, Zacanthoidid Zonule. Nevada: 3695–CO (1 pygidium), Nevada Test Site.

Genus ZACANTHOIDES Walcott

Zacanthoides Walcott, 1888, p. 165; Kobayashi, 1935, p. 123; Shimer and Shrock, 1944, p. 619; Palmer, 1954, p. 69; Rasetti, F., in Harrington and others, 1959, p. 227.

Type species.—*Embolimus spinosa* Rominger, 1887, p. 15, pl. 1, fig. 3.

Discussion.—This genus has already been fully described and illustrated by me and by Rasetti. The Cararra species agree with earlier diagnoses and descriptions in all essential features.

Zacanthoides variacantha n. sp.

Plate 11, figures 19–21

Description.—Cranidium subtrapezoidal in outline, gently convex transversely and longitudinally, anterior margin very slightly curved; width between palpebral lobes slightly greater than sagittal length of cranidium including occipital ring. Glabella low, long, sides subparallel, anterior end bluntly rounded, well defined all around by abrupt changes in slope of exoskeleton. Four pairs of glabellar furrows present; all pairs short and deep on larger cranidia, less deep on small cranidia. Occipital furrow of uniform depth on small specimens, shallow in axial region of larger specimens. Occipital ring has small axial node adjacent to posterior margin. Frontal area sagittally long for the genus, strongly expanded forward, bears wide plectrum whose posterolateral margin extends in an irregular curve inward from anterolateral corner of cranidium to anterolateral corner of glabella; sagittal length about one-third sagittal length of glabella exclusive of occipital ring. Fixed cheeks flat, horizontal; width of palpebral area three-fourths basal glabellar width on small specimens, slightly less than two-thirds basal glabellar width on large specimens. Palpebral lobe very long, crescentic, well defined by deep narrow palpebral furrow, slightly upsloping laterally, anterior end continuous with ocular ridge and near anterior end of glabella; posterior tip opposite anterior part of occipital ring. Posterior limb very slender, posterior margin curved; distal tip with well-developed fixigenal spine. Course of anterior section of facial suture strongly divergent forward from palpebral lobe; course of posterior section almost perpendicular to axis of cranidium.

Pygidium, exclusive of border spines, semielliptical in outline; sagittal length about three-fourths anterior width. Axis prominent, tapered posteriorly, bears four distinct ring furrows posterior to articulating furrow; axial rings without nodes or spines. Pleural region gently convex, subtriangular, slightly narrower than axis with only one distinct pleural furrow. Border poorly defined, flat, narrower than pleural field, bears one long pair of anterior marginal spines and three or four pairs of very short more posterior spinules.

External surfaces of cranidium and pygidium covered with closely spaced very fine granules barely apparent even after whitening.

Discussion.—This species has all the typical features of *Zacanthoides*: anteriorly divergent facial sutures, long palpebral lobes, posterior fixigenal spines, and semielliptical multispinose pygidium. Its closest relative, however, is a group of "species" described by Resser (1939b) from the Naomi Peak Limestone Member of Maxey (1958) of the Langston Formation and assigned to *Prozacanthoides*. Resser's concept of *Prozacanthoides* was not based on the type species. Study of a large suite of paratype material of this species, *Prozacanthoides stissingensis,* shows this to be a corynexochid with relatively short palpebral lobes, subparallel anterior sections to the facial sutures, subtriangular posterior limbs on the cranidium, and three strong pairs of lateral border spines on the pygidium of which the posterior pair, which is widely separated, is the longest. None of the 14 species assigned to *Prozacanthoides,* except the genotype, is properly identified, and the particular 5 "species" described by Resser (1939b) from a single collection in the Naomi Peak Limestone all conform fully to the characteristics of *Zacanthoides*. In addition, their differences are only matters of preservation and the single name *Z. alatus* (Resser) is recommended here for the specimens named by Resser as *Prozacanthoides alatus, decorosus, exilis, optatus,* and *aequus*. This is the only other species of *Zacanthoides* with a plectrum, and it differs from *Z. variacantha* n. sp. by having an occipital spinule and only weak development of the glabellar furrows on the cranidium and by having only three ring furrows and poor development of the anterior pair of large border spines on the pygidium. The strong development of only the anterior pair of border spines and the cranidial plectrum distinguish *Z. variacantha* n. sp. from all others assigned to *Zacanthoides*.

Occurrence.—Moderately common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766-CO (8 cranidia, 5 pygidia), Nevada Test Site.

Zacanthoides cf. Z. alatus (Resser)

Plate 11, figures 25, 26

Prozacanthoides alatus Resser, 1939b, p. 26, pl. 3, figs. 10–12.

Discussion.—Two cranidia of a species of *Zacanthoides* with a plectrum differ from *Z. variacantha* n. sp. by lacking strong development of the glabellar furrows on large specimens. The fixed cheeks are less than one-half the basal glabellar width, and the surface is distinctly ornamented by fine granules. The presence of an occipital spinule cannot be determined—the axial margin on the illustrated specimen is broken as if one might have been present. These specimens may be representative of *Z. alatus* (Resser), but a certain identification cannot be made without additional material. The reasons for the change in generic assignment for *alatus* are discussed under *Z. variacantha* n. sp.

A single pygidium (pl. 11, fig. 26) of general zacanthoidid morphology from the same collection as the cranidia may also belong to this species. The prominent axis is imperfectly preserved but shows at least two ring furrows posterior to the articulating furrow. The nearly flat pleural regions are narrower than the axis and show three pleural furrows and two shallow interpleural furrows. The pleural furrows are accentuated by the raised anterior bands of the segments. The border bears three pairs of short sharp border spines, with the anterior pair being the largest. This pygidium differs from the pygidium of *Z. variacantha* n. sp. by having strong pleural furrows, by having only three pairs of border spines, and by having the anterior pair of spines much shorter. Without more material, it is not even reasonably certain that this pygidium and the cranidia are conspecific.

Occurrence.—Rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3695–CO (2 cranidia, 1 pygidium), Nevada Test Site.

Zacanthoides? sp.

Plate 6, figure 11

Discussion.—A single fragment of the left half of a pygidium showing three slender border spines, narrow pleurae crossed by three pleural furrows, and an axis with two distinct ring furrows has the general shape of pygidia generally assigned to *Zacanthoides*. It is the only other trilobite found associated with abundant specimens of *Syspacephalus obscurus* n. sp. in beds assigned to the *Plagiura-Kochaspis* Zone.

Occurrence.—Rare, *Albertella* Zone. California: 4140–CO (1 fragmentary pygidium), Titanothere Canyon section, Grapevine Mountains.

Corynexochid cranidium undet. 1

Plate 16, figures 20, 25

Discussion.—A peculiar corynexochid, possibly related to *Glossopleura*, is represented by three specimens in the youngest collection from the *Glossopleura* Zone. It is characterized by a narrow elongate nearly straight sided glabella whose length, exclusive of the poorly differentiated occipital ring, is about twice its width. A narrow flat undivided frontal area is present only directly in front of the glabella; the anterolateral parts reach to the facial sutures. The anterior end of the glabella has a poorly defined median depression. The palpebral lobes are long, narrow, and situated opposite the posterior two-thirds of the glabella; a line connecting the posterior tips passes over the midlength of the occipital ring. The posterior limbs are not known. The external surfaces of all parts appear smooth.

Without associated parts, this species is not identifiable. The long slender anterior part of the glabella, anterior glabella depression, flat frontal area, and long arcuate palpebral lobes distinguish this from all known corynexochid species.

Occurrence.—Rare, uppermost *Glossopleura* Zone, Bonanza King Formation. Nevada: 7199–CO (3 cranidia), Striped Hills.

Corynexochid pygidium undet. 1

Plate 9, figure 26

Description.—Pygidium subquadrate in outline, gently convex transversely and longitudinally; sagittal length slightly more than one-half anterior width. Axis slender, sides subparallel, reaches nearly to posterior margin. All ring furrows obscure. Pleural regions undifferentiated; only first pleural furrow distinctly developed. Two pairs of marginal spines present; anterior pair small, posterolaterally directed, developed from anterolateral corners of pygidium; posterior pair moderately long, directed straight posteriorly, continuous with straight pygidial sides; margin between posterior pair of spines nearly straight. External surface smooth.

Discussion.—This distinctive species is known only from three specimens in two collections and no other parts can be associated with it. It is somewhat suggestive of *Mexicaspis diffuntoensis* Lochman (in Cooper and others, 1952), but it lacks the good definition of the first axial segment and has a narrower and less prominent axis. Without more knowledge of the whole trilobite, its generic and familial affinities are indeterminate.

Occurrence.—Rare, *Albertella* Zone, *Albertella-Mexicella* Zonule. Nevada: 1616–CO (2 pygidia), Spring Mountains. California: 4166–CO (1 pygidium), Resting Springs Range.

Corynexochid pygidium undet. 2

Plate 10, figure 21

Discussion.—A single pygidium closely resembles and is probably congeneric with a pygidium identified as *Athabaskia* sp. by Rasetti (1951, p. 156, pl. 22, fig. 12). The species is characterized by a prominent slender axis bearing three ring furrows and by pleurae crossed by three furrow-pairs composed of a pleural furrow and slightly shallower interpleural furrow that are subparallel to each other and closer to each other than to the furrows of the adjacent pair. A single more posterior pleural furrow is also present. Both pleural and interpleural furrows extend onto the moderately narrow poorly defined pygidial border.

The fact that the furrows extend across the pleural platform and onto the pygidial border probably influenced the generic identification of Rasetti's specimen. However, I reexamined the type species of *Athabaskia, A. ostheimeri* Raymond, and this has a markedly different structure in the pleural regions of the pygidium. The interpleural furrows are present only near the pygidial axis and are nearly perpendicular to it, while the pleural furrows extend diagonally posterolaterally across each pleuron so that the anterior band expands distally and the posterior band tapers distally rather than maintaining a uniform breadth. These structural differences indicate a morphologic difference of at least generic rank. Without sure knowledge of associated parts, this species is not assignable to any described genus.

Occurrence.—Rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3547-CO (1 pygidium), Nevada Test Site.

Order PTYCHOPARIIDA Swinnerton

This order of trilobites, whether recognized in the restricted sense of Bergström (1973) or in the more inclusive sense of the trilobite volume of the "Treatise on Invertebrate Paleontology" (Harrington and others, 1959), still provides the greatest problems for suprageneric classification among all the trilobites. In the early part of the Cambrian this problem is particularly acute because most of the ptychopariid trilobites are rather generalized forms for which there are still no consistently recognized suprageneric taxa. For this reason, the ptychopariid genera are presented here in alphabetical order. However, at least one suprageneric grouping might be recognized among them.

The genera *Caborcella, Kochaspis, Kochiellina, Nyella,* and *Schistometopus* are all characterized by a prominent tapered glabella with several pairs of moderately to strongly developed glabellar furrows and by a tendency for the glabellar sides to be very slightly concave opposite the second pair of glabellar furrows. (See pl. 8, figs. 3, 8; pl. 13, figs. 6–8; pl. 14, figs. 6, 7.) These trilobites also generally have moderately wide fixed cheeks, distinct narrow ocular ridges, and granular ornamentation. This cranidial morphology seems typical for trilobites only from *Glossopleura* Zone and older North American Middle Cambrian beds. These trilobites, which share stratigraphic proximity as well as considerable axial similarity, probably represent a genetically related group of forms for which a meaningful family designation could be made. At several places in this report, trilobites of this group are referred to as kochaspid trilobites. Differences in structure of the frontal area and the associated pygidium provide the most useful characters for discrimination of kochaspid genera.

In the "Treatise on Invertebrate Paleontology" (Harrington and others, 1959), *Kochaspis* and *Caborcella* are in different superfamilies, and *Schistometopus* was left without family assignment. Some other possibly related genera, such as *Kochiella* and *Kochina,* are in still a different suprageneric taxon. *Nyella* and *Kochiellina* are new genera. Until a thorough revision of the Cambrian Ptychopariida is undertaken, I prefer to consider the kochaspids to be an informal grouping to be evaluated in the light of the larger context of all ptychopariid groups.

Genus ALOKISTOCARE Lorenz

Alokistocare Lorenz, 1906, p. 62; Walcott, 1916a, p. 182; Resser, 1935, p. 4; Rasetti, 1951, p. 202; Palmer, 1954, p. 71, Poulsen, V., 1958, p. 11; Howell, B. F., in Harrington and others, 1959, p. 238; Lazarenko, 1962, p. 65; Kobayashi, 1962, p. 51; Demokidov and Lazarenko, 1964, p. 213; Yegorova and Savitskiy 1969, p. 237; Robison, 1971, p. 802.

Amecephalus Walcott, 1924, p. 53; Walcott, 1925, p. 65; Rasetti, 1951, p. 202; Kobayashi, 1962, p. 51; Poulsen, V., 1964, p. 41; Fritz, 1968, p. 227.

Strotocephalus Resser, 1935, p. 45.

Type species.—*Conocephalites subcoronatus* Hall and Whitfield, 1877, p. 237, pl. 2, fig. 1.

Discussion.—Robison (1971) has given the most recent complete description for this genus. At present, *Alokistocare* includes more than 57 named species, and almost every author seems to have a slightly different view of the morphology and morphologic limits of species assignable to it. Since the time of Walcott (1924), attempts have been made to discriminate a second genus, *Amecephalus,* from the group of micropygous Middle Cambrian ptychopariids with long frontal areas that are generally poorly differentiated into a flat or concave border and gently convex brim and that often bear a poorly defined low median swelling. Arguments both for (Resser, 1935, p. 4; Palmer, 1954, p. 71) and against (Rasetti, 1951, p. 202; Poulsen, V., 1958, p. 11; Poulsen, V., 1964, p. 41; Fritz, 1968, p. 227) suppression of *Amecephalus* have been presented. Most recently, Robison (1971) suppressed *Amecephalus* again, but pointed out the need for a thorough revision of this problematical complex of trilobites. The Carrara Formation contains generally fragmentary remains of several different trilobites belonging to this complex. Because the material is mostly inadequate for detailed study, the specimens are treated here with open nomenclature, pending a separate intensive study of the whole *Alokistocare* complex.

Alokistocare sp. 1

Plate 15, figure 18

Discussion.—This species is the most typical representative of the genus in the Carrara Formation. It is represented only by a few incomplete cranidia which have an obscurely furrowed glabella, a flaring frontal area; a concave poorly defined border slightly longer sagittally than the brim, and a low medium swelling located at the inner margin of the border and extending slightly backward onto the brim. The shallow border furrow passes over the posterior part of this swelling without deflection. The specimens are exfoliated and have anastomosing veins on the brim and fixed cheeks. No indication of any other ornamentation is present.

The median swelling on the frontal area distinguishes this species from others found in the Carrara Formation.

Occurrence.—Rare, *Glossopleura* Zonule. California: 7198–CO (3 cranidia), Eagle Mountain.

Alokistocare sp. 2

Plate 15, fig. 22

Discussion.—A single incomplete cranidium represents a species of *Alokistocare* that is easily distinguishable from the other species in the Carrara Formation by its distinctive ornamentation. The glabella, fixed cheeks behind the ocular ridges, and anterior part of the poorly differentiated concave border are covered with low closely spaced intergrown poorly defined granules, so that in some lightings the intergranular spaces are emphasized and give the area a pitted appearance. The frontal area has scattered large low granules that are also preserved on the internal mold. All other species of *Alokistocare* so far observed in the Carrara Formation lack granular ornamentation.

Occurrence.—Rare, uppermost *Glossopleura* Zone. Nevada: 7199–CO (1 cranidium), Striped Hills.

Genus ALOKISTOCARELLA Resser

Alokistocarella Resser, 1938a, p. 57; Howell, B. F., in Harrington and others, 1959, p. 238.

Type species.—*Alokistocarella typicalis* Resser, 1938a, p. 57, pl. 7, fig. 43.

Discussion.—At the time when this genus was first proposed, it was not adequately described and was characterized by Resser (1938) as intermediate "between *Alokistocare, Amecephalina,* and *Ehmaniella.*" Subsequently, without further discussion of generic characteristics, eight species from various Middle Cambrian collections have been assigned to it. In the absence of any clearly stated concept for the genus, various authors have stressed different morphologic features when relating their species to *A. typicalis*. The result of this is an amorphous genus of limited utility. Nevertheless, the species described below share many features of cranidial morphology, particularly those of glabellar shape and structure of the frontal area, with *A. typicalis* Resser or *A. brighamensis* Resser, both from the early part of the Middle Cambrian, and are more like these species in cranidial morphology than any other described American early Middle Cambrian simple ptychopariids. Until a better means is found for adequately evaluating generic relationships of species such as these, the generic identification is only tentative.

Alokistocarella? cf. A. brighamensis Resser

Plate 15, figures 9–14

Alokistocarella brighamensis Resser, 1939b, p. 53, pl. 13, figs. 17, 18.

Description.—Small simple ptychopariids with sagittal length of largest known cranidium about 15 mm. Cranidium subquadrate in outline, gently and evenly rounded at anterior margin, gently to moderately convex transversely and longitudinally. Glabella low, tapered forward, bluntly rounded anteriorly, unfurrowed, defined at sides and front by shallow lateral and preglabellar furrows; anterior end less well defined than sides. Occipital furrow shallow, straight, slightly deeper at sides than across top. Occipital ring simple, with moderately distinct median axial node. Frontal area subequally divided into gently convex downsloping brim and flat or slightly concave border by slight change in slope of exoskeleton; sagittal length of frontal area about two-thirds sagittal length of glabella exclusive of occipital ring. Fixed cheeks gently convex, horizontal, or slightly upsloping; width of palpebral area about one-half basal glabellar width. Palpebral lobe poorly defined, continuous with slope of palpebral area situated about opposite glabellar midlength; exsagittal length slightly less than one-half sagittal length of glabella exclusive of occipital ring. Posterior limb moderately broad exsagittally, bluntly terminated, crossed by moderately deep posterior border furrow; transverse length about equal to basal glabellar width. Course of anterior section of facial suture slightly divergent forward from palpebral lobe to sharply curved anterolateral corner of cranidium, merged imperceptibly with anterior margin. Course of posterior section of facial suture divergent-sinuous.

Free cheek has lateral margin moderately curved; lateral border poorly defined, flat, and slightly narrower than ocular platform; and flat genal spine of unknown length.

Pygidium possibly representing this species strongly convex transversely and longitudinally. Axis low, poorly defined, tapered posteriorly, bears one prominent ring furrow and two or three additional obscure furrows. Pleural regions strongly convex, margins depressed, border represented only by poorly defined anterolateral, less strongly depressed marginal area.

External surfaces of all parts either smooth or obscurely shagreened.

Discussion.—This species differs from all species presently assigned to *Alokistocarella* except *A. brighamensis* Resser by its low cranidial relief. The fixed cheek of *A. brighamensis* is slightly wider than that of the Carrara specimens, and the palpebral lobes seem to be situated slightly more posteriorly. Because all samples of these trilobites are small, the differences may not be significant.

Specimens possibly of this species from the Striped Hills section (USGS colln. 3690–CO) differ from those in the Echo Canyon section (USGS colln. 4155–CO) which were used for the description, by having a slightly better definition of the front of the glabella, a narrower and more distinctly concave border, and slightly longer posterior limbs. The associated free cheeks are essentially identical in both samples. Until more material is obtained of both *brighamensis* and the Carrara forms, the degree of relationship of the samples must remain uncertain.

Occurrence.—Moderately rare, *Glossopleura* Zonule. California: 4155–CO (8 cranidia, 1 free cheek, 3 pygidia), Echo Canyon section, Funeral Mountains. Nevada: 3690–CO (2 cranidia, 1 free cheek), Striped Hills section.

Alokistocarella? sp.

Plate 15, figures 17, 21

Discussion.—A simple ptychopariid represented by several cranidia and a pygidium, all exfoliated, represents a species unlike any others from the Cordilleran early Middle Cambrian. The cranidia range in size from 3 mm to about 8 mm and are characterized by an anteriorly tapered bluntly rounded glabella bearing four pairs of moderately distinct glabellar furrows and well defined by narrow lateral and preglabellar furrows. The frontal area is subequally divided by a narrow border furrow into a nearly flat and slightly downsloping brim and a slightly convex border. The fixed cheeks are moderately convex and horizontal and bear moderately large palpebral lobes situated opposite the posterior half of the glabella; the width of the palpebral area is about one-half the basal glabellar width, and the exsagittal length of the palpebral lobe is about one-half the sagittal glabellar length exclusive of the occipital ring. The form of the posterior limbs is not known. Internal molds have strongly developed caecal venation on the brim, and some specimens have a granular axial region indicating that this part is probably also granular on the external surface. One fragmentary specimen with part of the external surface preserved has a smooth border, brim, and fixed cheek.

This species is like *Alokistocarella typicalis* Resser in most features except for the frontal area. *A. typicalis* lacks a distinct separation of brim and border, and the border area is concave rather than slightly convex. An associated incomplete pygidium is essentially the same as *Alokistocarella*? cf. *A. brighamensis* Resser. Small cranidia have the glabellar furrows and border furrow accentuated. Without more knowledge of details of ornamentation, structure of the posterior limb, and other associated parts of this generalized form, its identification and relationships must remain uncertain.

Occurrence.—Moderately common, *Glossopleura* Zonule. Nevada: 3544–CO (1 cranidium), Desert Range; 3545–CO (2 cranidia), 3767–CO (11 cranidia, 1 pygidium), both from Nevada Test Site.

Genus CABORCELLA Lochman

Caborcella Lochman, 1948, p. 461; Howell, B. F., in Harrington, 1959, p. 233.

Type species.—*Caborcella arrojosensis*, Lochman, 1948, p. 461, pl. 70, figs. 19–21.

Description.—Moderate-sized kochaspid trilobites with known cranidial length as much as 15 mm. Cranidium gently to moderately convex transversely and longitudinally. Glabella prominent, tapered, strongly to bluntly rounded at front, well defined at sides by deep axial furrow and at front by abrupt change in exoskeletal slope or shallow preglabellar furrow. Three or four pairs of well-defined generally deep glabellar furrows present; posterior pair deepest, curved or straight. Occipital furrow deep, deepest distally. Occipital ring simple. Frontal area generally concave. Brim very narrow sagitally. Border broad, poorly defined, concave, bearing poorly to well-developed pseudofurrow. Sagittal length of frontal area ranges from slightly less than one-third to about two-thirds sagittal glabellar length exclusive of occipital ring. Fixed cheeks flat or convex, horizontal or upsloping; prominent ocular ridge usually present; width of palpebral area between one-half and two-thirds basal glabellar width. Palpebral lobes well defined, situated opposite or slightly posterior to glabellar midlength; exsagittal length about one-third sagittal glabellar length exclusive of occipital ring. Posterior limbs about equal in transverse length to basal glabellar width. External surface with granular ornamentation.

Course of anterior section of facial suture nearly straight forward from palpebral lobe. Course of posterior section divergent-sinuous.

Associated parts not known.

Discussion.—Lochman gave a good diagnosis of this genus based principally on the type species although she included in the genus the poorly preserved specimens described by Mason (1935) as *Acrocephalites*? *trifossatus* Mason. At that time, the potential value of the structure of the frontal area for recognition of the genus was unknown, and its characteristics were not emphasized. Subsequently, Rasetti (1951) and Fritz (1968) added several species to the genus including *Poulsenia granosa* Resser, which Lochman had specifically excluded. Neither Rasetti nor Fritz discussed the revised generic characters.

Among the kochaspid trilobites in the *Albertella* fauna in the Carrara Formation are two distinct groups of species. One has a poorly defined concave border, and the other has a deep border furrow and a convex border. The forms with the concave border are most like *C.*

arrojosensis Lochman and are retained in *Caborcella*. Those with convex borders are most like the species assigned to *Caborcella* by Rasetti and Fritz. These Carrara species with convex borders and deep border furrows, and most of the Rasetti and Fritz species, are here assigned to a new genus, *Nyella*.

Caborcella pseudaulax n. sp.

Plate 13, figure 6

Description.—Cranidium subtrapezoidal in outline, gently convex transversely and longitudinally, broadly rounded anteriorly; width between palpebral lobes greater than sagittal cranidial length. Glabella prominent, tapered forward, bluntly rounded anteriorly, well defined at sides and front by broad deep axial and preglabellar furrows. Four pairs of glabellar furrows present; posterior pair very deep, curved; anterior pairs progressively shallower. Occipital furrow deep, broadest on axial line. Occipital ring simple. Presence or position of node not known. Frontal area broad, concave, sagittal length slightly more than one-half sagittal length of glabella exclusive of occipital ring. Brim very narrow. Border concave, with broad shallow pseudofurrow. Inner margin of border slightly elevated above brim laterally, poorly defined, best shown by contrast in ornamentation. Exsagittal breadth of border decreases laterally. Fixed cheeks wide, gently convex, upsloping; width of palpebral area about two-thirds basal glabellar width. Palpebral lobe small, upsloping from palpebral area, connected to glabella by narrow well-defined gently curved ocular ridge; situated opposite posterior half of glabella. Exsagittal length of palpebral lobe slightly more than one-third sagittal glabellar length exclusive of occipital ring. Posterior limbs broad, strong, transverse length equal to or slightly more than basal glabellar width. Course of anterior section of facial suture nearly straight forward from palpebral lobe to anterior margin. Course of posterior section convex, strongly divergent behind palpebral lobe.

Other parts not known.

External surfaces of all parts covered with extremely fine closely spaced granules. Strong tubercular ornamentation developed only on cheeks, brim, outer margin of anterior border, convex parts of glabella, and posterior border.

Discussion.—This species differs from *C. arrojosensis* Lochman by having less transversely convex fixed cheeks and a less upturned border; and the pseudofurrow on the border is even in depth rather than noticeably shallow on the axial line. It differs from *C. reducta* n. sp. by its relatively long (sag.) frontal area and ornamentation of both fine granules and tubercules.

Occurrence.—Moderately rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3547–CO (6 cranidia), 3766–CO (4 cranidia), both from Nevada Test Site.

Caborcella reducta n. sp.

Plate 13, figures 7, 8

Description.—Cranidium subtrapezoidal in outline, moderately convex transversely, strongly convex longitudinally, gently rounded anteriorly; width between palpebral lobes greater than sagittal cranidial length. Glabella prominent, tapered forward, bluntly rounded anteriorly, well defined at sides by broad deep axial furrows; defined at front by abrupt change in slope of exoskeleton; reaches to poorly defined inner edge of border. Three pairs of glabellar furrows present, posterior pair deepest, forming distinct angle with axial furrow. Occipital furrow deep. Occipital ring simple. Axial node small. Frontal area short, subhorizontal, slightly concave, consists only of border in front of glabella. Border tapered laterally, inner margin defined only by change in slope of exoskeleton; sagittal length slightly less than one-third sagittal length of glabella exclusive of occipital ring. Fixed cheek broad, gently convex, horizontal; width of palpebral area slightly more than one-half basal glabellar width. Palpebral lobes small, well defined by palpebral furrow, connected to glabella by poorly defined narrow ocular ridge; exsagittal length slightly less than one-third sagittal glabellar length exclusive of occipital ring. Posterior limb broad; transverse length about equal to basal glabellar width.

Course of anterior section of facial suture nearly straight forward from palpebral lobe to anterior margin. Course of posterior section divergent, convex.

External surfaces of border, fixed cheeks—including palpebral lobes—convex parts of glabella, and posterior limb covered with closely spaced moderately coarse granules. Axial, glabellar, and occipital furrows lack ornamentation.

Discussion.—This species is related to and associated with *Caborcella pseudaulax* n. sp. It differs from that species by lacking even a narrow brim in front of the glabella, by having a shorter less concave frontal area, by having well-defined palpebral lobes set below the level of the cheek, and by having a coarse granular ornamentation without scattered tubercules.

Occurrence.—Rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3547–CO (3 cranidia), Nevada Test Site.

Genus CHANCIA Walcott

Chancia Walcott, 1924, p. 55; Walcott, 1925, p. 80; Shimer and Shrock, 1944, p. 609; Rasetti, 1951, p. 212; Howell, B. F., in Harrington, 1959, p. 238.

Type species.—*Chancia ebdome* Walcott, 1924, p. 55, pl. 10, fig. 4.

Discussion.—The characterization of this genus by Walcott (1925) gives the principal features of this generalized ptychopariid. The essential cranidial characters are a tapered well-defined poorly to moderately furrowed glabella, sagittally long frontal area with flat or slightly concave border, and transversely wide fixed cheeks and posterior limbs. The width of the fixed cheek, exclusive of the palpebral lobe, is greater than one-half the basal glabellar width; and the transverse width of the posterior limbs is greater than the basal glabellar width. The sagittal length of the frontal area is greater than one-half the glabellar length exclusive of the occipital ring.

Chancia? maladensis (Resser)

Plate 15, figure 4

Ehmaniella maladensis Resser, 1939b, p. 60, pl. 12, figs. 17–23.

Discussion.—Several cranidia associated with *Ogygopsis typicalis* (Resser) in the Belted Range, Nev., have all the distinctive characteristics of the species described by Resser in a similar association in southern Idaho. The extremely wide fixed cheeks and transversely long posterior limbs, together with small palpebral lobes and finely granular ornamentation (including scattered coarse granules), distinguish this species from all others in the Carrara Formation.

The assignment to *Ehmaniella* by Resser no longer seems appropriate for this species because typical *Ehmaniella* species lack the strikingly wide fixed cheeks and transversely long posterior limbs of the species discussed here. These features are more typical of *Chancia;* but the generic assignment is questioned because the type species, *C. ebdome* Walcott, has a concave cranidial border, whereas the border of *C.? maladensis* is distinctly convex. More information is needed about the whole trilobite before a confident generic assignment can be made.

Occurrence.—Moderately common, *Albertella* Zone, *Ogygopsis* Zonule. Nevada: 4436–CO (13 cranidia), 4437–CO (1 cranidium), 4438–CO (4 cranidia), all from Belted Range.

Chancia cf. C. venusta (Resser)

Plate 13, figures 11, 12

Kochina venusta Resser, 1939a, p. 53, pl. 6, figs. 9, 10.
Chancia venusta (Resser). Fritz, 1968, p. 230, pl. 40, figs. 31–34.

Discussion.—I agree with Fritz in that the cranidial characters of this species are entirely consistent with a placement in *Chancia*. The specimens from the Carrara Formation all have a finely granular external surface preserved and do not show the scattered coarse tubercules described for the types by Resser. They seem to have the same proportions for all parts. However, because of the differences in ornamentation, the specific identification is qualified. The Carrara forms differ from all other species of *Chancia,* except *C. venusta,* by having the border flat or slightly concave, downsloping, and slightly shorter sagittally than the slightly swollen brim. The border furrow is noticeably shallow on the axial line. The surface of the mold of the Carrara specimens is strongly pitted (pl. 13, fig. 11).

Occurrence.—Moderately common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3547–CO (>10 cranidia), Nevada Test Site.

Genus ELRATHINA Resser

Elrathina Resser, 1937a, p. 11; Deiss, 1939, p. 87; Rasetti, 1951, p. 221; Howell, B. F., in Harrington and others, 1959, p. 240.

Type species.—*Conocephalites cordillerae* Rominger, 1887, p. 17, pl. 1, fig. 7.

Discussion.—A reasonable diagnosis of this simple ptychopariid genus was given by Deiss (1939). Its most distinctive features are anteriorly convergent anterior sections to the facial sutures; a glabella that is strongly rounded at the front and has subparallel or only slightly convergent sides; small palpebral lobes situated slightly anterior to the glabellar midlength on gently convex, horizontal, or slightly downsloping fixed cheeks that are generally wider than half the basal glabellar width; free cheeks that lack significant development of genal spines; a thorax of 15–19 segments; and a simple nonspinose pygidium.

The species described here are associated with *Ogygopsis typicalis* (Resser) and other species typical of the *Albertella* Zone. This occurrence significantly extends the range of the genus backward in time and emphasizes the long-ranging character of many of the trilobites found in association with *Ogygopsis*. Elsewhere in North America, *Elrathina* is considered as a diagnostic element of the *Bathyuriscus-Elrathina* faunas.

Elrathina antiqua n. sp.

Plate 15, figures 1–3

Description.—Small, micropygous ptychopariid trilobites; length of largest observed specimen about 15 mm. Cranidium subtrapezoidal in outline, gently rounded anteriorly, gently to moderately convex transversely and longitudinally. Glabella prominent, well defined by moderately deep broad axial furrows and shallower preglabellar furrow; moderately to strongly convex transversely; very slightly tapered forward, strongly to bluntly rounded at front. Three pairs of glabellar furrows present, all shallow; posterior pair deepest. Occipital furrow moderately deep, straight; deepest distally. Occipital ring has prominent axial node situated at midlength. Frontal area short, subequally divided into gently convex border and brim by broad shallow nearly straight border furrow; sagittal length about 0.4 sagittal length of glabella exclusive of occipital ring. Fixed cheek gently to moderately convex, downsloping; transverse width about three-fourths basal glabellar width. Palpebral lobe small, defined only by change in slope of surface of cheek, situated slightly anterior to glabellar midlength; exsagittal length about 0.3 sagittal glabellar length exclusive of occipital ring. Posterior limb broad exsagittally; transverse length slightly greater than basal glabellar width. Posterior border furrow deep, straight.

Course of anterior section of facial suture slightly convergent forward from palpebral lobes; posterior section gently curved outward and posterolaterally behind palpebral lobes.

Free cheek flat, lacks clearly defined border; lateral margin gently curved; posterolateral corner angular, with small genal node. Width opposite eye about one-half length.

Thorax composed of 15–16 segments, each with broad deep straight pleural furrow extending nearly to short sharp tip; width of each pleural region slightly greater than width of axis.

Pygidium transverse elliptical in outline; sagittal length about 0.3 greatest width. Axis short, subparallel sided, poorly furrowed; pleural region smooth, convex, lacks furrows. Posterior margin smooth.

External surfaces of all parts smooth.

Discussion.—This is the oldest North American species assigned to *Elrathina*. It differs from others represented by complete specimens by having only 15 or 16 thoracic segments. It is most similar to *E. parallela* Rasetti from which it differs by having somewhat narrower fixed cheeks and transversely shorter posterior limbs.

Occurrence.—Common, *Albertella* Zone, *Ogygopsis* Zonule. Nevada: 4436–CO (3 cranidia); 4437–CO (20 cranidia, 5 partially articulated specimens, 2 free cheeks), 4438–CO (20 cranidia, 2 partially articulated specimens, 1 free cheek), all from Belted Range.

Genus EOPTYCHOPARIA Rasetti

Eoptychoparia Rasetti, 1955, p. 13; Rasetti, in Harrington and others, 1959, p. 236; Shaw, 1962, p. 339; Lazarenko, 1962, p. 64; Repina and others, 1964, p. 323.

Type species.—*Eoptychoparia normalis* Rasetti, 1955, p. 14, pl. 1, fig. 2; pl. 3, figs. 5–11.

Discussion.—Rasetti (1955) gave a good diagnosis of this generalized ptychopariid genus and a careful evaluation of its relationships to the similar genera *Antagmus, Onchocephalus,* and *Piazella*. Later, Shaw (1962) presented an elaborate classification of Early Cambrian simple ptychopariids, stressing the course of the anterior section of the facial sutures as a primary feature for discrimination of families. The resulting rearrangement of genera and species placed *Antagmus gigas,* which Rasetti considered typical of *Antagmus,* the nominal genus of the Antagmidae, in *Cyphambon,* a new subgenus of *Eoptychoparia,* in a new family Eoptychopariidae. Rasetti compared *A. gigas* to the type species of *Antagmus, A. typicalis* Resser, and had considered them possibly synonymous—hesitating to use *typicalis* primarily because of the poor preservation of the holotype. I have examined the holotype of *typicalis* and must concur with Rasetti regarding the close relationships of this specimen and *A. gigas*. The specimen does not have clearly convergent facial sutures, which Shaw cited as the characteristic discriminating the family Antagmidae from the family Eoptychopariidae, and separate family assignments for *A. typicalis* and *A. gigas* seem unrealistic. Therefore, the specimens here assigned to *Eoptychoparia* represent this taxon in the sense of Rasetti (1955). The subgenus *Cyphambon* is removed from *Eoptychoparia* and here is considered as a subjective synonym of *Antagmus*.

Eoptychoparia is perhaps the most central of the generalized Early and Middle Cambrian ptychopariids. The cranidium has a weakly furrowed anteriorly tapered and rounded glabella, an unmodified occipital ring with a median node, a subequally divided frontal area about one-third the sagittal length of the cranidium, a gently curved unmodified border furrow, subparallel or slightly divergent anterior facial sutures, subhorizontal gently convex fixed cheeks about one-half the width of the glabella, unmodified palpebral lobes about opposite the glabellar midlength and connected to it by low ocular ridges, and distally tapered posterior limbs with well-developed posterior border furrows. The free cheek has a broad-based flat pointed genal spine not deflected from the lateral margin of the cheek and about equal in length to the posterior section of the facial suture. The thorax consists of about 15 segments with broad shallow pleural furrows and short pleural tips. The pygidium is small, without any distinguishing characteristics.

Among similar genera, *Inglefieldia* and *Luxella* both have wider fixed cheeks and modified posterior limbs; those of *Inglefieldia* are slender, correlated with a longer palpebral lobe; those of *Luxella* have a short downturned distal part. *Piazella* has wider fixed cheeks than *Eoptychoparia,* and both it and *Antagmus* have a distinct median inbend to the anterior border furrow.

Although the species described here are assigned an earliest Middle Cambrian age, and are thus younger than any others previously included in the genus, no consistent criteria exist by which they can be differentiated from the Early Cambrian forms.

Eoptychoparia piochensis n. sp.

Plate 7, figures 1–5

Description.—Moderately small, micropygous ptychopariids, probably not exceeding 2 cm in length. Cranidium subtrapezoidal in outline; anterior margin gently curved; width between anterior sections of facial sutures slightly more than one-half width between tips of posterior limbs. Glabella low, well defined by shallow axial and preglabellar furrows, tapered forward, bluntly rounded anteriorly; sagittal length equal to or slightly less than basal glabellar width. Three or four pairs of moderately short glabellar furrows present; becoming deeper and more diagonally directed inward from axial furrows posteriorly. Occipital furrow nearly straight, shallowest on axial line. Occipital ring has prominent axial node at sagittal midlength. Frontal area gently downsloping, subequally divided into gently convex brim and border by shallow evenly curved border furrow. Fixed cheeks gently convex, horizontal or slightly upsloping; width of palpebral area between 0.4 and 0.6 basal glabellar width. Palpebral lobe short, arcuate, slightly upsloping from palpebral area, defined by shallow broad palpebral furrow; length 0.4 or less length of glabella exclusive of occipital ring. Posterior limb tapered distally to sharp point; transverse length about equal to basal glabellar width, distal part slightly longer than proximal part. Posterior border furrow straight, moderately deep.

Course of anterior section of facial suture nearly straight forward or slightly divergent anteriorly to border furrow, then curved gently inward across border. Course of posterior section of facial suture gently convex outward from palpebral lobe to posterior margin.

Free cheek has gently curved lateral margin continuous without deflection along side of flat sharp genal spine; length of spine about two-thirds length of posterior section of facial suture. Border defined by shallow continuous lateral and posterior border furrows; width about one-half that of ocular platform at anterior sutural margin. Border furrow not strongly curved at genal angle.

Thorax consists of about 15 segments, each with broad straight pleural furrow and short pointed pleural tip.

Pygidium small, individual segments not clearly discernable. Neither border nor border spines apparent.

External surface smooth or perhaps weakly granulated—no clear ornamentation apparent on specimens preserved in fine-grained shale.

Discussion.—This species is distinguished from others assigned to the genus by its more anteriorly tapered glabella, shallower border furrow, and lack of apparent ornamentation.

Occurrence.—Common, earliest Middle Cambrian. Nevada: 7231–CO (3 complete; 20 cranidia; 6 free cheeks), basal "C" Shale Member of Pioche Shale, Highland Range.

Genus KOCHASPIS Resser

Kochaspis Resser, 1935, p. 36; Rasetti, 1951, p. 225; Palmer, 1954, p. 79; Lochman, C., in Harrington and others, 1959, p. 250.
Paleocrepicephalus Kobayashi, 1935, p. 277.

Type species.—*Crepicephalus liliana* Walcott, 1886, p. 207, pl. 28, figs. 3, 3a, b.

Discussion.—The material from the Carrara Formation and Pioche Shale does not add significant new information to the generic diagnosis presented earlier (Palmer, 1954). The most distinctive part of this early Middle Cambrian ptychopariid genus is its pygidium, which bears a pair of posterior border spines. Cranidia of this genus are characterized by a broad-based anteriorly tapered glabella, bluntly rounded at its front and generally bearing three pairs of distinct glabellar furrows, by a well-developed brim and gently convex border, by generally well developed ocular ridges, by palpebral areas at least one-half the basal glabellar width and by granular ornamentation.

This is not an easy genus to identify in small collections because its pygidium can be confused with those of the corynexochid genera *Fieldaspis* and *Albertelloides.* Also, undescribed kochaspids with similar cranidia but nonspinose pygidia are present in collections from the Delamar Mountains in Nevada. Nevertheless, the combination of all parts characterizes a distinctive group of trilobites. The glabellar structure, which is shared, along with granular ornamentation, by *Eiffelaspis, Kochiellina, Schistometopus,* and the undescribed genus from the Delamar Mountains seems to be restricted to early Middle Cambrian North American trilobites; and even though generic identification of isolated cranidia may be in doubt, such specimens do have a stratigraphic utility for identifying beds of this age.

Kochaspis augusta (Walcott)

Plate 8, figures 15, 16

Crepicephalus augusta Walcott (Part), 1886, p. 208, pl. 28, fig. 2a; Walcott, 1891, p. 653, pl. 96, fig. 9a; Walcott, 1916a, p. 204, pl. 29, fig. 6b.
Kochaspis augusta Walcott. Resser, 1935, p. 37; Palmer, 1954, p. 80, pl. 17, fig. 6.

Discussion.—This species is characterized by short broad-based flat pygidial spines that have the posterior pygidial border strongly curved forward between them. Two pygidia from the Groom Range represent this species. The larger of the two specimens is indistinguishable from the holotype; the smaller specimen has one extra posterior pair of pleural furrows, which is attributed to probable variation of this feature with size.

A *Kochaspis* cranidium associated with the pygidia, and three free cheeks, may also represent this species. This cranidium (*Kochaspis*? sp. undet., pl. 8, fig. 11) has the glabellar structure, broad palpebral areas, gently convex border, and well-defined brim typical of *Kochaspis*, but it differs from *K. liliana*—represented in this collection by a pygidium—by having palpebral lobes only about one-fifth as long as the glabella instead of more than one-fourth the glabellar length. The associated free cheek (*Kochaspis*? sp. undet., pl. 8, fig. 11) has moderately deep and continuous lateral and posterior border furrows, a convex border about one-half the width of the ocular platform, and a slender genal spine about equal in length to the posterior section of the facial suture. Other occurrences of similar associations of *K. augusta* pygidia with cranidia and free cheeks of this type will be needed to establish the reliability of the parts as those of a single trilobite.

Occurrence.—Rare, "*Plagiura-Poliella*" Zone, Kochaspid Zonule. Nevada: 3691–CO (2 pygidia; ?1 cranidium; ?3 cheeks), Groom Range.

Kochaspis liliana? (Walcott)

Plate 8, figures 8, 12, 13

Crepicephalus liliana Walcott (part), 1886, p. 207, pl. 28, figs. 3, 3a; 1891, p. 653, pl. 96, figs. 7, 7a; 1916a, p. 209, pl. 29, figs. 5, 5a.

Kochaspis liliana (Walcott). Resser, 1935, p. 36; Palmer, 1954, p. 80, pl. 17, figs. 7, 8, 10, 11.

Discussion.—The pygidium of this species has slender subcylindrical pygidial spines directed slightly posterolaterally and two deep pleural furrows extending onto the base of each spine. The posterior border between the spines is more or less straight. These features easily distinguish it from *K. ceccina* (Walcott) which has four or five deep pleural furrows, and *K. augusta* (Walcott), discussed previously. Pygidia with the characteristics of *K. liliana* have been found in two collections and are associated with *Kochaspis* cranidia in one of them. However, the cranidia differ from the type cranidium of *K. liliana* by having a distinctly greater curvature to the plan view of the border furrow. With such an inadequate sample, the specific identification of the Carrara material must remain uncertain.

Pygidia assigned to *Kochaspis eiffelensis* by Rasetti (1951; 1957) have essentially the same structure as *K. liliana* but are significantly shorter. The cranidia that Rasetti tentatively associated with those pygidia, and which include the holotype, have long palpebral lobes situated opposite the posterior one-third of the glabella and differ in this respect from cranidia associated with *K. liliana.* If the associations are correct, and if the cranidial differences are of specific value, then the strong structural differences between pygidia of *K. augusta, K. ceccina,* and *K. liliana*/*K. eiffelensis* may represent generic differences. A thorough reevaluation of the systematics of species assigned to *Kochaspis* and related genera must await larger collections from the generally poorly fossiliferous early Middle Cambrian beds of the Cordilleran region.

Occurrence.—Rare, "*Plagiura-Poliella*" Zone, Kochaspid Zonule. Nevada: 3546–CO (2 pygidia, 1 cranidium), Jangle Ridge area, Nevada Test Site; 3691–CO (1 pygidium), Groom Range.

Genus KOCHIELLINA n. gen.

Type species.—*Kochiellina groomensis* n. sp.

Diagnosis.—Moderate-sized ptychopariid trilobites, length of largest individuals between 3 and 4 cm. Cranidium, excluding posterior limbs, subquadrate in outline. Glabella gently convex transversely and longitudinally, tapered forward, bluntly rounded anteriorly, well defined by deep axial and shallower preglabellar furrows. Three pairs of distinct glabellar furrows usually present. Occipital ring simple, well defined by occipital furrow that is deep at sides and shallow across axial region. Frontal area subequally divided into gently convex brim and flat or weakly concave border. Palpebral areas gently convex; width equal to or slightly greater than basal glabellar width. Palpebral lobes upsloping, well defined, connected to glabella by distinct narrow straight or slightly curved oblique ocular ridge, situated opposite middle third of glabella. Posterior limb moderately slender, about as long as basal glabellar width; posterior border furrow broad, deep. Anterior section of facial suture slightly convex outward, directed nearly straight forward from palpebral lobe to border furrow and then curved inward to intersect anterior margin near anterolateral cranidial corners. Posterior section of facial suture divergent, convex.

Free cheek has broad flat border, wider than ocular platform. Lateral margin evenly curved. Genal spine short, broad based, flat. Lateral and posterior border furrows continuous.

Pygidium semicircular in outline, gently convex transversely and longitudinally. Axis narrower than pleural regions, well defined, not reaching to posterior margin. Pleural regions have broad concave poorly defined border. Three or four narrow pleural furrows extend laterally onto but not across border. One or two shallow interpleural furrows may be present adjacent to second and third pleural furrows.

External surfaces of all parts granular.

Discussion.—This is one of several genera with a distinctive tapered and furrowed glabella, moderately wide palpebral areas, distinct ocular ridges, and well-developed brim and border that seem to be characteristic of lower Middle Cambrian beds in North America. Cranidia can be distinguished from *Kochaspis* primarily by having a flat or weakly concave border; the free cheek has a flat border and a broad-based short genal spine; and the pygidium lacks spines and has a broad concave border and several narrow shallow pleural furrows. *Kochiella* and *Eiffelaspis* both have considerably wider palpebral areas and consequently longer (tr.) posterior limbs.

In addition to the two species described below, *Onchocephalus maior* (Rasetti, 1951, p. 234, pl. 14, figs. 19–23), from the *Plagiura-Kochaspis* Zone of the southern Canadian Rockies seems to represent this genus. It is a much larger and more robust form than the typical Early Cambrian trilobites assigned to *Onchocephalus,* but confirmation of the generic change would have to come from finding the associated free cheeks and pygidia.

Kochiellina groomensis n. sp.

Plate 8, figures 3, 4, 7

Description.—Cranidium, excluding posterior limbs, subquadrate in outline, gently convex transversely and longitudinally; anterior margin gently rounded. Glabella low, broad, tapered forward, bluntly rounded anteriorly, well defined at sides by deep, straight, or slightly concave axial furrows; anterior end well defined by slightly shallower preglabellar furrow. Three pairs of distinct glabellar furrows; anterior pair weakest; posterior two pairs moderately deep, subparallel, directed obliquely inward and backward from axial furrows. Occipital furrow nearly straight, deepest distally. Occipital ring simple, with median node on axial line. Frontal area downsloping, divided into gently convex brim and flat or slightly concave border. Sagittal length of brim slightly more than two-thirds that of border. Fixed cheek gently convex, horizontal; width of palpebral area about one-half basal glabellar width. Palpebral lobe upsloping from surface of cheek, defined only by change in slope; located opposite middle third of glabella; exsagittal length about one-third sagittal glabellar length exclusive of occipital ring. Narrow ocular ridge connects palpebral lobe to anterior end of glabella along gentle curve. Posterior limb about equal in length to basal glabellar width; posterior border furrow deep, broad.

Course of anterior section of facial suture directed nearly straight forward in slightly convex outward curve between palpebral lobe and border furrow, then turned inward to intersect anterior margin near anterolateral cranidial corners. Posterior section directed strongly posterolaterally behind palpebral lobe; inner part forms gentle convex curve; course changes abruptly and is directed nearly straight backward between border furrow and posterior margin.

Free cheek gently convex; border broad, flat, slightly wider than ocular platform along anterior sutural margin; well defined by shallow narrow border furrow. Lateral and posterior border furrows meet at sharp curve at genal angle. Genal spine broad based, flat, sharply pointed; length about equal to length of posterior sutural margin.

Pygidium semicircular, posterior margin with slight median inbend; sagittal length slightly more than one-half greatest width. Axis narrow, obscurely furrowed; sagittal length about 0.6 sagittal length of pygidium; width slightly less than one-fourth greatest pygidial width. Pleural regions divided into gently convex pleural field and gently concave but not distinctly demarcated border. Three or four narrow pleural furrows continue onto inner part of border. Interpleural furrows are barely apparent adjacent to second and third pleural furrows on downsloping distal part of pleural field.

External surfaces of all parts covered with closely spaced fine granules. In addition, the cranidium has widely scattered coarse granules.

Discussion.—This species differs from *K. janglensis* n. sp. by having a longer brim and lacking a distinct low swelling on the posterior axial part of the border on the cranidium and by having a semicircular rather than subquadrate pygidium with one more clearly defined segment.

The association of the pygidium and the cheek with the cranidium seems reasonably reliable. The pygidia and cranidia occur in about equal abundance in the type collection and seem to represent the only large ptychopariid in the sample aside from *Kochaspis.* The presence of granular ornamentation on all parts supports the association. The lack of scattered large granules on the free cheek makes its assignment to *K. groomensis* less certain, but its ornamentation is the same as that of the pygidium. The association of similar, but specifically distinct, cranidia and pygidia in another sample further strengthens the probability that they are parts of the same trilobite.

Occurrence.—Moderately common, "*Plagiura-Poliella*" Zone, Kochaspid Zonule. Nevada: 3691–CO (8 cranidia; 1 cheek, 7 pygidia), Groom Range.

Kochiellina janglensis n. sp.

Plate 8, figures 20, 24

Description.—Cranidia are essentially like those of *K. groomensis,* differing only in features of the frontal area, width of the palpebral area, and length of the palpebral lobe. The sagittal length of the brim is about one-half that of the border, and the border has a broad low median swelling on its posterior part that noticeably reduces the depth of the border furrow on the axial line. The palpebral areas are slightly greater than one-half the basal glabellar width, and the exsagittal length of the palpebral lobe is about one-half the sagittal glabellar length exclusive of the occipital ring.

Free cheek not known.

Pygidium subquadrate in outline, gently convex transversely and longitudinally; sagittal length slightly more than one-half greatest width; posterior margin with slight median inbend. Axis obscurely furrowed, moderately broad, short; width slightly less than one-third greatest pygidial width; sagittal length about 0.6 length of pygidium. Pleural regions have gently convex pleural field, and concave border not clearly demarcated. Three or four narrow pleural furrows continue across pleural field onto inner part of border. Shallow interpleural furrows apparent adjacent to second and third pleural furrows.

External surfaces of all parts covered with closely spaced granules. Cranidium has scattered coarse granules in addition.

Discussion—.The differences between this species and *K. groomensis* n. sp. are discussed in the preceding species description. The slight median swelling on the inner part of the cranidial border and the subquadrate nonspinose pygidium distinguish this species from other trilobites with *Kochaspis*-like cranidia.

Occurrence.—Moderately rare, "*Plagiura-Poliella*" Zone, Kochaspid Zonule. Nevada:3546–CO (4 cranidia, 3 pygidia), Jangle Ridge area, Nevada Test Site.

Kochaspid, sp. undet. 1

Plate 8, figures 9, 14, 17, 18

Description.—Cranidium has well-defined anteriorly tapered glabella bearing three pairs of shallow glabellar furrows. Occipital ring well defined by straight occipital furrow and has prominent axial node adjacent to posterior margin. Frontal area gently downsloping, nearly flat, and lacks noticeable anterior arch. Narrow, shallow, straight, or slightly curved border furrow parallels anterior margin. Sagittal length of nearly flat border equal to or slightly greater than that of brim. Fixed cheeks strongly upsloping to prominent arcuate palpebral lobes, and crossed by a well-defined strongly oblique ocular ridge. Palpebral lobes situated posterior to glabellar midlength. Width of palpebral area about two-thirds basal glabellar width. Length of palpebral lobe about two-thirds sagittal glabellar length exclusive of occipital ring. Posterior limb slender; length slightly greater than basal glabellar width. Posterior border furrow broad, shallow.

Course of anterior section of facial suture nearly straight forward from palpebral lobe to border furrow, then curved broadly inward across border. Course of posterior section strongly divergent behind palpebral lobe and evenly curved nearly to posterior margin; just before margin, course is deflected slightly outward.

Surfaces of all parts covered with closely spaced fine granules and interspersed coarse granules.

Associated free cheek has a broad flat genal spine with length at least twice length of posterior section of facial suture and a few scattered coarse granules on border. Lateral border furrow defines nearly flat border and dies out posteriorly. Width of border about half length of anterior section of facial suture.

Discussion.—This distinctive kochaspid cannot be assigned with confidence to any kochaspid genus because of lack of knowledge of the associated pygidium. It is most similar to *Kochina macrops* (Rasetti, 1951, pl. 19, figs. 17–19), but it differs in having a nearly flat frontal area and a border that does not taper noticeably laterally. The position and size of the palpebral lobes of the Carrara species do not conform at all to the characterization of *Kochina* given by Resser (1935, p. 39), which cites anteriorly placed palpebral lobes and anteriorly convergent facial sutures as generic features. Rasetti did not explain why he included *K. macrops* in the genus. Neither species seems capable of generic assignment with present knowledge.

Occurrence.—Moderately common, "*Plagiura-Poliella*" Zone, *P. lomataspis* Zonule. Nevada: 4434–CO (7 cranidia, 2 free cheeks), Belted Range.

Kochaspid, sp. undet. 2

Plate 8, figures 21, 22

Discussion.—A small sample of silicified trilobites includes a few tiny cranidia and a pygidium of a kochaspid trilobite lacking pygidial spines. The cranidia have a strongly developed granular ornamentation, a well-defined poorly furrowed glabella, a narrow brim and convex border, and fixed cheeks wider than half of the basal glabellar width. The associated coarsely granular pygidium has a transversely subovate shape, poorly defined axis about one third of the pygidial width, and a narrow poorly defined border. The posterior margin is unevenly curved, and spines are absent.

No described kochaspid has these characteristics, but the specimens are too small and fragmentary to use for formal taxonomic designation. They are associated with equally small specimens of a species of *Poliella.*

Occurrence.—Moderately common, "*Plagiura-Poliella*" Zone, *P. lomataspis* Zonule. Nevada: 3790–CO (8 cranidia, 1 pygidium), Nevada Test Site.

Genus MEXICELLA Lochman

Mexicella Lochman, 1948, p. 456; Howell, B. F., in Harrington and others, 1959, p. 240.

Type species.—*Mexicella mexicana* Lochman, 1948, p. 457, pl. 69, figs. 12–22.

Discussion.—Lochman (1948) has given a thorough analysis of the characteristics of this genus. Slight modification of the generic diagnosis is required to include a new species *M. grandoculus,* with palpebral lobes whose exsagittal length is nearly equal to half of the sagittal glabellar length exclusive of the occipital ring. All species of *Mexicella* are characterized by a sagittally long swollen frontal area with a poorly defined border that is narrower than the brim and by wide gently convex slightly downsloping fixed cheeks. No other genus in the *Albertella* faunas of the Cordilleran region closely resembles *Mexicella.*

Mexicella mexicana Lochman

Plate 13, figures 13–21

Mexicella mexicana Lochman, 1948, p. 457, pl. 69, figs. 12–22; Lochman, C., in Cooper and others, 1952, p. 150, pl. 24, figs. 1–25.

Discussion.—This species has been well described and illustrated from the *Albertella* fauna of northern Mexico by Lochman. A distinctive feature not noted by Lochman but present on some specimens from both Mexico and the Carrara Formation is the presence of low scattered coarse granules on the border of the cranidium and free cheek (pl. 13, figs. 17, 19; also Cooper and others, 1952, pl. 24, fig. 24). This ornamentation has not been observed on either very small specimens or any of the larger specimens that may represent this species. Large cranidia, comparable in size to those of *Mexicella stator* (Walcott), are rare associates of the abundant smaller cranidia of this species. They are variably effaced (pl. 13, figs. 16, 18) and may have a distinct pitted ornamentation. An associated larger free cheek is slightly wider than the cheek associated with the small cranidia, but it has the characteristic presence of only a slight node for the genal spine. It has the same pitted ornamentation as the cranidium and has a very poorly defined border. This is quite unlike the large cheek assigned to the species by Lochman (1948, pl. 69, fig. 18; in Cooper and others, 1952, pl. 24, fig. 22) and casts some doubt on the correctness of the assignment to this species of the large cheek from Mexico.

Occurrence.—Common, *Albertella* Zone, *Albertella-Mexicella* Zonule (>20 cranidia and free cheeks, ?1 pygidium, including some silicified). Nevada: 1616–CO, Spring Mountains; 3543–CO, ?7195–CO, 7196–CO, Desert Range. California: 4165–CO, 7197–CO, Eagle Mountain; 4159–CO, Pyramid Peak section, Funeral Mountains; 4166–CO, Resting Springs Range.

Mexicella grandoculus n. sp.

Plate 13, figures 5, 9, 10

Description.—Small ptychopariid trilobites, sagittal length of largest observed cranidium 8 mm. Cranidium subquadrate in outline, gently to moderately curved anteriorly, gently to moderately convex transversely and longitudinally. Glabella prominent, sides slightly convex and convergent forward, anterior end bluntly rounded, defined at sides by moderately abrupt change in slope of exoskeleton, anterior end well defined by shallow preglabellar furrow; sagittal length, exclusive of occipital ring, slightly less than basal glabellar width. Three pairs of shallow short glabellar furrows apparent. Occipital furrow deepest distally. Occipital ring has well-developed axial node. Frontal area moderately convex in sagittal profile, slightly upsloping from front of glabella; sagittal length about three-fourths sagittal length of glabella exclusive of occipital ring. Border narrow, continuing outer downsloping surface of frontal area, very poorly differentiated from brim; sagittal length between one-third and one-half that of frontal area. Fixed cheek wide, flat, nearly horizontal, with moderately long, undifferentiated palpebral lobe; width, including palpebral lobe, between two-thirds and three-fourths basal glabellar width. Ocular ridge poorly defined, directed slightly posterolaterally from anterior end of glabella. Palpebral lobe situated about opposite glabellar midlength; exsagittal length between 0.4 and 0.5 sagittal glabellar length exclusive of occipital ring. Posterior limbs depressed distal to palpebral lobes; transverse length about equal to basal glabellar width. Posterior border furrow well defined, straight. Course of anterior section of facial suture very slightly divergent forward, strongly curved at anterolateral cranidial corners. Course of posterior section of facial suture convex.

External surface without obvious ornamentation.

Other parts not known.

Discussion.—This species is comparable in size to *M. mexicana* and can be distinguished by its larger palpebral lobes and slightly sunken anterior end of the glabella. The anterior sections of the facial sutures are also slightly divergent rather than slightly convergent forward. The species is included in *Mexicella* because of its large gently convex poorly differentiated frontal area.

Occurrence.—Moderately common, *Albertella* Zone, *Albertella-Mexicella* Zonule(?). California: 4141–CO (>10 cranidia), Titanothere Canyon section, Grapevine Mountains. Moderately common, *Albertella-Mexicella* Zonule. California: 4149–CO (4 cranidia), Echo Canyon section, Funeral Mountains; 4158–CO (7 cranidia), Pyramid Peak section, Funeral Mountains. Nevada: ?4169–CO (>10 cranidia), Spectre Range.

cf. Mexicella? stator (Walcott)

Plate 8, figure 23

Agraulos stator Walcott, 1916a, p. 173, pl. 36, fig. 6; Walcott, 1917, p. 28, pl. 6, fig. 6.

Mexicella stator (Walcott). Rasetti, 1951, p. 231, pl. 20, fig. 14–19.

Discussion.—A single cranidium, preserved in siltstone and somewhat compressed from front to back by compaction, has the extremely poorly defined narrow border, sagittally long frontal area, broad fixed cheeks, small palpebral lobes, broad posterior limbs, and low poorly defined anteriorly tapered and truncate glabella characteristic of *Mexicella*? *stator* (Walcott). The lack of other less compressed specimens for comparison, a straight rather than sinuous proximal part to the posterior section of the facial suture, and a position in slightly older beds than the types are the reasons for uncertainty of the specific identification.

Occurrence.—Rare, "*Plagiura-Poliella*" Zone. California: 7234–CO (1 cranidium), Titanothere Canyon section, Grapevine Mountains.

Genus NYELLA n. gen.

Type species.—*Poulsenia granosa* Resser, 1939b, p. 59, pl.13, figs. 19, 22–30.

Description.—Moderately small kochaspid trilobites, sagittal length of largest known cranidium about 10 mm. Cranidium subquadrate in outline, gently to moderately convex transversely and longitudinally, gently to moderately rounded at front; width between palpebral lobes slightly greater than sagittal length. Glabella prominent, tapered forward, strongly to bluntly rounded at front; sides straight or slightly concave, well defined by deep axial furrows; front defined by shallow preglabellar furrow or abrupt change in slope. Three or four pairs of moderately deep glabellar furrows usually present. Occipital furrow deep, shallowest and curved slightly forward across axis. Frontal area clearly divided by well-defined border furrow into flat brim and convex border. Fixed cheeks flat or gently convex, horizontal; width of palpebral area between 0.4 and 0.5 basal glabellar width. Ocular ridges moderately developed. Palpebral lobe well defined, situated about opposite glabellar midlength; exsagittal length varies from about one-third to about one-half sagittal glabellar length exclusive of occipital ring. Posterior limbs about equal in transverse length to basal glabellar width. Posterior border furrow broad, deep. Course of anterior section of facial suture straight forward from palpebral lobe. Course of posterior section divergent-sinuous.

Free cheek has broadly rounded lateral margin forming continuous curve with genal spine. Border convex, well defined anteriorly by border furrow that fades towards base of genal spine. Genal spine convex in cross section, sharply pointed, about as long as posterior section of facial suture.

Hypostome and thoracic segments not known.

Pygidium transversely subovate in outline with broad poorly defined slightly tapered axis. Axial furrows obscure. Only first pleural furrow distinct. Border not separately defined.

External surfaces of all parts covered with one or two sizes of granules.

Discussion.—This genus is proposed for species formerly included in *Caborcella* by Rasetti (1951) and Fritz (1968) and an additional species from the Carrara Formation, all of which differ from *Caborcella* as redefined previously (p. 701), by having a narrow well-defined border furrow separating a convex border from a generally narrow flat slightly downsloping brim. The species differ among themselves in proportions of the brim, border, and frontal area, and in ornamentation.

As constituted here, *Nyella* is found in both the *Plagiura-Kochaspis* Zone and the *Albertella* Zone and contains the following species: *Poulsenia granosa* Resser (syn. *P. bearensis* Resser), *Ptychoparia skapta* Walcott, *Caborcella rara* Rasetti, *Caborcella clinolimbata* Fritz, *Poulsenia columbiana* Rasetti, and *Nyella immoderata* n. sp. Rasetti (1957) changed the assignment of *P. skapta* from *Caborcella* to *Onchocephalus*, but this seems to require too broad a characterization for *Onchocephalus*. The grouping of the coarsely granular early Middle Cambrian ptychopariids with a well-defined convex border into a separate genus as proposed here seems to reflect more reasonable morphologic relationships. Fritz (1968, p. 233) implied that *Poulsenia columbiana* (Rasetti, 1957) belonged to *Caborcella*. In accord with the reorganization of these simple ptychopariids proposed here, this species would also belong to *Nyella*.

The most similar genus to *Nyella* is *Parapoulsenia* (Rasetti, 1957), which differs principally by having much broader fixed cheeks, a less anteriorly tapered glabella, generally smaller palpebral lobes, and shorter (tr.) and broader (sag.) distal parts to the posterior limbs.

Nyella clinolimbata (Fritz)

Plate 14, figures 1–4

Caborcella clinolimbata Fritz, 1968, p. 221, pl. 41, figs. 33–35.

Discussion.—This species has been adequately described and figured by Fritz although his statement that the preglabellar field is absent medially is not exactly correct. A distinct flattened or depressed brim (or preglabellar area) lies between the glabella and the border. The border is the most distinctive feature of this species. In longitudinal profile, it rises up from the border furrow and then turns downward to have a flattened or slightly concave downsloping marginal area. In anterior view, the anterior cranidial margin is nearly straight, but the border furrow rises to a high point on the axial line. In addition to the structure of the border, the palpebral lobes are larger and more medially located than those of

N. granosa, which is the other moderately common species of this genus in the Carrara Formation, and the ornamentation is more uniformly granular. The depth of the glabellar furrows is somewhat variable in the Carrara sample of this species.

A single free cheek may also belong to this species. It has a gently convex border separated from a slightly wider ocular platform by a shallow border furrow that disappears towards the genal angle. The genal spine is slender, oval in cross section, and slightly longer than the posterior section of the facial suture. The surface is covered with low obscure granules of uniform size.

A single small cranidium from the Funeral Mountains may also represent this species. It has the typical development of the border and the same cranidial dimensions and ornamentation as the cranidia from the Nevada Test Site, but the fixed cheeks are distinctly less convex transversely.

Occurrence.—Moderately rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (4 cranidia?, 1 free cheek, ?1 pygidium), Nevada Test Site. California: ?4141–CO (1 cranidium), Echo Canyon section, Funeral Mountains.

Nyella granosa (Resser)

Plate 14, figures 5–10

Poulsenia granosa Resser, 1939b, p. 59, pl. 13, figs. 19, 22–30 [not figs. 20, 21, assigned to *Amecephalus laticaudatum* (Resser) by Fritz (1968)]; Shimer and Shrock, 1944, pl. 259, figs. 6, 7.

Caborcella granosa (Resser). Fritz, 1968, p. 221, pl. 39, figs. 9–15.

Poulsenia bearensis Resser, 1939b, p. 60, pl. 13, figs. 5–8.

Description.—Cranidium gently to moderately convex transversely and longitudinally, moderately rounded anteriorly, width between palpebral lobes distinctly greater than sagittal length. Glabella well defined, tapered forward, strongly to bluntly rounded anteriorly, well defined by axial and preglabellar furrows; sides very slightly concave. Three or four pairs of moderately to strongly developed glabellar furrows present; posterior pair curved slightly backward. Occipital furrow deep distally, shallower across axial line. Occipital ring simple, with poorly defined axial node. Frontal area has deep gently curved border furrow separating convex border from nearly flat slightly downsloping brim; sagittal length of border slightly greater than that of brim. Sagittal length of frontal area about one-half sagittal length of glabella exclusive of occipital ring. Border on some specimens has slight median inbend. Brim varies in sagittal length and ornamentation from relatively short and nearly smooth, to nearly as long as sagittal length of border and bearing scattered tubercules. Fixed cheeks gently convex, horizontal; width of palpebral area variable between 0.4 and 0.5 basal glabellar width. Palpebral lobes upsloping, defined by abrupt change in slope of exoskeleton, connected to glabella by distinct narrow backswept ocular ridges; exsagittal length slightly more than one-third sagittal glabellar length exclusive of occipital ring. Posterior limbs have deep broad border furrow; transverse length about equal to basal glabellar width. Course of anterior section of facial suture slightly bowed outward, but directed nearly straight forward from palpebral lobe. Course of posterior section divergent-sinuous, outlining broad rounded tip of posterior limb.

Free cheek triangular in outline exclusive of genal spine. Lateral margin moderately and evenly curved. Border convex, defined anteriorly by deep border furrow that nearly fades out towards genal angle before intersecting posterior section of facial suture; slightly narrower than ocular platform at anterior section of facial suture. Genal spine convex, sharply pointed; length about equal to length of posterior section of facial suture.

Pygidium transversely subelliptical in outline; sagittal length about one-half width, greatest width about opposite midlength. Axis low, broad, poorly defined by changes in slope of exoskeleton. Two or three poorly defined ring furrows present. Pleural regions undifferentiated, gently convex, strongly downsloping posterolaterally. Anterior pleural furrow deep, extended nearly to margin. Shallower first interpleural furrow and second pleural furrow apparent on some specimens.

All parts of exoskeleton covered by fine closely spaced granular ornamentation. Cranidium and free cheek also thickly covered with scattered tubercules. Pygidium has tubercular ornamentation less well developed.

Discussion.—Specimens assigned to this species have now been described from southeastern Idaho and east-central and southern Nevada. The Carrara sample provides the first information about the free cheek and also shows the range of variability in the structure of the frontal area that was suspected by Fritz (1968) when he tentatively and correctly synonymized *Poulsenia bearensis* Resser with *N. granosa.* This species differs from *N. clinolimbata* Fritz by having the cranidial border evenly convex in lateral profile rather than slightly recurved and downsloping; and by having a much stronger tubercular ornamentation. The broad border furrow and consequently narrower border distinguish *N. rara* (Rasetti) from *N. granosa. N. skapta* (Walcott) is distinguished from *N. granosa* by having a uniform granular ornamentation, more convex and slightly downsloping fixed cheeks, a more prominent medially thickened anterior cranidial border, and shorter palpebral lobes. *N. columbiana* (Rasetti) has a more convex cranidium with a more anterolaterally depressed frontal area, less well developed glabellar furrows, and a coarser granular ornamentation with fewer scattered tubercules than *N. granosa.*

Occurrence.—Moderately common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3695–CO (>10 cranidia, 2 free cheeks, 1 pygidium), Nevada Test Site; 4440–CO (16 cranidia), Groom Range. Rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (1 cranidium), Nevada Test Site; 7195–CO (1 cranidium), Desert Range.

Nyella immoderata n. sp.

Plate 14, figures 11, 12

Diagnosis.—Small members of *Nyella* (largest known cranidium about 4 mm long) with three pairs of deeply incised glabellar furrows and with border furrow and furrows outlining the glabella also deep. Anterior border has distinct median inbend. Exsagittal length of palpebral lobes about one-half sagittal glabellar length exclusive of occipital ring. External surface covered with closely spaced moderately coarse granules that often grow together, producing a roughened appearance.

Discussion.—This distinctive species conforms in all respects to the description of the genus, and the diagnostic features cited above serve to distinguish it from other species in the genus. No other species so far described from the *Albertella* faunas of western North America has distinctive slotlike glabellar furrows comparable to those of *N. immoderata.*

Occurrence.—Moderately common, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (>15 cranidia), Nevada Test Site.

Genus PACHYASPIS Resser

Pachyaspis Resser, 1939b, p. 60; Shimer and Shrock, 1944, p. 615; Howell, B. F., in Harrington and others, 1959, p. 241; Balashova, E. A., in Chernysheva, 1960, p. 106; Yegorova, L. I., and others, in Khalfin, 1960, p. 223.

Type species.—Pachyaspis typicalis Resser, 1939b, p. 61, pl. 11, figs. 15–20; pl. 12, figs. 1–3.

Discussion.—Resser (1939b) gave a reasonably good diagnosis of the characteristics of this genus based only on its type species. The addition of several species from the *Albertella* and *Glossopleura* Zones by Resser (in McKee and Resser, 1945), Lochman (in Cooper and others, 1952), Rasetti (1951), and Fritz (1968) required very little modification of that original diagnosis. The species differ in subtleties of glabellar shape and development of glabellar furrows, in the structure and proportions of the frontal area on the cranidium, and in ornamentation. One of the more characteristic features of most species seems to be a well-defined narrow furrow continuously outlining the glabella.

Complete specimens of *P. gallagari* Fritz from the Groom Range show a trilobite with 16 thoracic segments and a small poorly furrowed pygidium, demonstrating that at least one species of *Pachyaspis* is a micropygous form with a moderate number of thoracic segments.

Pachyaspis gallagari Fritz

Plate 15, figure 8

Pachyaspis gallagari Fritz, 1968, p. 231, pl. 40, figs. 11–13.

Discussion.—Specimens from two collections in the Carrara Formation seem to conform to the characteristics of this species well described by Fritz. The slight differences in glabellar shape between specimens from the two collections are not considered to be sufficient justification for specific separation. The species is characterized by having a well-defined border only slightly narrower than the brim, moderately developed glabellar furrows, a slight axial shallowing of the anterior border furrow, and a variable, but generally finely granular ornamentation. The complete specimens from the Groom Range have 16 thoracic segments with short pleural spines and a deep narrow subcentrally located pleural furrow. The pygidium is small and transversely subovate, and seemingly lacks either axial or pleural furrows, although the axis is moderately prominent.

Occurrence.—Common, *Albertella* Zone, Zacanthoidid Zonule(?). Nevada: 3692–CO (>10 cranidia, 7 partially or completely articulated individuals), Groom Range. Rare and questionably identified, *Albertella* Zone, Zacanthoidid Zonule(?). Nevada: 3547–CO (3 cranidia), Nevada Test Site.

Genus PLAGIURA Resser

Plagiura Resser, 1935, p. 42; Lochman, 1947, p. 66; Rasetti, F., in Harrington and others, 1959, p. 516.

Plagiurella Resser, 1937a, p. 22.

Type species.—Ptychoparia? cercops Walcott, 1917, p. 81, pl. 12, figs. 1, 1a–d.

Diagnosis.—Cranidium subtrapezoidal, glabella subtriangular, weakly furrowed. Frontal area divided into brim and border; sagittal length less than half that of glabella. Fixed cheeks narrow. Palpebral lobes small, located opposite anterior end of glabella. Posterior limbs broad, with convex sutural margins.

Free cheek with curved lateral margin subparallel to posterior section of facial suture. Genal spine present or absent.

Discussion.—Lochman (1947) and Rasetti (in Harrington and others, 1959) presented diagnoses of this genus based on analysis of the type species, which was the only one known at that time. Both have pointed out that *Plagiurella* is based on small holaspids of *Plagiura.* The two species described here provide a better basis for evaluating generic characteristics and have led to the revised diagnosis of the cephalic features given. There is no other early Middle Cambrian trilobite with anteriorly located palpebral lobes and large posterior limbs with which this can be confused.

The cranidia of *P. extensa* n. sp., *P. retracta* n. sp., and small holaspid cranidia of *P. cercops*, out of context, could easily be associated with the Late Cambrian genus *Aphelotoxon* (Palmer, 1965); and perhaps a suprageneric relationship between *Plagiura* and *Aphelotoxon* should be considered. However, the pygidium of *P. cercops* is gently convex transversely, wide and short, with an axis narrower than the pleural fields, which contrasts with the strongly convex pygidium of *Aphelotoxon*, which is nearly as long as it is wide and which has an axis wider than the pleural fields. The contrasting pygidial structure suggests a contrasting thoracic structure, and the complete trilobites were probably not as similar as their cranidia suggest.

Although the large specimens of *P. cercops* and the small species described below seem too dissimilar to be congeneric, the small specimens of *P. cercops* are sufficiently similar to the new species in all cephalic features so that a consistent discrimination at the generic level cannot be satisfactorily made. The fact that all the species occur in the same approximate stratigraphic interval further supports a close relationship.

Plagiura extensa n. sp.

Plate 6, figures 17–20, 23

Description.—Small ptychopariid trilobites, cranidial length generally less than 5 mm. Cranidium subtrapezoidal in outline, moderately convex transversely and longitudinally, anterior margin slightly curved, width between anterior sections of facial sutures about one-third of width between tips of posterior limbs. Glabella subtriangular in outline, well defined by shallow axial and preglabellar furrows, strongly rounded anteriorly; sagittal length, exclusive of occipital ring, slightly less than basal glabellar width; three pairs of short evenly spaced moderately deep and broad glabellar furrows apparent near axial furrows. Occipital furrow deep, nearly straight. Occipital ring has short axial spine on posterior margin, continuous with upward slope of surface of ring. Frontal area broad, concave; sagittal length slightly greater than one-half sagittal glabellar length exclusive of occipital ring. Border upturned, strongly convex, not clearly separated from flat or slightly convex brim; sagittal length slightly less than that of brim. Fixed cheeks narrow, slightly upsloping; width between axial furrow and facial suture at palpebral lobe slightly less than one-half basal glabellar width. Palpebral lobe small, slightly upsloping, differentiated from surface of fixed cheek by change in slope, situated opposite anterior end of glabella; length slightly less than one-third sagittal glabellar length exclusive of occipital ring. Short ocular ridges barely apparent. Posterior limbs broad, moderately convex, downsloping; exsagittal and transverse dimensions nearly equal; transverse length slightly less than basal glabellar width. Posterior border furrow broad, deep, expanded slightly distally.

Course of anterior section of facial suture moderately convex anterolaterally in a more or less even curve from anterior end of palpebral lobe to anterior margin. Rostral suture nearly as long transversely as anterior cranidial width. Course of posterior section of facial suture strongly convex, directed posterolaterally behind palpebral lobe and curving uniformly backward to intersect posterior margin nearly at right angles; curvature reverses slightly after crossing posterior border furrow.

Free cheek moderately narrow, gently convex, has strongly curved lateral margin that is nearly parallel to posterior section of facial suture and continues without deflection along outer edge of genal spine. Border narrow, gently convex, poorly defined by shallow continuous lateral and posterior border furrows; width about one-third of distance between lateral and posterior sutural margins. Genal spine slender, shorter than posterior section of facial suture.

External surfaces of all parts covered by very fine closely spaced granules apparent only after lightly whitening best preserved specimens. Surface of mold has scattered fine pits.

Discussion.—This species differs from *P. cercops* (Walcott) by having a strongly upturned cranidial border, an occipital spine, and granular ornamentation. *P. cercops* also reaches significantly greater size, but the comparisons here are with comparable-sized specimens of *P. cercops*. Free cheeks for small specimens of *P. cercops* have short laterally directed genal spines, which also serve to distinguish these species.

P. extensa differs from *P. retracta* n. sp. by having a longer brim, shallower border furrow, slightly larger palpebral lobes, more convex posterior course to the facial suture, a genal spine whose lateral margin continues the curvature of the border of the free cheek, and a narrower free cheek border. Two small cranidia assignable to *P. extensa* are associated with *P. retracta* in USGS collection 3546–CO (pl. 6, figs. 19, 20). Although these were first thought to indicate that the differences between the species were only well developed in larger cranidia, the discovery of still smaller cranidia in the same sample with the typical characters of *P. retracta* (pl. 6, fig. 21) indicates that the characters hold true throughout the observed size range and that both species are present.

Occurrence.—Moderately common, "*Plagiura-Poliella*" Zone, Kochaspid Zonule. Nevada: 3691–CO (>10 cranidia, 6 free cheeks), Groom Range. Rare, "*Plagiura-Poliella*" Zone, Kochaspid Zonule. Nevada: 3546–CO (2 cranidia), Nevada Test Site.

Plagiura minor n. sp.

Plate 13, figures 22–25

Description.—Small ptychopariid trilobites, cranidial length generally less than 3 mm. Cranidium subtrapezoidal in outline, gently convex longitudinally, moderately convex transversely. Anterior margin nearly straight, width between anterior sections of facial sutures about one-half width between tips of posterior limbs. Glabella subtriangular in outline, defined all around by change in slope of exoskeleton; sagittal length, exclusive of occipital ring, about equal to basal glabellar width. Glabellar furrows not apparent. Occipital furrow deepest distally, shallow or absent across axial line. No occipital node or spine. Frontal area very short, subequally divided into concave brim and moderately convex border; sagittal length varies from one-fourth to slightly more than one-third sagittal length of glabella exclusive of occipital ring—shortest on smaller individuals. Fixed cheeks downsloping, narrow; width, including small poorly defined palpebral lobe, one-half or slightly less than one-half basal glabellar width. Palpebral lobe situated opposite anterior end of glabella; exsagittal length about one-fourth sagittal glabellar length exclusive of occipital ring. Posterior limb broad, downsloping; transverse width about equal to basal glabellar length.

Course of anterior section of facial suture directed nearly straight forward or convergent from palpebral lobe to anterolateral cranidial corners and then turned more sharply inward before intersecting border. Course of posterior section convex outward behind palpebral lobe and curved inward before reaching posterior margin.

Free cheek subtriangular in outline, gently convex, with moderately curved lateral and posterior margins. No genal spine.

Discussion.—This species is easily distinguished from *P. extensa* n. sp. and *P. retracta* n. sp. by its subdued cranidial relief, downsloping fixed cheeks, and absence of glabellar furrows. The short frontal area with a moderately convex border and a straight anterior margin that is bowed upward in anterior view distinguishes this species from comparably sized specimens of *P. cercops* (Walcott).

Occurrence.—Moderately rare, *Albertella* Zone, *Albertella-Mexicella* Zonule. California: 4154–CO (7 silicified cranidia), Echo Canyon section, Funeral Mountains; 4165–CO (10 silicified cranidia, 2 free cheeks), Eagle Mountain. Nevada: 7196–CO (>10 cranidia, 1 free cheek), Desert Range.

Plagiura retracta n. sp.

Plate 6, figures 21, 24–27

Description.—Small ptychopariid trilobites, cranidial length generally less than 5 mm. Cranidium subtrapezoidal in outline, moderately to strongly convex transversely and longitudinally. Anterior margin nearly straight; width between anterior sections of facial sutures slightly more than one-third width between tips of posterior limbs. Glabella subtriangular in outline, well defined at sides by shallow axial furrows, poorly defined at strongly rounded front; sagittal length, exclusive of occipital ring, about equal to basal glabellar width, three pairs of short, evenly spaced, moderately deep glabellar furrows present adjacent to axial furrows. Occipital furrow deepest distally, shallow and slightly curved forward across axial line, posterior margin not known; internal molds suggest presence of either node or short spine. Frontal area short, strongly concave; sagittal length slightly less than one-half sagittal glabellar length exclusive of occipital ring. Border upturned, strongly convex, outer margin nearly vertical, separated from very short brim by broad deep nearly straight border furrow; sagittal length to middle of border furrow nearly twice sagittal length of brim. Fixed cheeks narrow, slightly upsloping; width between axial furrow and facial suture at palpebral lobe one-half or slightly less than one-half basal glabellar width. Palpebral lobe small, poorly defined, located opposite anterior end of glabella; exsagittal length about one-fifth sagittal length of glabella exclusive of occipital ring. Short ocular ridges barely apparent. Posterior limbs broad, subtriangular, moderately convex, downsloping; transverse length about equal to basal glabellar width. Posterior border furrow broad, deep, expanded slightly distally.

Course of anterior section of facial suture directed nearly straight forward from palpebral lobe to border furrow and then curved sharply inward and across border. Course of posterior section gently convex posterolaterally from palpebral lobe to posterior margin.

Free cheek moderately narrow, gently convex, lateral margin strongly curved, more or less parallel to posterior section of facial suture. Border narrow, convex, moderately well defined by continuous lateral and posterior border furrows; width about one-half width of ocular platform between lateral border furrow and posterior section of facial suture. Genal spine slender, directed posterolaterally at strong angle to lateral margin of cheek; length slightly less than length of posterior section of facial suture.

External surfaces of all parts faintly roughened but not distinctly granular; vertical part of anterior cranidial border and anterior part of border of free cheek have well-developed terrace lines parallel to margin.

Discussion.—The differences between this species and *P. extensa* n. sp. have been discussed. *P. retracta* also differs from *P. cercops* by its smaller size, strongly upturned and convex cranidial border, and deep anterior border furrow.

Occurrence.—Moderately rare, "*Plagiura-Poliella*" Zone, Kochaspid Zonule. Nevada: 3546–CO (8 cranidia, 1 free cheek), Nevada Test Site.

Plagiura cf. P. cercops (Walcott)

Plate 6, figure 22

Plagiura cercops (Walcott), Rasetti, 1951, p. 237, pl. 13, figs. 10–16.

Discussion.—A single weathered cephalon from yellow-weathering silty limestone at the base of the Red Pass Member of the Carrara Formation in the Echo Canyon section in the Funeral Mountains is referable to *Plagiura*. The specimen preserves the cranidial outline, showing a tapered glabella reaching to the inner edge of a broad border, anteriorly placed palpebral lobes, and large triangular posterior limbs. The partly displaced free cheeks seem to lack genal spines. There is inadequate information about the external surface and about details of the cranidial and cheek margins to make comparisons at the specific level, but the specimen seems to agree in all observable characteristics with *P. cercops* (Walcott).

Occurrence.—Rare, "*Plagiura-Poliella*" Zone. California: 7189–CO (1 incomplete cephalon), Echo Canyon section, Funeral Mountains.

Genus SCHISTOMETOPUS Resser

Schistometopus Resser, 1938b, p. 10; Rasetti, F., in Harrington and others, 1959, p. 516.

Type species.—*Schistometopus typicalis* Resser, 1938b, p. 10, pl. I, fig. 12.

Discussion.—The present concept of this genus is based on the work of Rasetti (1951, 1957), who added three species to the monotypic genus of Resser, all based on cranidia, and who established the probable nature of the pygidium for one of these. Cranidia are characterized by a glabella that has three distinct pairs of lateral furrows, tapers forward, and reaches to the inner edge of a convex well-defined border. The fixed cheeks are relatively broad, with palpebral lobes situated opposite or slightly posterior to the glabellar midlength. The external ornamentation consists of granules of one or more sizes. The pygidium is characterized by convergence of the pleurae into a pair of broad-based flat spines and by having a short axis that does not reach to the posterior margin.

Schistometopus spp.

Plate 8, figures 1, 2, 5, 6

Discussion.—Several cranidia from one collection and a distorted cranidium and nearly complete pygidium from another seem to represent one or more species of *Schistometopus*. The pygidium and cranidium from USGS collection 4139–CO (pl. 8, figs. 1, 5) are most like *S. convexus* Rasetti, which is a common and diagnostic fossil for the *Plagiura-Kochaspis* Zone (Rasetti, 1957, p. 965). The cranidia from USGS collection 3546–CO include a small form (pl. 8, fig. 6), two larger fragments with nearly straight anterior border furrows, most similar to *S. convexus* Rasetti, and a larger form (pl. 8, fig. 2) with a broken anterior border and a suggestion of a slight posterior median inbend to the border furrow that is more like *S. collaris* Rasetti.

None of the specimens are well enough preserved or provide sufficient material to make adequate judgments about identifications at the species level.

Occurrence.—Rare, "*Plagiura-Poliella*" Zone, Kochaspid Zonule. Nevada: 3546–CO (3 cranidia), Nevada Test Site. California 4139–CO (1 cranidium, 1 pygidium), Titanothere Canyon section, Grapevine Mountains.

Genus SYSPACEPHALUS Resser

Syspacephalus Resser, 1936, p. 28; Lochman, 1947, p. 64; Rasetti, 1951, p. 241; Rasetti, F., in Harrington and others, 1959, p. 237; Shaw, 1962, p. 337.

Type species.—*Agraulos charops* Walcott, 1917, p. 72, pl. 13, figs. 2, 2a.

Discussion.—This genus has been well characterized by Lochman (1947) and Rasetti (1951; in Harrington and others, 1959). It includes small, micropygous simple ptychopariids with small palpebral lobes situated slightly anterior to the glabellar midlength and with slightly convergent anterior sections of the facial sutures. The new species described hereafter have the cranidial characteristics typical for the genus and provide new information about the free cheek, rostral plate, thorax, and pygidium.

Syspacephalus longus n. sp.

Plate 7, figures 14, 16–18

Description.—Small simple ptychopariids, total length probably not exceeding 2 cm. Cranidium subtrapezoidal in outline, anterior margin moderately rounded. Glabella low, obscurely furrowed, tapered slightly forward, bluntly rounded at front, defined by shallow lateral and preglabellar furrows. Occipital furrow deepest at sides, shallow across axial line. Occipital ring has median axial node. Frontal area subequally divided by shallow border furrow into gently convex brim and border. Border tapered towards anterolateral cranidial corners. Fixed cheeks gently convex, horizontal or downsloping; width about one-half basal glabellar width. Palpebral lobe small, poorly defined, situated slightly anterior to glabellar midlength; exsagittal length about one-fourth sagittal glabellar length exclusive of occipital ring. Posterior limb moderately broad exsagittally; transverse length about equal to basal glabellar width. Posterior border furrow about as deep as occipital furrow. Course of anterior section of facial suture subparallel to axis or slightly convergent forward. Course of posterior section moderately convex.

Free cheek small, with poorly defined lateral border. Genal spine short, deflected laterally from margin of cheek; length slightly less than length of posterior section of facial suture; base adjacent to junction of suture with posterior margin.

Thorax consists of 15 or 16 segments. Pleural regions of each segment traversed by broad, deep, straight pleural furrow; pleural tips geniculated downward; short posterolaterally directed spines present.

Pygidium simple, transversely subovate in outline. Axis low, broad, bluntly terminated, reaches nearly to posterior margin; one ring furrow present posterior to articulating furrow. Pleural regions crossed by pleural furrow of first segment and faint first interpleural furrow. Border narrow, poorly defined.

Discussion.—This species has a cranidium most like that of *S. perola* (Walcott) (Rasetti, 1951, pl. 9, figs. 17–22), but it has a free cheek with a well-developed genal spine, at least two more thoracic segments, and less strongly convergent anterior sections of the facial sutures. Isolated cranidia of *S. longus* n. sp. would be difficult to distinguish from *S. perola,* but the total trilobite morphology indicates that the Nevada and Canadian specimens are otherwise quite distinct.

Occurrence.—Common, "*Plagiura-Poliella*" Zone. Nevada: 4435–CO (5 partial individuals, 20 cranidia, 4 free cheeks, 1 pygidium), Belted Range.

Syspacephalus obscurus n. sp.

Plate 7, figures 6–13, 15

Description.—Small, micropygous ptychopariid trilobites probably not exceeding 1 cm in total length. Cranidium subtrapezoidal in outline, gently to moderately rounded at front. All parts barely outlined by extremely shallow furrows on most specimens; some individuals may have better definition of the glabella or border. Glabella low, tapered forward, bluntly rounded anteriorly. Glabellar furrows obscure. Occipital furrow moderately deep distally, shallow across axis; broad poorly defined median axial node may be observable. Frontal area downsloping, barely differentiated into border and brim by gently curved or straight shallow furrow or slight change in slope. Sagittal length of border variable, most commonly subequal to length of brim; may be as little as one-half length of brim. Fixed cheeks downsloping, palpebral lobes only differentiated by slight upward deflection of cheek surface; width of cheek including palpebral lobe about 0.6 basal glabellar width. Palpebral lobe situated just anterior to middle third of glabella; length about one-third sagittal length of glabella. Posterior limbs subtriangular; exsagittal length behind palpebral lobe about twice length of palpebral lobe; posterior border furrow shallow, well defined.

Course of anterior section of facial suture subparallel or slightly convergent forward from palpebral lobes to border furrow, then curved gently inward to intersect anterior margin near anterolateral cranidial corners. Course of posterior section of facial suture forms gentle outwardly convex curve from palpebral lobe to posterior margin.

Rostral plate broad transversely, narrow; sagittal length about one-fifth breadth; slightly narrower distally.

Free cheek narrow, border not differentiated; width opposite ocular notch about 0.3 total length. Genal angle acute, projected backward into short broad-based genal spine.

Pygidium simple, subovate in outline; sagittal length slightly more than one-half greatest width. Axis low, broad, weakly to moderately defined at sides, poorly defined posteriorly; one to three ring furrows barely apparent; width about 0.4 greatest pygidial width; length about 0.9 sagittal pygidial length. Pleural regions downsloping, triangular. Border not differentiated; two shallow pleural furrows and intervening interpleural furrow may be present, not reaching to margin.

Ornamentation consists of extremely densely packed uniform granules that merge at their contacts so that many specimens appear pitted.

Discussion.—The small anteriorly placed palpebral lobes and consequently broad posterior limbs of this simple ptychopariid are the basis for including it in *Syspacephalus*. It differs from all other species in the genus by the poor development of furrows outlining the glabella and border. In addition to its generally poor relief, it is characterized by its distinctive granular ornamentation.

Occurrence.—Common, *Albertella* Zone. California: 4140–CO, (>20 cranidia, 3 free cheeks; >10 pygidia), Titanothere Canyon section, Grapevine Mountains. Rare and questionably identified, *Albertella* Zone. California: 7191–CO (5 distorted cranidia), Echo Canyon section, Funeral Mountains.

Genus VOLOCEPHALINA n. gen.

Type species.—*Volocephalina connexa* n. sp.

Description.—Small ptychopariid trilobites, largest cranidia about 4 mm in sagittal length. Cranidium subtrapezoidal in outline, gently to moderately convex transversely and longitudinally, all parts well defined, anterior margin nearly straight. Glabella prominent, well defined at sides by broad axial furrows; defined at front by abrupt change in slope of exoskeleton; tapered slightly forward, bluntly rounded anteriorly. Three or four moderately deep glabellar furrows present; anterior pair or pairs short, not connected to axial furrows. Occipital furrow very shallow across axis, deep distally. Occipital ring moderately broad, bears prominent median node. Frontal area subequally divided into depressed, concave brim and strongly upturned convex border; sagittal length between one-third and two-thirds sagittal length of glabella exclusive of occipital ring. Fixed cheeks broad, flat, slightly to moderately upsloping; width, including palpebral lobes, between two-thirds and equal to basal glabellar width. Palpebral lobes small, upsloping from surface of cheek, situated opposite anterior third of glabella, connected to glabella by moderately to strongly developed anteriorly curved ocular ridge. Exoskeleton in front of ocular ridge sharply depressed. Posterior limb large, broad; transverse length equal to or greater than basal glabellar width. Posterior border furrow deep, well defined. Course of anterior section of facial suture slightly convergent forward from palpebral lobes and then curved inward more sharply at cranidial corners to intersect cephalic margin about midway to axial line. Posterior section convex.

Free cheek elongate, subtriangular, with poorly defined border and short flat broad-based genal spine.

Hypostome, rostral plate, and pygidium unknown. External surface of cranidium bears scattered coarse tubercules.

Discussion.—This distinctive small genus is unlike any other described early Middle Cambrian genus. It is most similar to the Early Cambrian genus *Periommella* from which it is most easily distinguished by having large broad posterior limbs and small upsloping palpebral lobes. *Volocephalina* may represent an early form in the lineage of small ptychopariids leading to *Bolaspidella* and the Menomoniidae in the upper Middle and lower Upper Cambrian.

Volocephalina connexa n. sp.

Plate 14, figures 17, 18, 21, 22

Description.—Members of *Volocephalina* with sagittal length of frontal area about two-thirds sagittal length of glabella exclusive of occipital ring; width of fixed cheeks about equal to basal glabellar width; and transverse width of posterior limbs about 1½ times basal glabellar width. Palpebral lobes and anterior end of glabella connected by nearly continuous ocular ridge only slightly or not at all interrupted by axial furrow. External surface between scattered tubercules smooth or obscurely pitted.

Discussion.—This species differs from *V. contracta* n. sp. by having broader fixed cheeks, a longer frontal area, and larger posterior limbs and by having the ocular ridge nearly imperceptibly merged with both the palpebral lobe and glabella. The ornamentation between the tubercules is also smooth or pitted rather than finely granular.

Occurrence.—Rare, *Albertella* Zone, Zacanthoidid Zonule(?). Nevada: 3483–CO (2 cranidia) and 3547–CO (5 cranidia), both from Nevada Test Site; 3543–CO (1 silicified cranidium), Desert Range. California: 4141–CO (8 cranidia), Titanothere Canyon section, Grapevine Mountains.

Volocephalina contracta n. sp.

Plate 14, figures 13–16, 20

Description.—Members of *Volocephalina* with sagittal length of frontal area about one-half sagittal length of glabella exclusive of occipital ring, width of fixed cheeks about two-thirds basal glabellar width, and transverse width of posterior limbs about equal to basal glabellar width. Exoskeleton between scattered tubercules is finely granular. Ocular ridge clearly interrupted by axial furrows at junction with glabella.

Free cheek gently convex, elongate, triangular. Border poorly defined by shallow border furrow; width about one-half width of anterior part of ocular platform. Genal spine moderately short, broad based, flat. Length of posterior sutural margin about twice length of anterior sutural margin.

Discussion.—This species differs from *V. connexa* n. sp. by having less prominent ocular ridges reaching to, but not interrupting, the axial furrow, a shorter frontal area, narrower fixed cheeks, and shorter posterior limbs; and it has a granular ornamentation between the scattered tubercules.

Occurrence.—Moderately rare, *Albertella* Zone, *Albertella-Mexicella* Zonule. California: 4149–CO (12 cranidia, 1 free cheek), Echo Canyon section, Funeral Mountains; 4158–CO (8 silicified cranidia, 1 limestone cranidium) and 4159–CO (2 silicified cranidia), both from Pyramid Peak section, Funeral Mountains.

Ptychopariid sp. undet. 1

Plate 5, figures 12, 13

Discussion.—This species has the relatively wide fixed cheeks, anteriorly downsloping and truncate glabella, subparallel anterior sections of facial sutures, and medially expanded border indicated by Rasetti (1955) to be generally characteristic of *Onchocephalus*. It is distinguished from other Early Cambrian ptychopariids in the Carrara Formation by having the glabella only slightly tapered forward, deep axial furrows, and a sagitally long occipital ring. The external surface lacks any distinct ornamentation.

The most similar described species are *Antagmus truncatus* Fritz and *Onchocephalus solitarius* (Lochman) (Fritz, 1972; Lochman, in Cooper and others, 1952), from which this differs by lacking granular ornamentation and a prominent occipital node.

Occurrence.—Rare, lower part of *Bristolia* Zonule. California: 7179–CO, Cucomungo Canyon section, Last Chance Range. Nevada: 7192–CO, Desert Range.

Ptychopariid sp. undet. 2

Plate 5, figure 14

Discussion.—This species is represented by two fragmentary cranidia and one moderately well preserved cranidium in one collection. It is the largest of the Early Cambrian ptychopariids found in the Cararra Formation and is characterized by a low anteriorly tapered glabella (rounded at the front), very weak glabellar furrows, deep axial furrows, a moderately deep nearly straight border furrow, a sagitally narrow occipital ring, moderately wide fixed cheeks, and moderately small palpebral lobes located about opposite glabellar midlength. The external ornamentation is not known. The form of the occipital ring and glabellar outline distinguish this form from other Early Cambrian ptychopariids in the Cararra Formation.

This generalized species is not closely similar to any of the Early Cambrian Cordilleran ptychopariids although it shares many cranidial proportions with species assigned to *Antagmus* and *Onchocephalus*.

Occurrence.—Rare, *Bristolia* Zonule. California: 4153–CO, Echo Canyon section, Funeral Mountains.

Ptychopariid sp. undet. 3

Plate 5, figure 15

Discussion.—This species is represented by several imperfectly preserved internal molds of cranidia from one collection. It is characterized by having a low bluntly rounded glabella defined by shallow narrow axial and by preglabellar furrows of nearly uniform depth. The border is not expanded mesially and is separated from the brim by a narrow shallow gently curved border furrow. The fixed cheeks are only about one-half as wide as the basal part of the glabella, and they are gently convex and slightly downsloping. The occipital furrow is broad and deep, and the occipital ring has an axial node. The surface of the mold is strongly pitted on all parts except the glabella. The species is most similar to a species described by Fritz (1972) as *Piazella*? *rara* from which it differs principally by lacking the slight posterior median deflection of the anterior border furrow. The low cranidial relief and uniform nature of the furrows outlining the glabella distinguish this species from other Early Cambrian ptychopariids in the Carrara Formation.

Occurrence.—Rare, upper part of Early Cambrian, thin limestone just above Gold Ace Limestone Member of Carrara Formation. Nevada: 7194–CO, Desert Range.

Ptychopariid sp. undet. 4

Plate 5, figure 16

Discussion.—This species is represented by the only cranidium that has been found in the Early Cambrian shales of the Carrara Formation. It is characterized by a glabella tapered gently forward and strongly rounded anteriorly, by three moderately distinct pairs of glabellar furrows, by a shallow border furrow deflected posteriorly by a median expansion of the anterior border, and by palpebral lobes that are situated about opposite the glabellar midlength. The general cranidial proportions are most like those suggested for *Onchocephalus* by Rasetti (1955), but the moderately distinct glabellar furrows are unusual and distinguish this form from other Early Cambrian ptychopariids in the Carrara Formation and elsewhere in the Cordilleran region.

Occurrence.—Rare, upper part of Lower Cambrian, in shales immediately above the Gold Ace Limestone Member of Carrara Formation. California: 7188–CO, Echo Canyon section, Funeral Mountains.

Ptychopariid sp. undet. 5

Plate 15, figure 5

Discussion.—The diverse *Albertella* Zone assemblage in USGS collection 3547–CO contains two small cranidia of a simple ptychopariid species of uncertain affinities. It is characterized by a well-defined slightly tapered anteriorly truncate glabella bearing weak glabellar furrows. The occipital furrow is deep distally, and the occipital ring is simple. The frontal area has a gently convex downsloping brim slightly wider than the gently convex downsloping border. The border furrow is shallowest on the axial line. The fixed cheeks are gently convex, horizontal; and the transverse width of the palpebral areas is about 0.6 as much as the basal glabellar width. Nearly straight poorly defined ocular ridges are almost perpendicular to the axis. The palpebral lobe is poorly defined, situated opposite the glabellar midlength and about 0.4 the length of the glabella exclusive of the occipital ring. The posterior limbs are broad, and their transverse length is slightly greater than the basal glabellar width. The anterior facial sutures are slightly divergent forward, and the posterior sutures are divergent and convex. The external surface is covered with very fine obscure granular ornamentation.

No other parts can be certainly associated with the cranidia of this species. Because it is such a nondescript form, its generic assignment must await more knowledge of the whole trilobite. It differs from the associated simple form assigned to *Pachyaspis gallagari* Fritz by having the glabella truncated at the front, by lacking a well-defined preglabellar furrow, and by having the palpebral lobes more centrally placed.

Occurrence.—Rare, *Albertella* Zone, Zacanthoidid Zonule(?). Nevada: 3547–CO (2 cranidia), Nevada Test Site.

Ptychopariid sp. undet. 6

Plate 15, figure 6

Discussion.—Two small cranidia in the large collection from 3766–CO, Nevada Test Site, represent an unknown additional species to the *Albertella* fauna. It is characterized by a glabella only slightly tapered forward and bluntly rounded anteriorly, by a subequally divided frontal area with the shallow border furrow interrupted by a slight swelling on the axial line, by small palpebral lobes, about 0.4 sagittal length of the glabella, situated opposite the anterior third of the glabella, and by an exsagittally broad posterior limbs with a well-developed broad posterior border furrow. Three pairs of shallow glabellar furrows are visible, and the occipital furrow is very deep and straight. The occipital ring seems to have had an occipital spine, because there is a large subcircular broken area at the back of the occipital ring.

This species seems closest to *Syspacephalus charops* (Walcott). The principal differences are the deep occipital furrow of the form described here and its less anteriorly convergent facial sutures. Without more material, a meaningful identification cannot be applied to this specimen.

Occurrence.—Rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (2 cranidia), Nevada Test Site.

Ptychopariid sp. undet. 7

Plate 15, figure 7

Discussion.—This small simple ptychopariid represents a species perhaps related to *Nyella* n. gen. It is characterized by an anteriorly tapered glabella with the sides well defined by deep axial furrows and slightly concave. Glabellar furrows are barely apparent. The frontal area is divided into a narrow brim and convex slightly downsloping border. The distinct border furrow seems to be shallowest across the axial line. The fixed cheeks are gently convex and slightly downsloping, and the palpebral lobes are situated about opposite the glabellar midlength. A part of the exoskeleton is preserved and has an apparently coarsely pitted ornamentation that could reflect the interstices between intergrown coarse granules.

The species lacks the well-developed glabellar furrows of species of *Nyella* and has an ornamentation unlike that of any of the other species in the *Albertella* Zone of the Cararra Formation. More material is needed to evaluate its generic affinities and to justify a formal identification.

Occurrence.—Rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3695–CO (1 cranidium), Nevada Test Site.

Ptychopariid sp. undet. 8

Plate 8, figure 19

Discussion.—A unit of orange-weathering silty limestones at the base of the Red Pass Member of the Cararra Formation in the Echo Canyon section of the Funeral Mountains, Calif., has yielded rare poorly preserved trilobites representing at least two genera. One is an indeterminate species of *Plagiura*, and the other is a form with a broad cranidium of low relief that has a broad concave border about equal in sagittal length to the brim. The fixed cheeks are considerably wider than one-half of the basal glabellar width, and the palpebral lobes are of moderate length and are situated slightly anterior to the glabellar midlength. The anterior sections of the facial sutures are directed slightly anterolaterally from the palpebral lobes. A partial articulated specimen shows the species to have had at least 14 thoracic segments and a long genal spine. The forms seem to be closest to species assigned by Rasetti (1951) and Fritz (1968) to *Amecephalus;* but the position of the palpebral lobe is more anterior than in other species of *Amecephalus,* and more material of better quality is needed before a meaningful identification of this species can be made.

Occurrence.—Rare, "*Plagiura-Poliella*" Zone. California: 4148–CO (1 cranidium; 1 partially articulated specimen) and 7189–CO (2 poor cranidia), Echo Canyon section, Funeral Mountains.

Ptychopariid sp. undet. 9

Plate 14, figure 19

Discussion.—Several simple ptychopariid cranidia in one collection are characterized by a prominent poorly furrowed anteriorly tapered and truncate glabella, a subequally divided frontal area with the border furrow nearly effaced on the axial line, and medially placed poorly defined palpebral lobes. The width of the fixed cheeks is slightly more than one-half the basal glabellar width and the exsagittal length of the palpebral lobe is about one-half the sagittal glabellar length exclusive of the occipital ring. The external surface is covered with closely spaced moderately coarse granules that grow together in the frontal area to give it a superficial pitted appearance.

No other trilobites in the Carrara Formation have the cranidial morphology and distinctive ornamentation of this species. Until more and better material can be found, it is left unnamed.

Some poorly preserved cranidia in a second collection, at least one with a pitted ornamentation on the fixed cheeks, may also represent this species.

Occurrence.—Moderately rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 4440–CO (6 cranidia), Groom Range; ?7195–CO (6 cranidia), Desert Range.

Ptychopariid sp. undet. 10

Plate 15, figure 15.

Discussion.—Several small cranidia, the largest only 5 mm in sagittal length, represent a species unlike any other simple ptychopariid in the lower Middle Cambrian beds of the Cordilleran region. The glabella is large, moderately convex transversely, tapered forward, strongly rounded at front, and distinctly defined by abrupt changes in slope of the exoskeleton. Glabellar furrows are marked by smooth areas in an otherwise strongly granular glabellar ornamentation. The occipital furrow is deep and narrow distally, is broad and shallow across the axis, and bears granular ornamentation in its axial part. The occipital ring is simple, with a low axial swelling near its posterior margin. The frontal area consists of a smooth flat or concave brim and a convex granular border; the sagittal length of the frontal area varies from 0.4 to 0.5 the sagittal length of the glabella exclusive of the occipital ring. The fixed cheeks are gently convex and granular, with low ocular ridges and prominent, slightly upturned palpebral lobes. Transverse width of the palpebral area is slightly less than one-half the basal glabellar width. The posterior limbs are short and blunt; transverse width varies from about 0.7 to 0.8 of the basal glabellar width. The anterior sections of the facial sutures are directed nearly straight forward from the palpebral lobes and the posterior sections are moderately to strongly convex.

This species is one of three associated ptychopariids in USGS collection 4155–CO. It is easily distinguishable from the others, *Alokistocarella*? cf. *A. brighamensis* Resser and ptychopariid sp. undet. 11, by its strongly granular ornamentation and strongly convex border.

Occurrence.—Rare, *Glossopleura* Zonule. California: 4155–CO (3 cranidia), Echo Canyon section, Funeral Mountains.

Ptychopariid sp. undet. 11

Plate 15, figure 16

Discussion.—Several small cranidia, length of largest specimen about 3 mm, represent a simple ptychopariid unlike any other from the early Middle Cambrian of the Cordilleran region. The glabella is tapered forward, sharply rounded anteriorly, well defined at sides and front by shallow axial and preglabellar furrows, and bears four pairs of narrow moderately distinct glabellar furrows of which the anterior pair is most deeply impressed. The occipital ring is simple, without a distinct node or spine. The frontal area is subequally divided into a flat brim and slightly convex border by a narrow border furrow. The sagittal length of the frontal area is slightly less than one-half of the sagittal length of glabella exclusive of the occipital ring. The fixed cheeks are gently convex, horizontal, crossed by low and straight ocular ridges, and have moderately large palpebral lobes situated about opposite the glabellar midlength. The width of the palpebral area is about one-half the basal glabellar width, and the exsagittal length of the palpebral lobe is about one-half the glabellar length exclusive of the occipital ring. The posterior limb is bluntly terminated and bears a deep posterior border furrow; its transverse width is about 0.8 of the basal glabellar width. The course of the anterior section of the facial suture is nearly straight forward from the palpebral lobe and the course of the posterior section is divergent and convex. The external surfaces of all convex parts are very faintly granular.

This species differs from the two associated simple ptychopariids, *Alokistocarella*? cf. *A. brighamensis* Resser and ptychopariid sp. undet. 10, by having moderately distinct glabellar furrows, a short frontal area, and moderately wide fixed cheeks.

Occurrence.—Moderately rare, *Glossopleura* Zonule. California: 4155–CO (5 cranidia), Echo Canyon section, Funeral Mountains.

Ptychopariid sp. undet. 12

Plate 15, figures 19, 20

Discussion.—Two small very distinctive cranidia represent a species unlike any other early Middle Cambrian ptychopariid so far described from the Cordilleran region. It is characterized by a prominent convex glabella, slightly tapered forward, strongly rounded at front, reaching to a broad deep border furrow, and well defined by deep axial furrows. Four pairs of glabellar furrows are present; the posterior pair is deepest and is deflected strongly posteriorly. The occipital furrow is deep and narrow, and the occipital ring is simple. The frontal area consists only of a convex border with a sagittal length about one-seventh of the sagittal length of the glabella exclusive of the occipital ring. The fixed cheeks are moderately to strongly convex and slightly downsloping, with a well defined moderately small palpebral lobe situated opposite the second pair of glabellar furrows and below the level of the cheek. The transverse width of the palpebral area is about one-third the basal glabellar width, and the exsagittal length of the palpebral lobe is about one-third the sagittal glabellar length exclusive of the occipital ring. The posterior limbs are downsloping, have a deep posterior border furrow, and are bluntly terminated; the transverse length is about two-thirds of the basal glabellar width. The external surfaces of all convex parts are thickly covered with granules.

This species is associated with *Glossopleura* in the youngest collection from the *Glossopleura* Zone in the southern Great Basin. There are no comparable forms known from the *Glossopleura* Zone elsewhere, but the general morphology, particularly the glabellar shape and deep glabellar furrows, suggests a possible relationship to trilobites of the younger Middle and Late Cambrian family Lonchocephalidae.

Occurrence.—Rare, uppermost *Glossopleura* Zone. Nevada, Bonanza King Formation: 7199–CO (2 cranidia), Striped Hills.

Ptychopariid pygidium undet. 1

Plate 14, figure 23

Discussion.—Several small simple transversely subelliptical pygidia are characterized by a prominent slightly tapered axis bearing two ring furrows posterior to the articulating furrow. The pleural regions are crossed by three broad shallow pleural furrows that reach to the inner edge of a slightly raised posteriorly tapered border. These appear to be ptychopariid pygidia and may belong to a species of *Nyella*, which is the commonest ptychopariid in the collection with these pygidia. The specimens lack obvious ornamentation, however, so the affiliation with the granular *Nyella* cranidia is uncertain.

Occurrence.—Moderately rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (5 pygidia), Nevada Test Site.

Ptychopariid pygidium undet. 2

Plate 14, figure 24

Discussion.—A single pygidium has the general morphology of a pygidium assigned to *Nyella granosa* (Resser) by Fritz (1968, pl. 39, figs. 12, 13). It is characterized by a transversely elliptical shape, a poorly defined axis, one deep narrow pleural furrow, and an unusual fold of the exoskeleton producing a narrow furrow wrapping around the posterior end of the axis. The surface is covered with closely spaced granules. This pygidium differs from the one illustrated by Fritz by having an ornamentation of only one size of granules. Without more specimens, the affinities of this pygidium are uncertain. It has an ornamentation analogous to that of *N. clinolimbata* (Fritz) which is found in the associated sample.

Occurrence.—Rare, *Albertella* Zone, Zacanthoidid Zonule. Nevada: 3766–CO (1 pygidium), Nevada Test Site.

REFERENCES CITED

Aitken, J. D., 1966, Middle Cambrian to Middle Ordovician cyclic sedimentation, southern Rocky Mountains of Alberta: Bull. Canadian Petroleum Geology, v. 14, no. 4, p. 405–441.

———1967, Classification and environmental significance of cryptalgal limestones and dolomites, with illustrations from the Cambrian and Ordovician of southwestern Alberta: Jour. Sed. Petrology, v. 37, no. 4, p. 1163–1178.

———1971, Control of lower Paleozoic sedimentary facies by the Kicking Horse Rim, southern Rocky Mountains, Canada: Bull. Canadian Petroleum Geology, v. 19, no. 3, p. 557–569.

Albers, J. P., and Stewart, J. H., 1962, Precambrian(?) and Cambrian stratigraphy in Esmeralda County, Nevada, *in* Short Papers in geology, hydrology, and topography: U.S. Geol. Survey Prof. Paper 450–D, p. D24–D27.

Armstrong, R. L., 1968, Sevier orogenic belt in Nevada and Utah: Geol. Soc. America Bull., v. 79, no. 4, p. 429–458.

Ball, M. M., 1967, Carbonate sand bodies of Florida and the Bahamas: Jour. Sed. Petrology, v. 37, no. 2, p. 556–591.

Barnes, Harley, and Christiansen, R. L., 1967, Cambrian and Precambrian rocks of the Groom district, Nevada, southern Great Basin: U.S. Geol. Survey Bull. 1244–G, 34 p.

Barnes, Harley, Christiansen, R. L., and Byers, F. M., Jr., 1962, Cambrian Carrara Formation, Bonanza King Formation, and Dunderberg Shale east of Yucca Flat, Nye County, Nevada, *in* Short papers in geology, hydrology, and topography: U.S. Geol. Survey Prof. Paper 450–D, p. D27–D31.

Barnes, Harley, and Palmer, A. R., 1961, Revision of stratigraphic nomenclature of Cambrian rocks, Nevada Test Site and vicinity, Nevada, *in* Short papers in the geologic and hydrologic sciences: U.S. Geol. Survey Prof. Paper 424–C, p. C100–C103.

Barnes, J., and Klein, G., 1975, Tidal deposits in the Zabriskie Quartzite (Cambrian), eastern California and western Nevada, *in* R. N. Ginsburg, Tidal deposits: New York, Springer-Verlag, p. 163–170.

Bates, E. E., 1965, Stratigraphic analysis of the Cambrian Carrara Formation Death Valley Region, California-Nevada: California Univ., Los Angeles, M.S. thesis, 228 p.

Bathurst, R. G. C., 1966, Boring algae, micrite envelopes and lithification of molluscan biosparites: Geol. Jour., v. 5, pt. 1, p. 15–32.

———1971, Carbonate sediments and their diagenesis, *in* Developments in sedimentology [Volume] 12: New York, Elsevier Publishing Co., 620 p.

Bell, G. K., Jr., 1931, The disputed structures of the Mesonacidae and their significance: Am. Mus. Novitates, no. 475, 23 p.

Bergström, Jan, 1973, Organization, life, and systematics of trilobites: Fossils and Strata, v. 2, 69 p.

Best, R. V., 1952, Two new species of *Olenellus* from British Columbia: Royal Soc. Canada Trans., 3rd ser., v. 46, sec. 4, p. 13–21.

Beyrich, H. E., 1845, Ueber einige bohmische trilobiten (Concerning some Bohemian trilobites): Berlin, G. Reimer, 47 p.

Billings, E., 1861, On some new or little known species of Lower Silurian fossils from the Potsdam group (Primordial zone), *in* Edward Hitchcock, Jr., Hager, A. D., and Hitchcock, C. H., 1861, Report of the geology of Vermont—Descriptive, theoretical, economical, and scenographical, Volume 2: Claremont, N. H., Claremont Manufacturing Co., p. 942–960.

Bird, J. M., and Rasetti, Franco, 1968, Lower, Middle, and Upper Cambrian faunas in the Taconic sequence of eastern New York—Stratigraphic and biostratigraphic significance: Geol. Soc. America Spec. Paper 113, 66 p.

Bloom, A. L., 1971, Glacial-eustatic and isostatic controls of sea level since the last glaciation, *in* K. Turekian, ed., The Late Cenozoic glacial ages: New Haven-London, Yale Univ. Press, p. 355–379.

Buchanan, H., Streeter, S. S., and Gebelein, C. D., 1972, Possible living algal-foraminiferal consortia in nodules from modern carbonate sediments of Great Bahama Bank [abs.]: Am. Assoc. Petroleum Geologists Bull., v. 56, no. 3, p. 606.

Burchfiel, B. C., 1964, Precambrian and Paleozoic stratigraphy of Specter Range quadrangle, Nye County, Nevada: Am. Assoc. Petroleum Geologists Bull., v. 48, no. 1, p. 40–56.

Burling, L. D., 1916, The *Albertella* fauna located in the Middle Cambrian of British Columbia and Alberta: Am. Jour. Sci., v. 42, p. 469–472.

Campbell, L. D., 1971, Occurrence of "*Ogygopsis* shale" fauna in southeastern Pennsylvania: Jour. Paleontology, v. 45, no. 3, p. 437–440.

Campbell, D. P., 1974, Biostratigraphy of the *Albertella* and *Glossopleura* zones (lower middle Cambrian) of northern Utah and southern Idaho: Utah Univ. M.S. thesis, 295 p.

Carozzi, A. V., 1961, Distorted oolites and pseudoolites: Jour. Sed. Petrology, v. 31, no. 2, p. 262–274.

Chernysheva, N. E., ed., 1960, Osnovy paleontologii spravochnik dlya paleontologov i geologov SSSR; Chlenistonogie, trilobito-obraznye i rakoobraznye [Principles of paleontology-arthropods, trilobites and crustaceans]: Moscow, Gosudar. Nauchno-Tekh. Izd. Lit. Geologii i Okhrane Nedr., 515 p.

————1961, Stratigrafiya kembriya Aldanskoy anteklizy i paleontologicheskoe obosnovanie vydeleniya Amginskogo yarusa [Cambrian stratigraphy of the Aldan anticline and paleontological basis of separation of Amginsk formation]: Vses. Nauchno-Issled, Geol. Inst. Trudy, new ser., v. 49, 347 p.

————1962, Kembriyskie trilobity semeystva Oryctocephalidae [Cambrian trilobites of the family Oryctocephalidae]: Nauchno-Issled. Inst. Geol. Arktiki (NIIGA) Trudy, v. 127, p. 3–53.

Clark, C. W., 1921, Lower and Middle Cambrian formations of the Mohave Desert: California Univ. Pubs. Geol. Sci., v. 13, no. 1, p. 1–7.

Cloud, P. E., Jr., 1962, Environment of calcium carbonate deposition west of Andros Island, Bahamas: U.S. Geol. Survey Prof. Paper 350, 138 p.

Cobbold, E. S., 1931, Additional fossils from the Cambrian rocks of Comley, Shropshire: Geol. Soc. London Quart. Jour., v. 87, p. 459–512.

Cooper, G. A., Arellano, A. R. V., Johnson, J. H., Okulitch, V. J., Stoyanow, Alexander, and Lochman, Christina, 1952, Cambrian stratigraphy and paleontology near Caborca, northwestern Sonora, Mexico: Smithsonian Misc. Colln., v. 119, no. 1, 184 p.

Cornwall, H. R., and Kleinhampl, F. J., 1961, Geology of the Bare Mountain quadrangle, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ–157.

Cowie, J. W., 1968, Lower Cambrian faunas from Ellesmere Island, District of Franklin: Canada Geol. Survey Bull. 163, p. 3–27.

Deiss, Charles, 1939, Cambrian stratigraphy and trilobites of northwestern Montana: Geol. Soc. America Spec. Paper 18, 135 p.

Demokidov, K. K., and Lazarenko, N. P., 1964, Stratigrafiya Verkhnego dokembriya i kembriya i nizhenkem briyskie trilobity severnoy chasti sedney Sibiri i ostrovov Sovetskoy Arktiki [Stratigraphy of the Upper Precambrian and Cambrian and Lower Cambrian trilobites from the northern part of Middle Siberian and islands of the Soviet Arctic]: Naucho-Issled. Inst. Geologii Arktiki (NIIGA) Trudy, v. 137, 286 p.

Dunham, R. J., 1962, Classification of carbonate rocks according to depositional textures, *in* W. E. Ham, ed., Classification of carbonate rocks—A symposium: Am. Assoc. Petroleum Geologists Mem. 1, p. 108–121.

————1969, Early vadose silt in Townsend mound (reef), New Mexico, *in* G. M. Friedman, ed., Depositional environments in carbonate rocks—A symposium: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 14, p. 139–181.

Ekren, E. B., Anderson, R. E., Rogers, C. L., and Noble, D. C., 1971, Geology of northern Nellis Air Force Base Bombing and Gunnery Range, Nye County, Nevada: U.S. Geol. Survey Prof. Paper 651, 91 p.

Evamy, B. D., 1963, The application of a chemical staining technique to a study of dedolomitization: Sedimentòlogy, v. 2, p. 163–170.

————1969, The precipitational environment and correlation of some calcite cements deduced from artificial staining: Jour. Sed. Petrology, v. 39, no. 2, p. 787–793.

Evans, G., Schmidt, V., Bush, P., and Nelson, H., 1969, Stratigraphy and geologic history of the sabhka, Abu Dhabi, Persian Gulf: Sedimentology, v. 12, p. 145–159.

Fischer, A. G., 1964, The Lofer cyclothems of the Alpine Triassic: Kansas Geol. Survey Bull. 169, v.1, p. 107–149.

Folk, R. L., 1959, Practical petrographic classification of limestones: Am. Assoc. Petroleum Geologists Bull., v. 43, no. 1, p. 1–38.

————1965, Some aspects of recrystallization in ancient limestone, *in* L. C. Pray, R. C. Murray, eds., Dolomitization and limestone diagensis—A symposium: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 13, p. 14–48.

Fritz, W. H., 1968, Lower and early Middle Cambrian trilobites from the Pioche shale, east-central Nevada, U.S.A.: Palaeontology, v. 11, no. 2, p. 183–235.

————1972, Lower Cambrian trilobites from the Sekwi formation type section, Mackenzie Mountains, northwestern Canada: Canadian Geol. Survey Bull. 212, 90 p.

Gebelein, C. D., 1971, Sedimentology and ecology of Holocene carbonate facies mosaic, Cape Sable, Florida [abs.]: Am. Assoc. Petroleum Geologists Bull., v. 55, no. 2, p. 339–340.

————1973, Sedimentology and stratigraphy of recent shallow-marine and tidal-flat sediments, southwest Andros Island, Bahamas [abs.]: Am. Assoc. Petroleum Geologists Bull., v. 57, no. 4, p. 780 –781.

Ginsburg, R. N., 1957, Early diagenesis and lithification of shallow-water carbonate sediments in south Florida, *in* R. J. LeBlanc, and J. G. Breeding, eds., Regional aspects of carbonate deposition—A symposium: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 5, p. 80 –99.

Gregory, J. W., 1903, The Heathcotian—A Pre-Ordovician series and its distribution: Royal Soc. Victoria Proc., new ser., v. 15, pt. 2, p. 148 –175.

Hall, James, and Whitfield, R. P., 1877, Paleontology, Pt. 2: U.S. Geol. Explor. 48th Parallel (King), v. 4, p. 197 –302.

Ham, W. E., 1954, Algal origin of the "birdseye" limestone in the McLish Formation: Oklahoma Acad. Sci. Proc., v. 33, p. 200 –203.

Hardie, L. A., and Ginsburg, R. N., 1971, The sedimentary record of a tidal flat lamination: Geol. Soc. America Abr. with Programs, v. 3, no. 7, p. 591.

Harrington, H. J., 1956, Olenellidae with advanced cephalic spines: Jour. Paleontology, v. 30, no. 1, p. 56 –61.

Harrington, H. J., and others, 1959, Arthropoda 1—Arthropoda, general features; Protarthropoda; Euarthropoda, general features; Trilobitmorpha, Part O *of* R. C. Moore, ed., Treatise on invertebrate paleontology: Geol. Soc. America and Kansas Univ. Press, 560 p.

Hawle, I., and Corda, A. J. C., 1847, Prodrom einer Monographie der bohmischen Trilobiten [Preliminary introduction to a monograph of the Bohemian trilobites]: Bohmischen Gesell., Wiss. Abh., v. 5, p. 1 –176.

Hazzard, J. C., 1954, Rocks and structures of the northern Providence Mountains, San Bernardino County, California, *in* R. H. Jahns, ed., Geology of southern California: California Div. Mines and Geology Bull. 170, p. 27 –35.

Hazzard, J. C., and Mason, J. F., 1936, Middle Cambrian formations of the Providence and Marble Mountains, California: Geol. Soc. America Bull., v. 47, no. 2, p. 229 –240.

————1953, The Goodsprings dolomite at Goodsprings, Nevada: Am. Jour. Sci., v. 251, no. 9, p. 643–655.

Houbolt, J. J., 1957, Surface sediments of the Persian Gulf near the Qatar Penninsula: Thesis, University of Utrecht, Utrecht, 113 p.

Humphrey, F. L., 1945, Geology of the Groom district, Lincoln County, Nevada: Nevada Bur. Mines Bull., v. 39, no. 5, Geology and Mining Ser. 42, 53 p.

Hupé, Pierre, 1953, Classification des trilobites: Annales Paleontologie, v. 39, p. 61–198.

————1955, Classification des trilobites [concluding part]: Annales Paleontologie, v. 41, p. 91–325.

Hunt, C. B., and Mabey, D. R., 1966, Stratigraphy and structure, Death Valley, California: U.S. Geol. Survey Prof. Paper 494–A, 162 p.

Ivshin, N. K., 1957, Srednekembriiskie trilobity Kazakhstana; chast II, Agyrekskii faunisticheskii gorizont raiona gor Agyrek [Middle Cambrian trilobites from Kazakhstan, part 2, Agyreksk faunal horizon of the Agyrek Mountain region]: Akad. Nauk. Kazakh. SSR Inst. Geol. Nauk., Alma-Ata, 112 p.

Jell, P. A., 1970, *Pagetia ocellata*, a new Cambrian trilobite from northwestern Queensland: Queensland Museum Mem., v. 15, pt. 4, p. 303–313.

————1975, Australian Middle Cambrian Eodiscoids with a review of the superfamily: Paleontographica, Abst. A. Bd. 150, 97 p.

Jindrich, Vladimir, 1969, Recent carbonate sedimentation by tidal channels in the lower Florida Keys: Jour. Sed. Petrology, v. 39, no. 2, p. 531–553.

Johnson, M. S., and Hibbard, D. E., 1957, Geology of the Atomic Energy Commission Nevada proving grounds area, Nevada: U.S. Geol. Survey Bull. 1021–K, p. 333–349.

Kendall, C. G. St., and Skipwith, Bt. P. A. d'E., 1968, Recent algal mats of a Persian Gulf lagoon: Jour. Sed. Petrology, v. 38, no. 4, p. 1040–1058.

Khalfin, L. L., ed., 1955, Atlas rukovodyashchikh form iskopaemykh fauny i flory zapadnoi Sibiri [Atlas of leading forms of fossil fauna and flora from western Siberia]: Zapadno-Sibir. Geol. Uprav.-Tomsk. Politekh. Inst., Moscow, Gosudar; Nauchno-Tekh. Izd. Lit. Geol. i Okhrane Nedr., v. 1, 502 p.

————1960, Biostratigrafiya Paleozoya Sayano-Altayskoy gornoy oblasti; tom 1, Nizhniy Paleozoy [Biostratigraphy of the Paleozoic of the Sayan-Altay Mountain region, v. 1, Lower Paleozoic]: Sibir. Nauchno-Issled. Inst. Geologii, Geofiziki i Mineral'nogo Syr'ya (SNIIGGIMS) Trudy, v. 19, 498 p.

Kindle, C. H., and Tasch, Paul, 1948, Lower Cambrian fauna of the Monkton formation of Vermont: Canadian Field-Naturalist, v. 62, no. 5, p. 133–139.

Kinsman, D. J., 1964, The Recent carbonate sediments near Halat el Bahrani, Trucial Coast, Persian Gulf: *in* L. M. J. U. Van Straaten, ed., Deltaic and shallow marine deposits: Amsterdam, Elsevier, p. 185–192.

Kinsman, D. J. and Holland, H. D., 1969, The co-precipitation of cations with $CaCO_3$, [Part] 4, The co-precipitation of Sr^{2}+ with aragonite between 16°C and 96°C: Geochim. et Cosmochim. Acta, 33: p. 1–17.

Kobayashi, Teiichi, 1935, The Cambro-Ordovician formations and faunas of south Chosen—Paleontology, part 3: Tokyo Imperial Univ. Faculty Science Jour., sec. 2, v. 4, p. 49–344.

————1942, On the Dolichometopinae: Tokyo Imperial Univ. Faculty Science Jour., sec. 2, v. 6, pt. 10, p. 141–206.

————1943, Brief notes on the Eodiscids I, their classification, with a description of a new species and a new variety: Imp. Acad. Tokyo Proc., v. 19, no. 1, p. 37–42.

————1944, On the Eodiscids: Tokyo Imperial Univ. Faculty Science Jour., sec. 2, v. 7, pt. 1, p. 1–74.

————1962, The Cambro-Ordovician formations and faunas of south Korea; pt. 9, Paleontology 8: Tokyo Imperial Univ. Faculty Science Jour., sec. 2, v. 14, pt. 1, p. 1–152.

Kupfer, D. H., 1960, Thrust faulting and chaos structure, Silurian Hills, San Bernadino County, California: Geol. Soc. America Bull., v. 71, no. 2, p. 181–214.

Lake, Philip, 1937, A monograph of the British Cambrian trilobites, part 10: Paleontographical Soc., v. 90, p. 225–248.

Laporte, L. F., 1967, Carbonate deposition near mean sea-level and resultant facies mosaic—Manlius Formation (Lower Devonian) of New York State: Am. Assoc. Petroleum Geologists Bull., v. 51, p. 73–101.

Lazarenko, N. P., 1962, Novye nizhnekembriyskie trilobity Sovetskoy Arktiki [New Lower Cambrian trilobites from the Soviet Arctic]: Sbornik statei po paleontologii i biostratigrafii, no. 29, p. 29 –78.

Lebauer, L. R., 1965, Genesis and environment of deposition of the Meagher Formation in southwestern Montana: Jour. Sed. Petrology, v. 35, no. 2, p. 428 –447.

Lermontova, E. V., 1951, Nizhnekembriyskie trilobity i brakhiopody vostochnoy Sibiri [Lower Cambrian trilobites and brachiopods from eastern Siberia]: Moscow, Vses. Nauchno. Issled. Geol. Inst. (VSEGEI), 218 p.

Lochman, Christina, 1947, Analysis and revision of eleven Lower Cambrian trilobite genera: Jour. Paleontology, v. 21, no. 1, p. 59 –71.

————1948, New Cambrian trilobite genera from northwest Sonora, Mexico: Jour. Paleontology, v. 22, no. 4, p. 451–464.

————1972, Cambrian system: *in* Rocky Mountain Association of Geologists, ed., Geologic Atlas of the Rocky Mountains Regions: Rocky Mountain Assoc. Geologists.

Lochman, Balk, Christina, and Wilson, J. L., 1958, Cambrian biostratigraphy in North America: Jour. Paleontology, v. 32, no. 2, p. 312–350.

Logan, B. W., 1961, Cryptozoon and associate stromatolites from the Recent, Shark Bay, western Australia: Jour. Geology, v. 69, no. 5, 517–533.

Logan, B. W., Davies, G. R., Read, J. F., and Cebulski, D. E. 1970, Carbonate sedimentation and environments, Shark Bay, Western Australia: Am. Assoc. Petroleum Geologists Mem. 13, 223 p.

Logan, B. W., Rezak, R., and Ginsburg, R. N., 1964, Classification and environmental significance of algal stromatolites: Jour. Geology, v. 72, no. 1, p. 68–83.

Loreau, J. P., and Purser, B. H., 1973, Distribution and ultrastructure of Holocene ooids in the Persian Gulf, *in* B. H. Purser, ed., The Persian Gulf: New York, Springer-Verlag, p. 279–329.

Lorenz, Th., 1906, Beitrage uur Geologie and Palaontologie von Ostasien unter besonderer Berucksichtigung der Provinz Schantung in Chine [Contribution to the geology and paleontology of east Asia with special consideration of the province of Shantung, China]: Deutsche Geol. Gesell. Zeitschr., Bd. 58, p. 53 –108.

Mason, J. F., 1935, Fauna of the Cambrian Cadiz formation, Marble Mountains, California: Southern California Acad. Sci. Bull., v. 34, pt. 2, p. 97–119.

Matthews, R. K., 1966, Genesis of Recent lime mud in southern British Honduras: Jour. Sed. Petrology, v. 36, no. 2, p. 428–454.

Maxey, G. B., 1958, Lower and Middle Cambrian stratigraphy in northern Utah and southeastern Idaho: Geol. Soc. America Bull., v. 69, no. 6, p. 647–688.

McKee, E. D., and Resser, C. E., 1945, Cambrian history of the Grand Canyon region, Arizona: Carnegie Inst. Washington Pub. 563, 232 p.

McLaughlin, K. P., and Enbysk, B. B., 1950, Middle Cambrian trilobites from Pend Oreille County, Washington: Jour. Paleontology, v. 24, no. 4, p. 466–471.

Merriam. C. W., 1964, Cambrian Rocks of the Pioche mining district, Nevada, *with a section on* Pioche shale faunules, by A. R. Palmer: U.S. Geol. Survey Prof. Paper 469, 59 p.

Monty, C. L. V., 1967, Distribution and structure of Recent stromatolitic algal mats, eastern Andros Island, Bahamas: Soc. Géol. Belgioue Annales, v. 90, Bull. 3, p. B55–B100.

————1972, Recent algal stromatolitic deposits, Andros Island, Bahamas, Preliminary Report: Geologische Rundschau, Band 61, Heft No. 2, p. 742–783.

Moore, C. H., Jr., 1971, Beachrock cements, Grand Cayman Island, B. W. I., *in* O. P. Bricker, ed., Carbonate cements: Johns Hopkins Univ. Studies Geology, no. 19, p. 9–12.

————1973, Intertidal carbonate cementation, Grand Cayman, West Indies: Jour. Sed. Petrology, v. 43, no. 3, p. 591–602.

Mountjoy, E. W., 1962, Mount Robson (southeast) map-area, Rocky Mountains of Alberta and British Columbia (83 E/SE): Canada Geol. Survey Paper 61–31, 114 p.

Nelson, C. A., 1962, Lower Cambrian-Precambrian succession, White-Inyo Mountains, California: Geol. Soc. America Bull., v. 73, no. 1, p. 139–144.

————1965, Monola Formation, *in* G. V. Cohee, and W. S. West, Changes in stratigraphic nomenclature by the U.S. Geological Survey, 1963: U.S. Geol. Survey Bull. 1194–A, p. A29–A33.

Nelson, C. A., and Durham, J. W., 1966, Guidebook for field trip to Precambrian-Cambrian succession White-Inyo Mountains, California: Geol. Soc. America 79th Ann. Mtg., San Francisco, California, 1966, p. 17.

Neumann, A. C., 1965, Processes of recent carbonate sedimentation in Harrington Sound, Bermuda: Bull. Marine Sci., v. 15, no. 4, p. 987–1035.

Norford, B. S., 1962, Illustrations of Canadian fossils—Cambrian, Ordovician, and Silurian of the western Cordillera: Canada Geol. Survey Paper 62–14, 25 p.

Öpik, A. A., 1961, Alimentary caeca of agnostids and other trilobites: Palaeontology, v. 3, pt. 4, p. 410–438.

Pack, P. D., and Gayle, H. B., 1971, A new olenellid trilobite, *Biceratops nevadensis*, from the lower Cambrian near Las Vegas, Nevada: Jour. Paleontology, v. 45, no. 5, p. 893–898.

Palmer, A. R., 1954, An appraisal of the Great Basin Middle Cambrian trilobites described before 1900: U.S. Geol. Survey Prof. Paper 264–D, p. 55–58.

————1957, Ontogenetic development of two olenellid trilobites: Jour. Paleontology, v. 31, no. 1, p. 105–128.

————1960, Some aspects of the early Upper Cambrian stratigraphy of White Pine County, Nevada and vicinity, *in* Geology of east central Nevada: Intermountain Assoc. Petroleum Geologists, 11th Ann. Field Conf., 1960 Guidebook, p. 53–58.

————1964, An unusual Lower Cambrian trilobite fauna from Nevada: U.S. Geol. Survey Prof. Paper 483–F, 13 p.

————1965, Trilobites of the Late Cambrian Pterocephaliid biomere in the Great Basin, United States: U.S. Geol. Survey Prof. Paper 493, 105 p.

————1968, Cambrian trilobites of east-central Alaska: U.S. Geol. Survey Prof. Paper 559–B, 115 p.

————1971, The Cambrian of the Great Basin and adjacent areas, western United States, *in* C. H. Holland, ed., Lower Palaeozoic rocks of the World, Volume 1, The Cambrian of the New World: New York, Wiley-Interscience, p. 1–77.

————1972, Problems of Cambrian biogeography, *in* Paleontology: Internat. Geol. Cong., 24th, 1972, Paleontology, sec. 7, p. 310–315.

Palmer, A. R., and Campbell, D. P., 1976, Biostratigraphic implications of trilobite biofacies—*Albertella* zone, Middle Cambrian, western United States: Brigham Young Univ. Studies, v. 23, p. 39–56.

Palmer, A. R., and Gatehouse, C. G., 1972, Early and Middle Cambrian trilobites from Antarctica: U.S. Geol. Survey Prof. Paper 456–D, 36 p.

Peach, B. N., 1894, Additions to the fauna of the *Olenellus*-zone of the Northwest Highlands: Geol. Soc. London Quart. Jour., v. 50 p. 661–676.

Pokrovskaya, N. V., 1959, Trilobitovaya fauna i stratigrafiya kembriyskikh otlozheniy Tuvy [Trilobite fauna and stratigraphy of the Cambrian deposits of Tuva]: Akad. Nauk SSSR, Geol. Inst. Trudy, no. 27, 199 p.

Poulsen, Chr., 1927, The Cambrian, Ozarkian, and Canadian faunas of northwest Greenland: Medd, om Gronland, v. 70, p. 233–343.

————1932, The Lower Cambrian faunas of east Greenland: Medd, om Gronland, v. 87, no. 6, 66 p.

Poulsen, Valdemar, 1958, Contributions to the middle Cambrian paleontology and stratigraphy of Argentina: Copenhague Univ. Mus. Minéralogie et Géologie Commun. Paléont., no. 103, 22 p.

————1964, Contribution to the Lower and Middle Cambrian paleontology and stratigraphy of northwest Greenland [with Danish and Russian summaries]: Medd. om Gronland, v. 164, no. 6, 105 p.

Purdy, E. G., 1963, Sedimentary facies, [Part] 2, *of* Recent calcium carbonate facies of the Great Bahama Bank: Jour. Geology, v. 71, no. 4, p. 472–497.

Rasetti, Franco, 1945, Fossiliferous horizons in the "Sillery formation" near Levis, Quebec: Am. Jour. Sci., v. 243, no. 6, p. 305–319.

————1948a, Lower Cambrian trilobites from the conglomerates of Quebec (exclusive of the Ptychopariidea): Jour. Paleontology, v. 22, no. 1, p. 1–24.

————1948b, Middle Cambrian trilobites from the conglomerates of Quebec (exclusive of the Ptychopariidea): Jour. Paleontology, v. 22, no. 3, p. 315–339.

————1951, Middle Cambrian stratigraphy and faunas of the Canadian Rocky Mountains: Smithsonian Misc. Colln., v. 116, no. 5, 277 p.

————1955, Lower Cambrian ptychopariid trilobites from the conglomerates of Quebec: Smithsonian Misc. Colln., v. 128, no. 7, 35 p.

————1957, Additional fossils from the Middle Cambrian Mt. Whyte formation of the Canadian Rocky Mountains: Jour. Paleontology, v. 31, no. 5 p. 955–972.

————1966a, Revision of the North American species of the Cambrian trilobite genus *Pagetia:* Jour. Paleontology, v. 40, no. 3, p. 502–511.

————1966b, New Lower Cambrian trilobite faunule from the Taconic sequence of New York: Smithsonian Misc. Colln., v. 148, no. 9, 52 p.

————1967, Lower and Middle Cambrian trilobite faunas from the Taconic sequence of New York: Smithsonian Misc. Colln., v. 152, no. 4, 111 p.

Raw, Frank, 1927, The ontogenies of trilobites and their significance: Am. Jour. Sci., 5th ser., v. 14, p. 7–35, 131–149, 240.

————1935, Mesonacidae of Comley in Shropshire with a discussion of the classification within the family: Geol. Soc. London Quart. Jour., v. 92, p. 236–286.

————1957, Origin of Chelicerates: Jour. Paleontology, v. 31, no. 1, p. 139–192.

Raymond, P. E., 1912, Notes on parallelism among the Asaphidae: Royal Soc. Canada Trans., 3d ser. v. 5, sec. 4, p. 111–120.

————1928a, Two new Cambrian trilobites: Am. Jour. Sci., 5th ser., v. 15, p. 309–313.

————1928b, The ontogenies of trilobites and their significance: Am. Jour. Sci. 5th ser., v. 15, p. 168–170.

Reed, F. R. C., 1910, The Cambrian fossils of Spiti: India Geol. Survey Mem., ser. 15, v. 17, mem. 1, 70 p.

Repina, L. N. and others, 1964, Biostratigrafiya nizhnego kembriya Sayano-Altayskoy skladchatoy oblists [Biostratigraphy of the Lower Cambrian from the Sayan-Altay folded region]: Akad. Nauk SSSR Sibirskoe Otdelenie, Inst. Geologii i Geofiziki, 364 p.

————1974, K voprosu o granitse nizhnego i srednego kembriya Sibirskoy platformy i copredel'nykh territoriy [Concerning the question of the Lower and Middle Cambrian boundary in the Siberian Platform and surrounding territories]: *in* I. T. Zhuravleva, and A. Yu. Rozanov, eds., 1974, Biostratigrafiya i Paleontologiya nizhnego kembriya Europy i Severnoy Azii [Biostratigraphy and Paleontology of the Lower Cambrian of Europe and Northern Asia] Izd. "Nauka," Moscow, 311 p.

Resser, C. E., 1928, Cambrian fossils from the Mohave Desert: Smithsonian Misc. Colln., v. 81, no. 2, 14 p.

————1935, Nomenclature of some Cambrian trilobites: Smithsonian Misc. Colln., v. 93, no. 5, 46 p.

————1936, Second contribution to nomenclature of Cambrian trilobites: Smithsonian Misc. Colln., v. 95, no. 4, 29 p.

———1937a, Third contribution to nomenclature of Cambrian trilobites: Smithsonian Misc. Colln., v. 95, no. 22, 29 p.

———1937b, Elkanah Billings' Lower Cambrian trilobites and associated species: Jour. Paleontology, v. 11, p. 43–54.

———1938a, Cambrian system (restricted) of the Southern Appalachians: Geol. Soc. America Spec. Paper 15, 140 p.

———1938b, Middle Cambrian fossils from Pend Oreille Lake, Idaho: Smithsonian Misc. Colln. v. 97, no. 3, 12 p.

———1939a, The Spence shale and its fauna: Smithsonian Misc. Colln., v. 97, no. 12, 29 p.

———1939b, The Ptarmigania strata of the northern Wasatch Mountains: Smithsonian Misc. Colln., v. 98, no. 24, 72 p.

Resser, C. E., and Howell, B. F., 1938, Lower Cambrian *Olenellus* zone of the Appalachians: Geol. Soc. America Bull., v. 49, no. 2, p. 195–248.

Reynolds, M. W., 1971, Stratigraphy and structural geology of the Titus and Titanothere Canyon areas, Death Valley, California: California Univ., Berkeley, Ph. D. thesis, 310 p.; available from Univ. Microfilms, Ann Arbor, Mich., no. 69–18, 962, 406 p.

Riccio, J. F., 1952, The Lower Cambrian Olenellidae of the southern Marble Mountains, California: So. Calif. Acad. Sci. Bull., v. 51, pt. 2, p. 25–49.

Richter, Rudolph and Richter, Emma, 1941, Die Fauna des Unter-Kambriums von Cala in Andalusien [Lower Cambrian fauna from Cala in Andalusia]: Senckenbergiana Naturf. Gesell. Abh., v. 455, p. 1–90.

Robison, R. A., 1960, Lower and Middle Cambrian stratigraphy of the eastern Great Basin, *in* Geology of east central Nevada: Intermountain Assoc. Petroleum Geologists, 11th Ann. Field Conf., 1960 Guidebook, p. 43–52.

———1964, Late Middle Cambrian faunas from western Utah: Jour. Paleontology, v. 38, no. 3, p. 510–566.

———1971, Additional Middle Cambrian trilobites from the Wheeler Shale of Utah: Jour. Paleontology, v. 45, no. 5, p. 796–804.

Robison, R. A., and Cambell, D. P., 1974, A Cambrian corynexochoid trilobite with only two thoracic segments: Lethaia, v. 7, p. 273–282.

Robison, R. A., and Hintze, L. F., 1972, An Early Cambrian trilobite faunule from Utah: Brigham Young Univ. Studies, v. 19, pt. 1, p. 3–13.

Rominger, C. L., 1887, Description of primordial mordial fossils from Mt. Stephens, NW Territory of Canada: Acad. Nat. Sci. Philadelphia Proc. for 1887, p. 12–19.

Rusnak, G. A., 1960, Some observations of Recent oolites: Jour. Sed. Petrology, v. 30, p. 471–480.

Scholle, P., and Kling, S., 1972, Southern British Honduras: Lagoonal Coccolithid Ooze: Jour. Sed. Petrology, v. 42, p. 195–204.

Shaw, A. B., 1955, Paleontology of northwestern Vermont, pt. V, The Lower Cambrian fauna: Jour. Paleontology, v. 29, no. 5, p. 775–805.

———1962, Paleontology of northwestern Vermont—[Part] 9, Fauna of the Monkton Quartzite: Jour. Paleontology, v. 36, no. 2, p. 322–345.

Shearman, D. J., Twyman, J., Karimi, M., 1970, The genesis and diagenesis of oolites: Proceedings of the Geologist's Assoc., v. 81, p. 561–575.

Shergold, J. H., 1969, Oryctocephalidae (Trilobita: Middle Cambrian) of Australia: Australia, Bur. Mineral Resources, Geology and Geophysics Bull. 104, 66 p.

Shimer, H. W., and Shrock, R. R., 1944, Index Fossils of North America: Massachusetts Institute of Technology, the Technology Press, 837 p.

Shinn, E. A., 1968, Burrowing in Recent lime sediments of Florida and the Bahamas: Jour. Paleontology, v. 42, no. 4, p. 879–894.

Shinn, E. A., Ginsburg, R. N. and Lloyd, R. M., 1965, Recent supratidal dolomite from Andros Island, Bahamas: *in* L. C. Pray, R. C. Murray, eds., Dolomitization and limestone diagenesis—A Symposium: Soc. Econ. Paleontologists and Mineralogists, Spec. Pub. 13, p. 112–123.

Shinn, E. A., Lloyd, R. M., and Ginsburg, R. N., 1969, Anatomy of a modern carbonate tidal-flat, Andros Island, Bahamas: Jour. of Sed. Petrology, v. 39, p. 1202–1228.

Stauffer, K. W., 1962, Quantitative petrographic study of Paleozoic carbonate rocks, Caballo Mountains, New Mexico: Jour. Sed. Petrology, v. 32, no. 3, p. 357–396.

Stewart, J. H., 1965, Precambrian and Lower Cambrian formations in the Last Chance Range area, Inyo County, California: *in* G. V. Cohee, and W. S. West, eds., Changes in stratigraphic nomenclature by the U.S. Geological Survey 1964: U.S. Geol. Survey Bull. 1224-A, p. 60–70.

———1970, Upper Precambrian and Lower Cambrian strata in the southern Great Basin, California and Nevada: U.S. Geol. Survey Prof. Paper 620, 206 p.

———1971, Basin and Range structure—A system of horsts and grabens produced by deep-seated extension: Geol. Soc. America Bull., v. 82, no. 4, p. 1019–1043.

Stewart, J. H., and Barnes, Harley, 1966, Precambrian and Lower Cambrian formations in the Desert Range, Clark County, Nevada, *in* G. V. Cohee, and W. S. West, eds., Changes in stratigraphic nomenclature by the U.S. Geological Survey, 1965: U.S. Geol. Survey Bull. 1244–A, p. A35–A42.

Stockman, K. W., Ginsburg, R. N., and Shinn, E. A., 1967, The production of lime mud by algae in south Florida: Jour. Sed. Petrology, v. 37, no. 2, p. 633–648.

Störmer, Lief, 1939, Studies on trilobite morphology, Pt. 1, The thoracic appendages and their phylogenetic significance: Norsk Geol. Tidsskr., v. 19, p. 143–273.

Suvorova, N. P., 1964, Trilobity koroneksokhoidy i ikh istoricheskoe razvitie [Corynexochid trilobites and their historical development]: Akad. Nauk SSSR, Paleont. Inst. Trudy, v. 103, 319 p.

Swinchatt, J. P., 1970, The Great Barrier Reef: Regional sedimentation in a terrigenous-carbonate province: Geol. Soc. America Bull., v. 81, p. 691–724.

Taylor, J. C. M., and Illing, L. V., 1971, Development of Recent cemented layers within intertidal sand-flats, Qatar, Persian Gulf, *in* O. P. Bricker, ed., Carbonate Cements: Johns Hopkins Univ. Studies Geology, no. 19, p. 27–31.

Tebbutt, G. E., Conley, C. D., Boyd, D. W., 1965 Lithogenesis of a distinctive carbonate rock fabric: Wyoming Univ. Contr. Geology, v. 4, no. 1, p. 1–13.

Thorslund, Per, 1949, Notes of *Kootenia* n. sp. and associated *Paradoxides* species from the lower middle Cambrian of Jemtland, Sweden: Sveriges Geologiska Undersökning, Arsbok 43, no. 8, ser. C, no. 510, p. 3–7.

Vologdin, A. G., Atlas of the leading forms of the fossil fauna of the U.S.S.R., Volume 1, Cambrian: Moscow, Vses. Nauchno. Issled. Geol. Inst. (VSEGEI), 193 p.

Walcott, C. D., 1884, Paleontology of the Eureka district [Nevada]: U.S. Geol. Survey Mon. 8, 298 p.

———1885, Paleozoic notes—New genus of Cambrian trilobites, *Mesonacis:* Am. Jour. Sci., 3d ser., v. 29, no. 172, p. 328–330.

———1886, Second contribution to the studies on the Cambrian faunas of North America: U.S. Geol. Survey Bull. 30, 369 p.

———1888, Cambrian fossils from Mount Stephens, Northwest Territory of Canada: Am. Jour. Sci., 3d ser., v. 36, no. 213, p. 163–166.

———1889, Description of new genera and species of fossils from the Middle Cambrian: U.S. Natl. Mus. Proc., v. 11, p. 441–446.

———1891, The fauna of the Lower Cambrian or *Olenellus* zone: U.S. Geol. Survey Ann. Rept. 10, p. 509–763.

__________1908, Cambrian geology and paleontology, 2, Cambrian trilobites: Smithsonian Misc. Colln., v. 53, no. 2, p. 13–52.

__________1910, *Olenellus* and other genera of the Mesonacidae: Smithsonian Misc. Colln., v. 57, no. 6, p. 233–422.

__________1916a, Cambrian geology and paleontology, 3, Cambrian trilobites: Smithsonian Misc. Colln., v. 64, no. 3, p. 157–258.

__________1916b, Cambrian geology and paleontology, 5, Cambrian trilobites: Smithsonian Misc. Colln., v. 64, no. 5. p. 303–456.

__________1917, Cambrian geology and paleontology, 3, Fauna of the Mount Whyte formation: Smithsonian Misc. Colln., v. 67, no. 3, p. 61–114.

__________1924, Cambrian geology and paleontology, Part 5, Number 2, Cambrian and lower Ozarkian trilobites: Smithsonian Misc. Colln., v. 75, no. 2, p. 53–60.

__________1925, Cambrian geology and paleontology, Part 5, Number 3, Cambrian and Ozarkian trilobites: Smithsonian Misc. Colln. v. 75, no. 3, p. 61–146.

Wanless, H. R., 1973, Microstylolites, bedding, and dolomitization [abs.]: Am. Assoc. Petroleum Geologists Bull., v. 57, no. 4, p. 811.

Wheeler, H. E., 1948, Late Precambrian-Cambrian stratigraphic cross section through southern Nevada: Nevada Univ., [v. XLII,] Geology and Mining Ser. 47, no. 3, 58 p.

Wheeler, H. E., and Mallory, V. S., 1956, Factors in lithostratigraphy: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 11, p. 2711–2723.

White, C. A., 1874, Preliminary report upon invertebrate fossils: U.S. Geog. and Geol. Surveys W. 100th Mer. Rept., p. 5–27.

__________1877, Report upon the invertebrate fossils collected in portions of Nevada, Utah, Colorado, New Mexico, and Arizona: U.S. Geog. and Geol. Surveys W. 100th Mer. Rept., v. 4, pt. 1, p. 3–219.

Whitehouse, F. W., 1939, The Cambrian faunas of northeastern Australia: Part 3, The Polymerid trilobites: Queensland Mus. Mem., v. 11, pt. 3, p. 179–242.

Wilhel, D. E., 1963, Geology of part of the Nopah and Resting Spring Ranges, Inyo County, California: California Univ., Los Angeles, Ph. D. thesis; available from Univ. Microfilms, Ann Arbor, Mich., no. 63-3884, 297 p.

Wright, L. A., and Troxel, B. W., 1966, Strata of late Precambrian-Cambrian age, Death Valley region, California-Nevada: Am. Assoc. Petroleum Geologists Bull., v. 50, no. 5, p. 846–857.

Yegorova, L. I., 1961, Trilobity nizhnego kembriya basseyna r. Katun' (Gornyy Altay) [Lower Cambrian trilobites from the Katun River basin (Altay Mountains)], *in* Materialy po paleontologii i stratigrafii zapadnoy Sibiri: Sibir. Nauchno-Issled. Inst. Geologii, Geofiziki i Mineral'nogo Syr'ya (SNIIGGIMS) Trudy, v. 15, p. 215–231.

Yegorova, L. I., and Savitskiy, V. E., 1969, Stratigrafiya i biofatsii kembriya Sibirskoy platformy, Zapadnoe Prianabar'ye [Stratigraphy and biofacies of the Cambrian of the Siberian Platform, western pre-Anabar]: Sibir Nauchno-Issled, Inst. Geologii, Geofiziki i Mineral'nogo Syr'ya (SNIIGGIMS) Trudy, v. 43, 408 p.

Zhuravleva, I. T., and others, 1970, K poznaniyu rannego Kembriya yuzhnogo Tyan'-Shanya [Concerning knowledge of the Early Cambrian of the southern Tien Shan]: Trest "Tashkentgeologiya" Kompl. Geol. Poiskobaya Ekspeditsiya, Izd. "Fan" Uzbekskoy SSR, Tashkent, 53 p.

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PLATES 1–16

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PLATE 1

OLENELLUS ZONE

FIGURES 1–13. *Bristolia anteros* n. sp. (p. 63).

1. Cephalon, stage I, ×15, USNM 177179a.
2. Cephalon, stage II, ×12, USNM 177179b.

3–6. Cephala, stage III, ×12, USNM 177179c–f.

7,8. Cephala, stage IV, ×12, USNM 177179g, h.

9,12. Cephalon, top view and anterior oblique view showing eye surface, stage V, ×6, USNM 177180.

10. Closeup of glabella of holotype showing ornamentation, ×6, USNM 177181.

11. Latex cast of holotype cephalon, ×2.5, USNM 177181.

13. Cephalon, stage V, ×3, USNM 177182.

All except figures 9 and 12 from USGS colln. 4144–CO, Grapevine Mountains, Calif. Specimen in figures 9 and 12 from USGS colln. 3694–CO, Nevada Test Site.

14–19. *Bristolia bristolenis* (Resser) (p. 64).

14, 15. Top and right side views of latex mold of cephalon, ×1.5, USNM 177183. USGS colln. 4144–CO, Grapevine Mountains, Calif.

16. Cephalon, ×1.5, USNM 177184, USGS colln. 4153–CO, Funeral Mountains, Calif.

17. Cephalon, ×1.5, USNM 177185, USGS colln. 3673–CO, Resting Springs Range, Calif.

18. Cephalon, ×1.5, USNM 177186, USGS colln. 4168–CO, Salt Spring Hills, Calif.

19. Cephalon, ×2, USNM 177187, USGS colln. 4144–CO, Grapevine Mountains, Calif.


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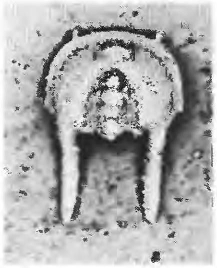
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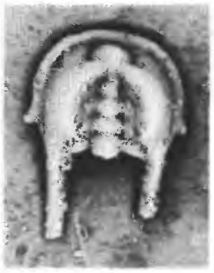
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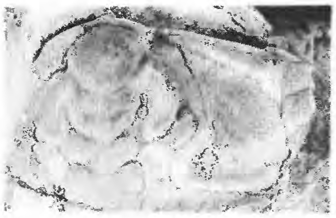
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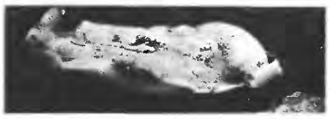
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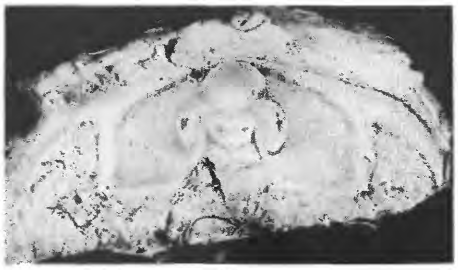
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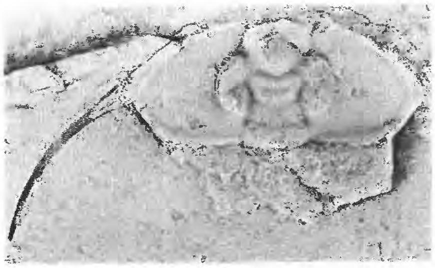
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OLENELLUS ZONE

PLATE 2

OLENELLUS ZONE

FIGURES

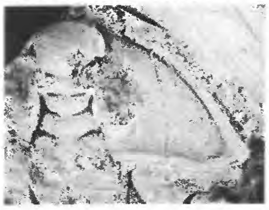
1–6. *Bristolia fragilis* n. sp. (p. 65).
- 1. Cephalon, ×2, USNM 177188, USGS colln. 3694–CO, Nevada Test Site.
- 2. Immature silicified cephalon, stage III, ×10, USNM177189a.
- 3. Immature silicified cephalon, stage IV, ×5, USNM 177189b.
- 4. Holotype cephalon, ×1.5, USNM 177190.
- All from USGS colln. 4144–CO, Grapevine Mountains, Calif.
- 5. Latex cast of cephalon, ×1.5, USNM 177191, USGS colln. 6399–CO, Desert Range, Nev.
- 6. Cephalon, ×2, USNM 177192, USGS colln. 3786–CO, Nevada Test Site.

7, 8. *Olenellus brachyomma* n. sp. (p. 68).
- 7. Holotype cephalon, ×3, USNM 177193.
- 8. Closeup of genal spine, ×6, USNM 177194.
- Both from USGS colln. 3696–CO, Desert Range, Nev.

9, 10, 13, 14. *Olenellus cylindricus* n. sp. (p. 69).
- 9. Latex cast of small cephalon, ×2, USNM 177195.
- 10. Latex cast of larger cephalon, ×1.5, USNM 177196.
- 13. Holotype cephalon, ×1.5, USNM 177197.
- 14. Questionably assigned cephalon lacking advanced genal spines, ×1, USNM 177198.
- All from USGS colln. 4146–CO, Grapevine Mountains, Calif.

11, 12. *Olenellus arcuatus* n. sp. (p. 67).
- 11. Latex cast of cephalon, ×3, USNM 177199, USGS colln. 4146–CO, Grapevine Mountains, Calif.
- 12. Holotype cephalon, ×3, USNM 177200, USGS colln. 3148–CO, Funeral Mountains, Calif.

15–18. *Olenellus euryparia* n. sp. (p. 69).
- 15. Left part of large cephalon showing intergenal spine, ×1, USNM 177201.
- 16. Cephalon, ×2, USNM 177202.
- 17. Cephalon, showing ornamentation, ×2, USNM 177203.
- 18. Holotype cephalon, ×1.5, USNM 177204.
- All from USGS colln. 3680–CO, Eagle Mountain, Calif.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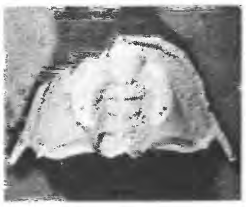
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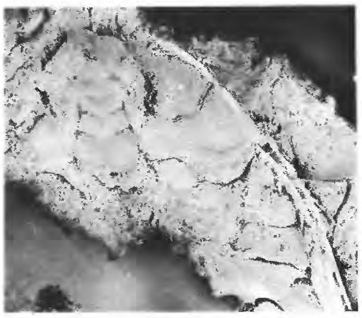
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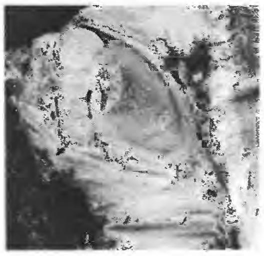
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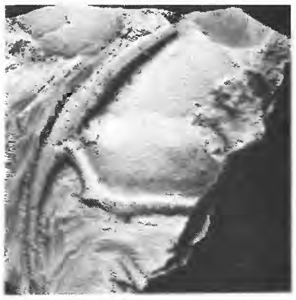
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OLENELLUS ZONE

PLATE 3

OLENELLUS ZONE

FIGURES 1–5. *Olenellus clarki* (Resser) (p. 68).

- 1, 2. Cephala showing differences due to deformation, ×1.5, USNM 177205, 177206, USGS colln. 2304–CO, Funeral Mountains, Calif.
- 3. Latex cast of cephalon, ×1, USNM 177207, USGS colln. 4168–CO, Salt Spring Hills, Calif.
- 4. Latex cast of cephalon, ×1, USNM 177208, USGS colln. 6399–CO, Desert Range, Nev.
- 5. Latex cast of cephalon showing ornamentation, ×3, USNM 177209, USGS colln. 2304–CO, Funeral Mountains, Calif.

6–13. *Olenellus gilberti* Meek (p. 71).

- 6–8. Latex casts of cephala showing variation in outline due to distortion, ×1, USNM 177210, 177211, 177212, USGS colln. 2304–CO, Funeral Mountains, Calif.
- 9. Latex cast of cephalon, ×0.7, USNM 177213, USGS colln. 4153–CO, Funeral Mountains, Calif.
- 10. Latex cast of large cephalon, ×0.5, USNM 177214.
- 11. Latex cast of cephalon, ×1.5, USNM 177215.

Both from USGS colln. 4168–CO, Salt Spring Hills, Calif.

- 12. Small cephalon, ×2, USNM 177216, USGS colln. 4153–CO, Funeral Mountains, Calif.
- 13. Cephalon, ×1, USNM 177217, USGS colln. 3681–CO, Eagle Mountain, Calif.

14–17. *Olenellus fremonti* (Walcott) (p. 70).

- 14. Cephalon, ×1, USNM 177218.
- 15. Cephalon, ×1.5, USNM 177219.
- 16. Latex cast of cephalon, ×1.5, USNM 177220.

All from USGS colln. 2304–CO, Funeral Mountains, Calif., showing variability of advancement of genal spine.

- 17. Cephalon, ×1, USNM 177221, USGS colln. 4168–CO, Salt Spring Hills, Calif.


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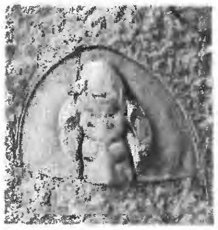
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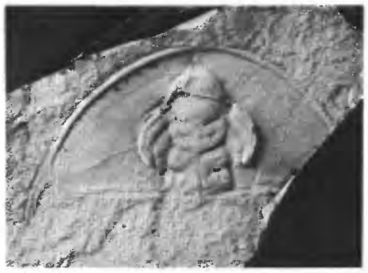
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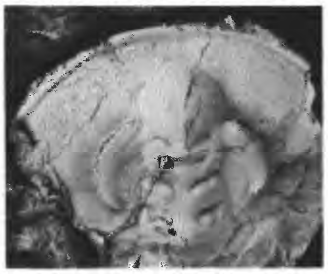
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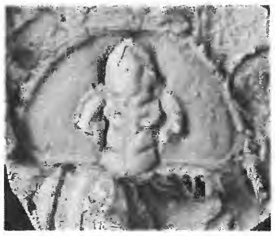
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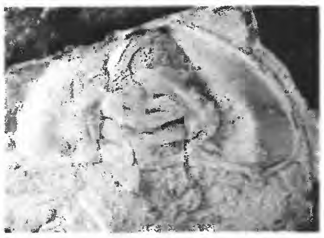
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OLENELLUS ZONE

PLATE 4

OLENELLUS ZONE

FIGURES 1–9. *Olenellus multinodus* n. sp. (p. 72).

1. Latex cast of small cephalon, ×4.5, USNM 177222.
2, 3. Latex casts of cephala showing effects of deformation, ×3, USNM 177223, 177224.

All from USGS colln. 2304–CO, Funeral Mountains, Calif.

4. Latex cast of holotype cephalon, ×4, USNM 177225, USGS colln. 3097–CO, Funeral Mountains, Calif.
5. Latex cast showing profile of left side of cephalon and axial nodes, ×4, USNM 177226, USGS colln. 3676–CO, Resting Springs Range, Calif.
6. Plaster replica of cephalon, ×2, GSC 16858, GSC loc.42591, Jasper Park, Alberta, Canada.
7. Closeup of opisthothorax of specimen shown in figure 8, ×6, USNM 177227.
8. Only known specimen showing thorax, ×3, USNM 177227, USGS colln. 7224–CO, northern Delamar Mountains, Nev.
9. Cephalon, ×3, USNM 177228, USGS colln. 3095–CO, Panamint Range, Calif.

10, 13, 17. *Olenellus nevadensis* (Walcott) (p. 73).

10. Latex cast of cephalon, ×1, USNM 177229, USGS colln. 4144–CO, Grapevine Mountains, Calif.
13. Latex cast of cephalon, ×2, USNM 177230, USGS colln. 3148–CO, Funeral Mountains, Calif.
17. Cephalon, ×2, USNM 177231, USGS colln. 4144–CO, Grapevine Mountains, Calif.

11, 14. *Olenellus puertoblancoensis* (Lochman) (p. 74).

11. Latex cast of cephalon, ×3, USNM 177232.
14. Latex cast of cephalon, ×2, USNM 177233.

Both from USGS colln. 4145–CO, Grapevine Mountains, Calif.

12, 15. *Olenellus* sp. 1 (p. 74).

12. Closeup of glabella and ocular lobe of specimen in figure 15 showing ornamentation, ×4, USNM 177234.
15. Cephalon, ×2, USNM 177234, USGS colln. 7184–CO, Grapevine Mountains, Calif.

16. *Olenellus* howelli? (Meek) (p. 72).

Cephalon ×2, USNM 177235, USGS colln. 4145–CO, Grapevine Mountains, Calif.


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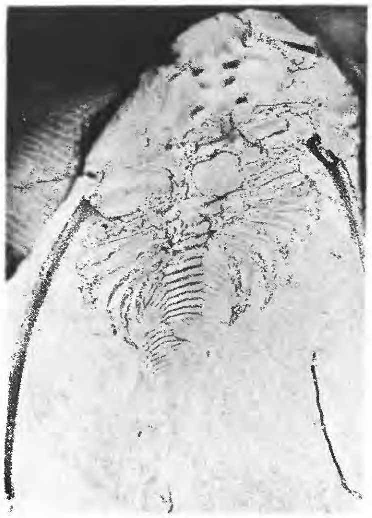
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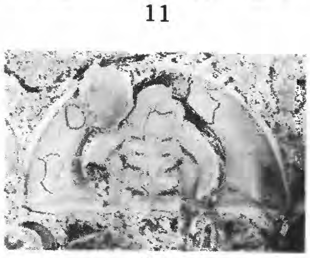
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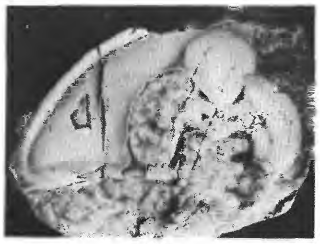
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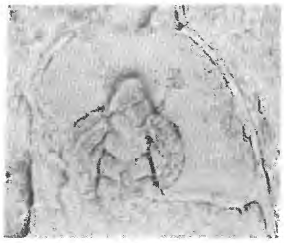
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OLENELLUS ZONE

PLATE 5

OLENELLUS ZONE

FIGURES 1–3. *Peachella brevispina* n. sp. (p. 75).

- 1. Holotype cephalon, ×2, USNM 177236.
- 2. Cephalon, ×3, USNM 177237.

Both from USGS colln. 4167–CO, Dublin Hills, Calif.

- 3. Cephalon, ×2, USNM 177238, USGS colln. 3679–CO, Eagle Mountain, Calif.

4–9. *Peachella iddingsi* (Walcott) (p. 75).

- 4. Holotype cephalon, ×2, USNM 15407a, USNM loc. 52, Eureka, Nev.
- 5. Typical surface showing only tumid spines of *P. iddingsi,* ×1, USNM 177239, USNM loc. 22s.
- 6. Small silicified cephalon, ×5, USNM 177240, USGS colln. 4144–CO, Grapevine Mountains, Calif.
- 7, 8. Latex casts of cephala, ×2, USNM 177241, 177242.
- 9. Cephalon, ×2, USNM 177243.

All from USGS colln. 3786–CO, Nevada Test Site.

10, 11. *Bonnia* spp. (p. 81).

- 10. Cranidium, ×4, USNM 177244, USGS colln. 3646–CO, Nevada Test Site.
- 11. Small cranidium, ×9, USNM 177245, USGS colln. 7181–CO, Last Chance Range, Calif.

12, 13. Ptychopariid sp. undet. 1 (p. 117).

- 12. Latex cast of cranidium, ×8, USNM 177246, USGS colln. 7179–CO, Last Chance Range, Calif.
- 13. Cranidium, ×6, USNM 177247, USGS colln. 7192–CO, Desert Range, Nev.

14. Ptychopariid sp. undet. 2 (p. 118).

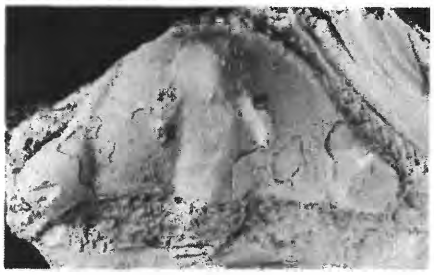
Cranidium, ×3, USNM 177248, USGS colln. 4153–CO, Funeral Mountains, Calif.

15. Ptychopariid sp. undet. 3 (p. 118).

Latex cast of cranidium, ×8, USNM 177249, USGS colln. 7194–CO, Desert Range, Nev.

16. Ptychopariid sp. undet. 4 (p. 118).

Latex cast of cranidium, ×8, USNM 177250, USGS colln. 7188–CO, Funeral Mountains, Calif.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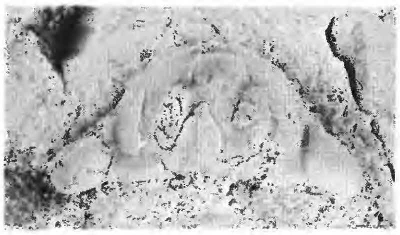
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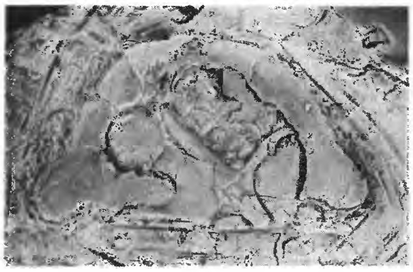
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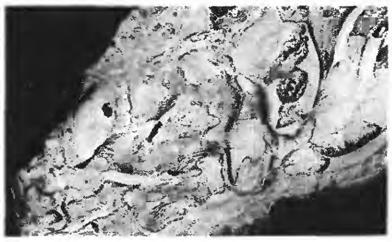
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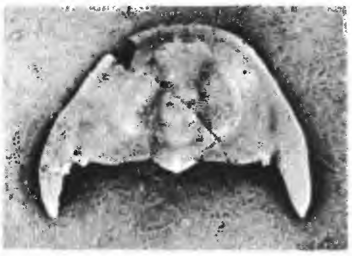
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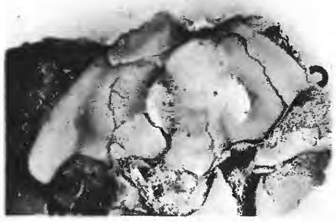
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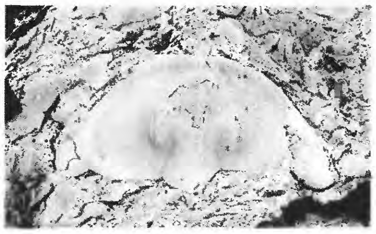
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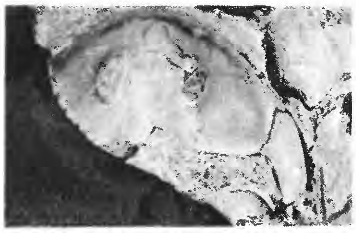
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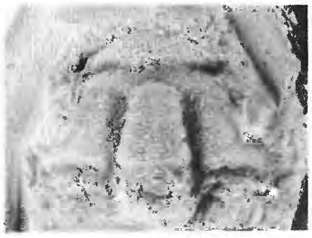
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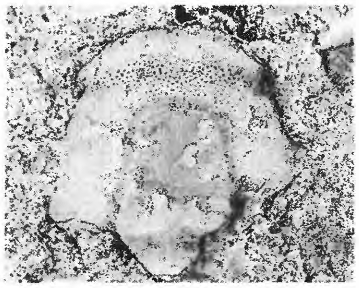
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OLENELLUS ZONE

PLATE 6

"PLAGIURA-POLIELLA" ZONE

FIGURES 1–5, 12. *Poliella lomataspis* n. sp. (p. 80).
- 1. Free cheek, ×10, USNM 177251.
- 2, 3. Top and oblique views of holotype cranidium, ×6, USNM 177252.
- 4. Pygidium, ×5, USNM 177253.
- 5. Latex cast of pygidium, ×12, USNM 177254.
- All from USGS colln. 4434–CO, Belted Range, Nev.

6–10. *Poliella* cf. *P. lomataspis* n. sp. (p. 80).
- 6. Cranidium, ×10, USNM, 177255a.
- 7. Free cheek, ×10, USNM 177255d.
- 8. Thoracic segment, ×10, USNM 177255c.
- 9. Hypostome, ×10, USNM 177255b.
- 10. Pygidium, ×10, USNM 177255e.
- All from USGS colln. 3790–CO, Nevada Test Site.

11. *Zacanthoides*? sp. (p. 98).
- Pygidium, ×4, USNM 177256, USGS colln. 4140–CO, Grapevine Mountains, Calif.

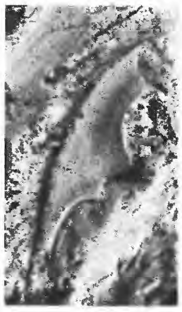
13–15. *Oryctocephalus nyensis* n. sp. (p. 84).
- 13. Latex cast of holotype cranidium, ×5, USNM 177257.
- 14. Latex cast of pygidium, ×5, USNM 208042.
- 15. Latex cast of thorax and pygidium, ×5, USNM 208043.
- All from USGS colln. 4435–CO, Belted Range, Nev.

16. *Fieldaspis*? sp. (p. 92).
- Pygidium, USNM 208044, USGS colln. 4139–CO, Grapevine Mountains, Calif.

17–20, 23. *Plagiura extensa* n. sp. (p. 113).
- 17. Holotype cranidium, ×10, USNM 208045.
- 18. Exfoliated cranidium, ×5, USNM 208046.
- 19, 20. Top and oblique views, small cranidium, ×10, USNM 208047.
- 23. Free cheek, ×10, USNM 208048.
- Figures 17, 18, and 23 from USGS colln. 3691–CO, Groom Range, Nev. Figures 19 and 20 from USGS colln. 3546–CO, Nevada Test Site.

21, 24–27. *Plagiura retracta* n. sp. (p. 114).
- 21. Small cranidium, ×10, USNM 208049.
- 24. Free cheek, ×8, USNM 208050.
- 25. Cranidium, ×10, USNM 208051.
- 26, 27. Top and oblique views, holotype cranidium, ×6, USNM 208052.
- All specimens from USGS colln. 3546–CO, Nevada Test Site.

22. *Plagiura* cf. *P. cercops* (Walcott) (p. 115).
- Incomplete cephalon, ×5, USNM 208053, USGS colln. 7189–CO, Funeral Mountains, Calif.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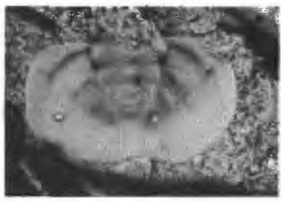
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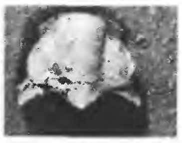
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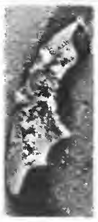
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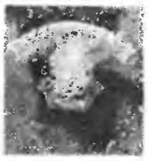
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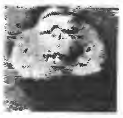
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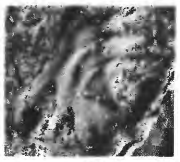
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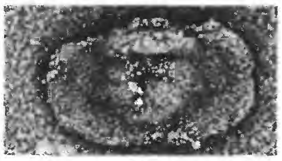
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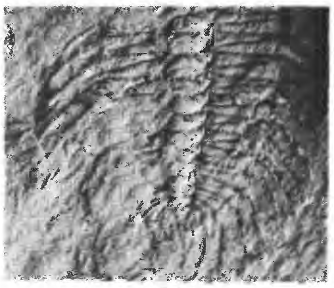
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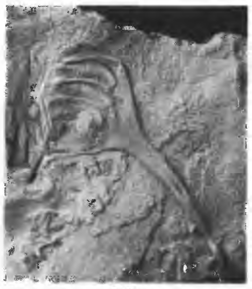
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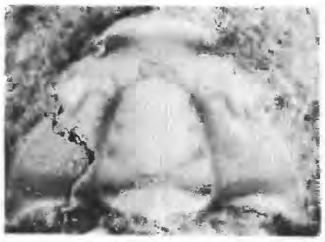
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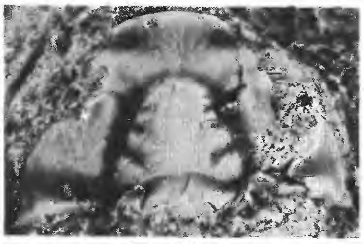
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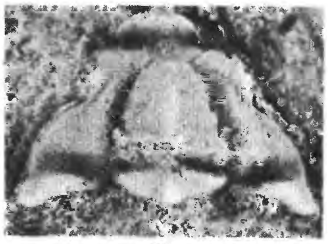
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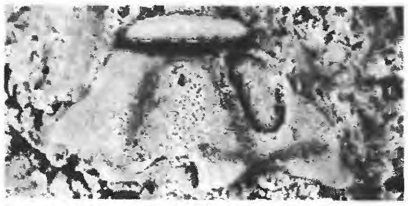
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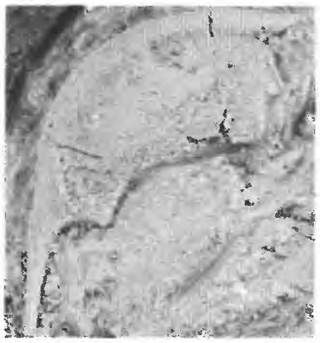
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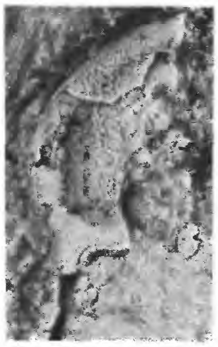
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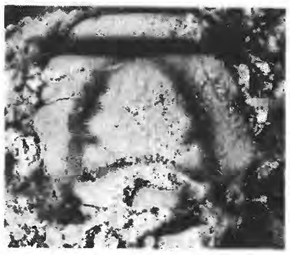
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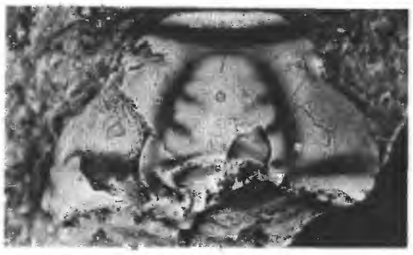
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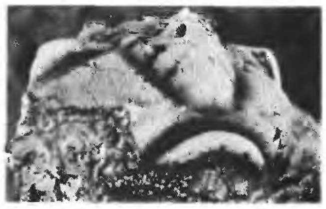
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"PLAGIURA-POLIELLA" ZONE

PLATE 7

"PLAGIURA-POLIELLA" AND *ALBERTELLA* ZONES

FIGURES

- 1–5. *Eoptychoparia piochensis* n. sp. (p. 105).
  - 1. Free cheek, ×4, USNM 208054.
  - 2. Latex cast of cranidium and partial thorax, ×5, USNM 208055.
  - 3. Latex cast of surface of shale showing abundance of specimens and effects of tectonic distortion, ×5, USNM 208056.
  - 4. Holotype cranidium, ×6, USNM 208057.
  - 5. Left lateral view of partially preserved complete specimen, ×6, USNM 208058.
  - All from USGS colln. 7231–CO, *"Plagiura-Poliella"* Zone, Highland Range, Nev.
- 6–13, 15. *Syspacephalus obscurus* n. sp. (p. 116).
  - 6. Typical cranidium, ×10, USNM 208059.
  - 7. Free cheek, ×8, USNM 208060.
  - 8, 12. Top and right side views of holotype cranidium, ×10, USNM 208061.
  - 9. Small cranidium showing dorsal furrows moderately well developed, ×20, USNM 208062.
  - 10. Cranidium—variant with unusually well developed glabellar furrows, ×15, USNM 208063.
  - 11. Rostral plate, silicified, ×10, USNM 208064.
  - 13. Pygidium, ×10, USNM 208065.
  - 15. Pygidium, ×10, USNM 208066.
  - All from USGS colln. 4140–CO, *Albertella* Zone, Grapevine Mountains, Calif.
- 14, 16–18. *Syspacephalus longus* n. sp. (p. 115).
  - 14. Latex cast of free cheek, ×5, USNM 208067.
  - 16. Latex cast of pygidium, ×8, USNM 208068.
  - 17. Latex cast of cranidium and attached thorax, ×5, USNM 208069. Note—small bumps on cranidium are artifacts of preparation. Surface is smooth.
  - 18. Latex cast of holotype specimen, ×5, USNM 208070.
  - All from USGS colln. 4435–CO, *"Plagiura-Poliella"* Zone, Belted Range, Nev.


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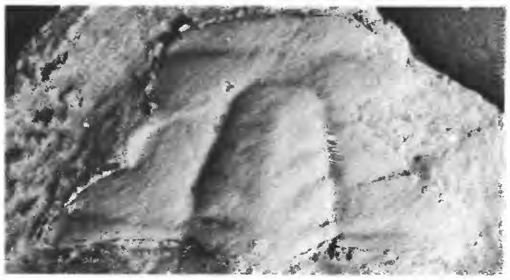
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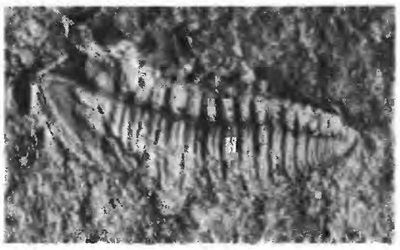
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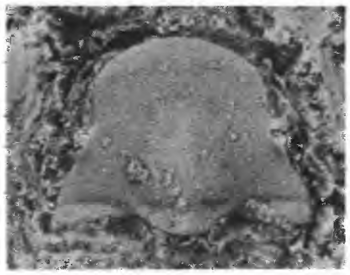
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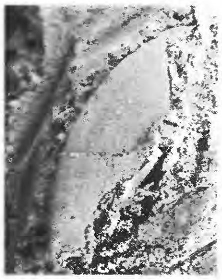
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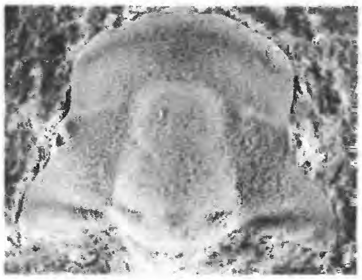
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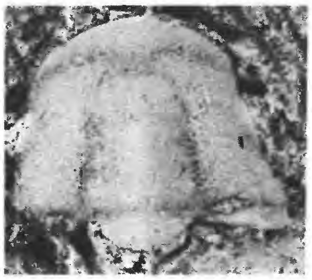
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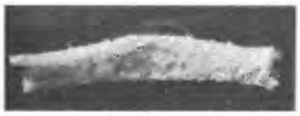
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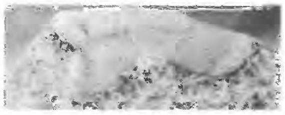
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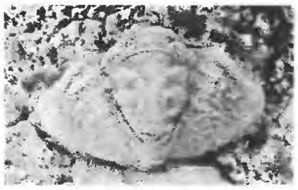
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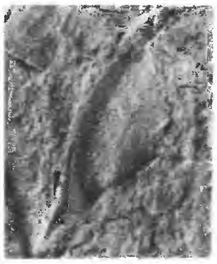
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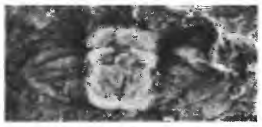
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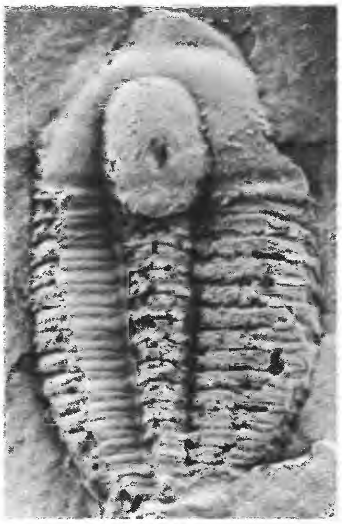
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"*PLAGIURA-POLIELLA*" AND *ALBERTELLA* ZONES

PLATE 8

"PLAGIURA-POLIELLA" ZONE

FIGURES 1, 2, 5, 6. *Schistometopus* spp. (p. 115).
- 1. Cranidium, ×3, USNM 208071, USGS colln. 4139–CO, Grapevine Mountains, Calif.
- 2. Cranidium, ×6, USNM 208072, USGS colln. 3546–CO, Nevada Test Site.
- 5. Pygidium, ×3, USNM 208073, USGS colln. 4139–CO, Grapevine Mountains, Calif.
- 6. Cranidium, ×10, USNM 208074, USGS colln. 3546–CO, Nevada Test Site.

3, 4, 7. *Kochiellina groomensis* n. gen., n. sp. (p. 107).
- 3. Holotype cranidium, ×4, USNM 208075.
- 4. Free cheek, ×6, USNM 208076.
- 7. Pygidium, ×5, USNM 208076a.
- All from USGS colln. 3691–CO, Groom Range, Nev.

8, 12, 13. *Kochaspis liliana*? (Walcott) (p. 106).
- 8. Latex cast of cranidium, ×4, USNM 208077.
- 12. Pygidium, ×5, USNM 208078.
- 13. Pygidium, ×8, USNM 208079.
- All from USGS colln. 3546–CO, Nevada Test Site.

9, 14, 17, 18. Kochaspid sp. undet. 1 (p. 108).
- 9, 14. Oblique and top views of cranidium, ×6, USNM 208080.
- 17. Free cheek, ×8, USNM 208081.
- 18. Cranidium, ×6, USNM 208082.
- All from USGS colln. 4434–CO, Belted Range, Nev.

10, 11. *Kochaspis*? sp. undet. (p. 106).
- 10. Cranidium, ×2, USNM 208083.
- 11. Free cheek, ×2, USNM 208084.
- Both from USGS colln. 3691–CO, Groom Range, Nev.

15, 16. *Kochaspis augusta* (Walcott) (p. 105).
- 15. Pygidium, ×6, USNM 208085.
- 16. Pygidium, ×4, USNM 208086.
- Both from USGS colln. 3691–CO, Groom Range, Nev.

19. Ptychopariid sp. undet. 8 (p. 119).
- Cranidium, ×2, USNM 208087, USGS colln. 4148–CO, Funeral Mountains, Calif.

20, 24. *Kochiellina janglensis* n. gen., n. sp. (p. 107).
- 20. Holotype cranidium, ×2, USNM 208088.
- 24. Pygidium, ×4, USNM 208089.
- Both from USGS colln. 3546–CO, Nevada Test Site.

21, 22. Kochaspid sp. undet. 2 (p. 108).
- 21. Cranidium, ×10, USNM 208090.
- 22. Pygidium, ×10, USNM 208091.
- Both from USGS colln. 3790–CO,Nevada Test Site.

23. cf. *Mexicella*? *stator* (Walcott) (p. 109).
- Cranidium, ×3, USNM 208092, USGS colln. 7234–CO, Grapevine Mountains, Calif.


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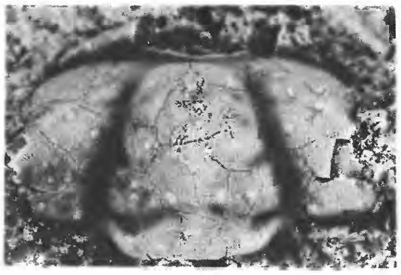
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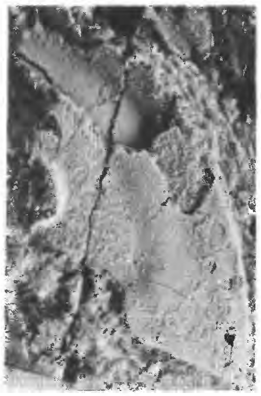
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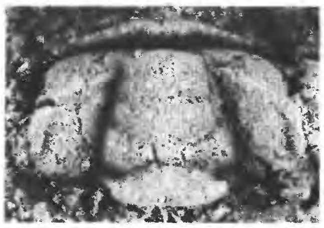
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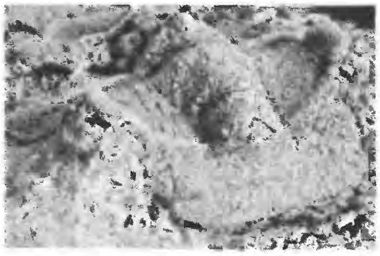
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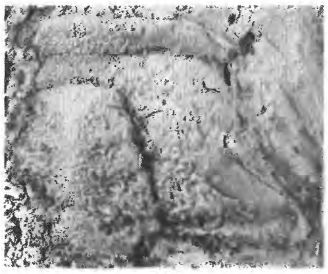
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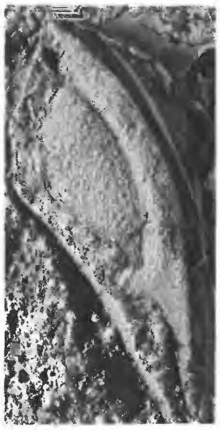
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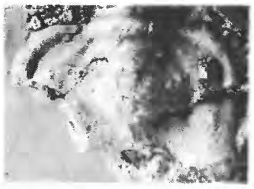
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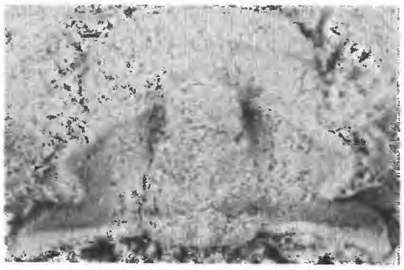
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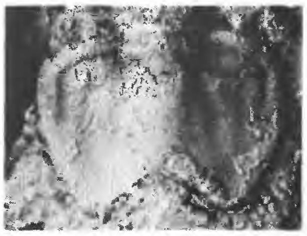
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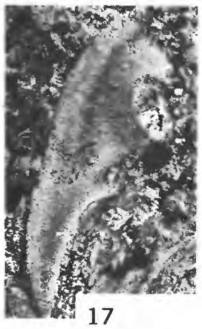
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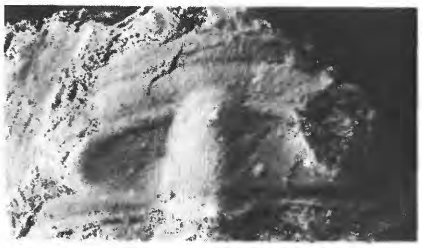
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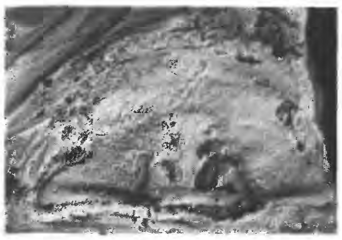
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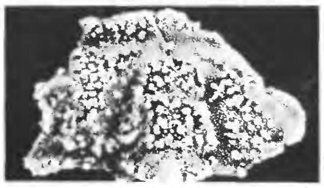
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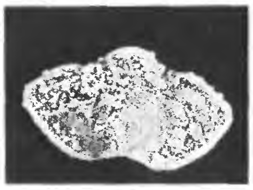
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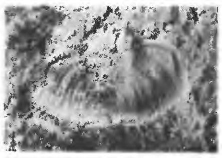
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"PLAGIURA-POLIELLA" ZONE

PLATE 9

ALBERTELLA ZONE

FIGURES 1–3, 6, 7, 9, 10. *Albertella longwelli* n. sp. (p. 87).
1. Free cheek, ×3, USNM 208093.
2. Cranidium, ×3, USNM 208094.
3. Cranidium, ×4, USNM 208095.
6. Hypostome, ×4, USNM 208096.
7. Free cheek, ×4, USNM 208097.
9. Holotype pygidium, ×3, USNM 208098.
10. Pygidium, ×6, USNM 208099.

Figures 1, 2, 9 from USGS colln. 1616–CO, Spring Mountains, Nev.; figures 3, 6, 7, 10 from USGS colln. 4165–CO, Eagle Mountain, Calif.

4, 5, 8, 11, 12, 16. *Albertella spectrensis* n. sp. (p. 88).
4. Cranidium, ×4, USNM 208100.
5. Free cheek, ×4, USNM 208101.
8. Cranidium, ×6, USNM 208102.
11. Hypostome, ×5, USNM 208103.
12. Holotype pygidium, ×4, USNM 208104.
16. Pygidium, ×8, USNM 208105.

All from USGS colln. 4169–CO, Spectre Range, Nev.

13–15, 17, 18. *Albertella schenki* (Resser) (p. 88).
13. Latex cast of cranidium, ×3, USNM 208106.
14. Free cheek,×4, USNM 208107.
15. Pygidium, ×2, USNM 208108.
17. Latex cast of cranidium, ×5, USNM 208109.
18. Latex cast of hypostome, ×3, USNM 208110.

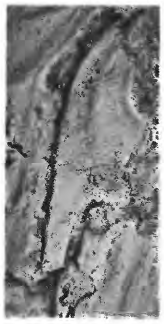
All from USGS colln. 3543–CO, Desert Range, Nev.

19–25. *Paralbertella bosworthi* (Walcott) (p. 94).
19. Cranidium, ×2, USNM 208111.
20. Cranidium, ×3, USNM 208112.
21. Cranidium, ×4, USNM 208113.
22. Hypostome, ×3, USNM 208114.
23. Pygidium, ×2, USNM 208115.
24. Pygidium, ×4, USNM 208116.
25. Pygidium, ×4, USNM 208117.

All from USGS colln. 3766–CO, Nevada Test Site.

26. Corynexochid pygidium undet. 1 (p. 98).

Pygidium, ×4, USNM 208118, USGS colln. 1616–CO, Spring Mountains, Nev.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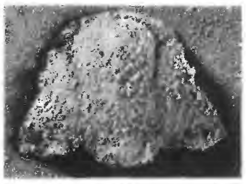
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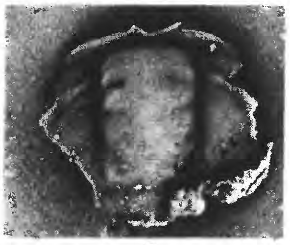
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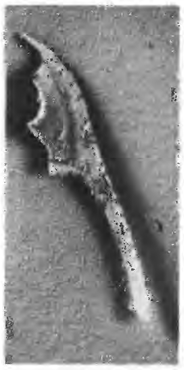
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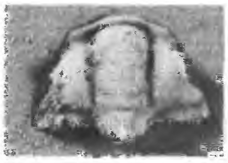
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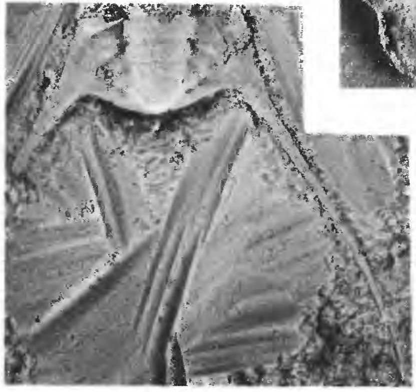
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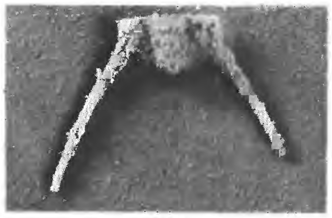
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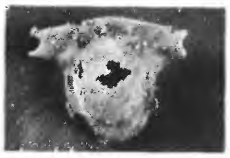
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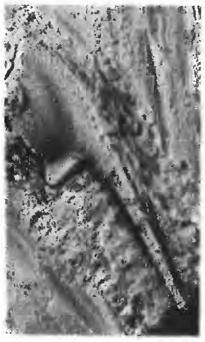
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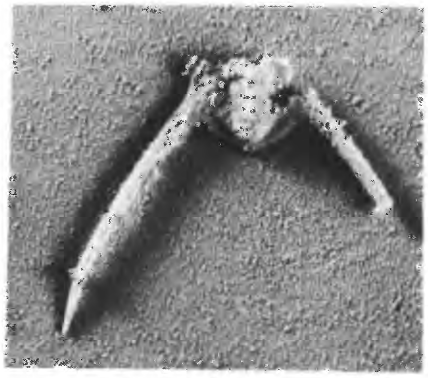
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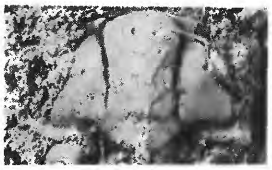
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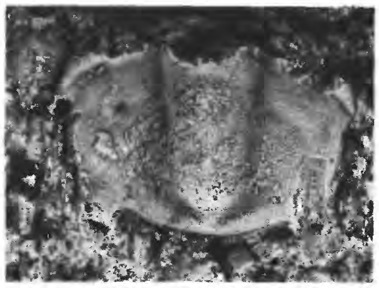
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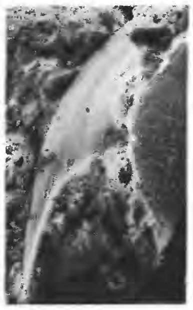
ALBERTELLA ZONE

PLATE 10

ALBERTELLA ZONE

FIGURES 1–6. *Albertella aspinosa* n. gen., n. sp. (p. 90).
  1. Latex cast of free cheek, ×4, USNM 208119.
  2. Cranidium, ×3, USNM 208120.
  3. Holotype pygidium, ×3, USNM 208121.
  4. Pygidium, ×3, USNM 208122.
  5. Hypostome, ×4, USNM 208123.
  6. Pygidium, ×4, USNM 208124.
  Figures 1–3, 5, 6 from USGS colln. 7195–CO, Desert Range, Nev.; figure 4 from USGS colln. 4169–CO, Spectre Range, Nev.
7–13. *Albertelloides mischi* (Fritz) (p. 90).
  7. Free cheek, ×2, USNM 208125.
  8. Cranidium, ×2, USNM 208126.
  9. Articulated specimen, ×2, USNM 208127.
  10. Free cheek, ×1.5, USNM 208128.
  11. Pygidium, ×3, USNM 208129.
  12. Pygidium, ×3, USNM 208130.
  13. Hypostome and cranidium, ×3, USNM 208131.
  Figure 9 from USGS colln. 3484–CO; all other specimens from USGS colln. 3766–CO; both collections from Nevada Test Site.
14–20. *Albertelloides rectimarginatus* n. sp. (p. 91).
  14. Free cheek, ×1.5, USNM 208132.
  15. Latex cast of cranidium, ×2, USNM 208133.
  16. Cranidium, ×2, USNM 208134.
  17. Cranidium, ×3, USNM 208135.
  18. Holotype pygidium, ×3, USNM 208136.
  19. Pygidium, ×3, USNM 2081037.
  20. Hypostome, ×2, USNM 208138.
  All from USGS colln. 3547–CO, Nevada Test Site.
21. Corynexochid pygidium undet. 2 (p. 98).
  Pygidium, ×4, USNM 208139, USGS colln. 3547–CO, Nevada Test Site.
22–25. *Mexicaspis radiatus* n. sp. (p. 92).
  22. Pygidium, ×3, USNM 208140.
  23. Holotype pygidium, ×3, USNM 208141.
  24. Cranidium, ×3, USNM 208142.
  25. Free cheek, ×2, USNM 208143.
  All from USGS colln. 4141–CO, Titanothere Canyon section, Grapevine Mountains, Calif.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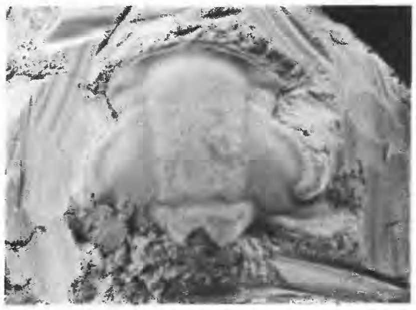
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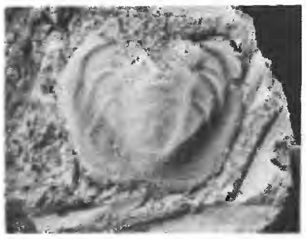
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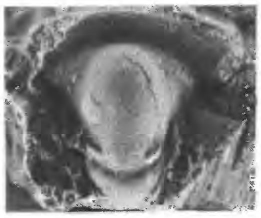
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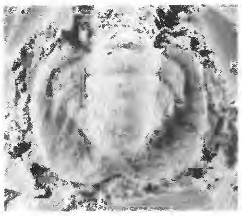
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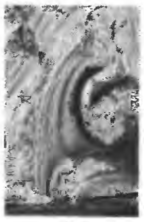
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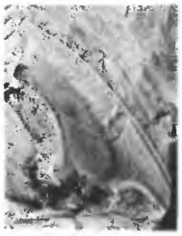
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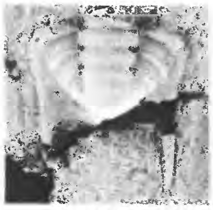
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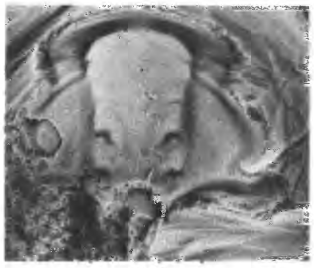
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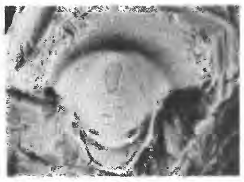
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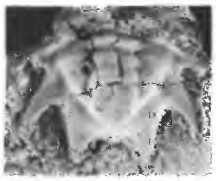
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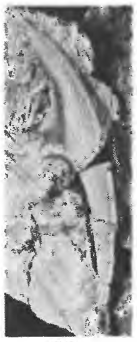
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ALBERTELLA ZONE

PLATE 11

ALBERTELLA ZONE

FIGURES 1–8. *Poliella germana* (Resser) (p. 79).

- 1. Latex cast of free cheek, ×2, USNM 208144.
- 2. Cranidium, ×2, USNM 208145.
- 3. Cranidium, ×2, USNM 208146.
- 4. Small cranidium, ×5, USNM 208147.
- 5. Pygidium, ×2, USNM 208148.
- 6. Pygidium, ×2, USNM 208149.
- 7. Hypostome, ×3, USNM 208150.
- 8. Pygidium, ×3, USNM 208151.
- All from USGS colln. 3695–CO, Nevada Test Site.

9–11, 14–16. *Ptarmiganoides hexacantha* n. sp. (p. 96).

- 9. Cranidium, ×2, USNM 208152.
- 10. Cranidium, ×3, USNM 208153.
- 11. Free cheek, ×2, USNM 208154.
- 14. Cranidium, ×3, USNM 208155.
- 15, 16. Top and profile views of holotype pygidium, ×3, USNM 208156.
- All from USGS colln. 4141–CO, Titanothere Canyon section, Grapevine Mountains, Calif.

12, 13, 17, 18. *Ptarmiganoides crassaxis* n. sp. (p. 95).

- 12. Cranidium, ×2, USNM 208157.
- 13. Free cheek, ×2, USNM 208158.
- 17. Holotype pygidium, composite photo, ×4, USNM 208159.
- 18. Small cranidium, ×6, USNM 208160.
- All from USGS colln. 3766–CO, Nevada Test Site.

19–21. *Zacanthoides variacantha* n. sp. (p. 97).

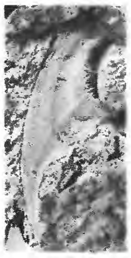
- 19. Cranidium, ×4, USNM 208161.
- 20. Holotype pygidium, ×4, USNM 208162.
- 21. Latex cast of pygidium, ×3, USNM 208163.
- All from USGS colln. 3766–CO, Nevada Test Site.

22–24, 27–30. *Kootenia germana* (Resser) (p. 81).

- 22. Cranidium, ×1.5, USNM 208164.
- 23. Cranidium, ×3, USNM 208165.
- 24. Cranidium, ×3, USNM 208166.
- 27. Pygidium, ×2, USNM 208167.
- 28. Pygidium,×1.5, USNM 208168.
- 29. Pygidium, ×2, USNM 208169.
- 30. Latex cast of articulated specimen, ×1.5, USNM 208170.
- Figures 22–28 from USGS colln. 3695–CO, Nevada Test Site; figure 29 from USGS colln. 3547–CO, Nevada Test Site; figure 30 from USGS colln. 3692–CO, Groom Range, Nev.

25, 26. *Zacanthoides* cf. *Z. alatus* (Resser) (p. 97).

- 25. Cranidium, ×3, USNM 208171.
- 26. Pygidium, ×4, USNM 208172.
- Both from USGS colln. 3695–CO, Nevada Test Site.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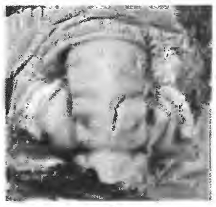
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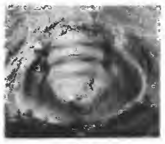
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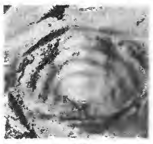
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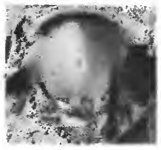
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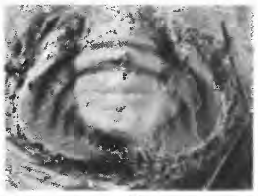
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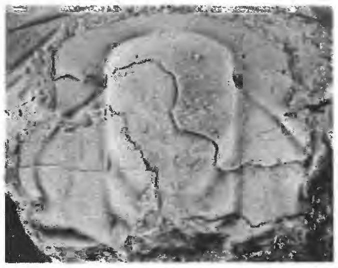
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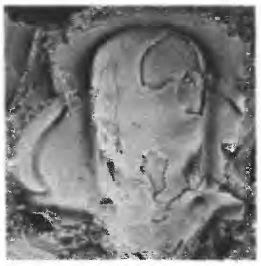
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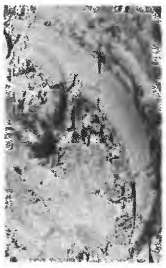
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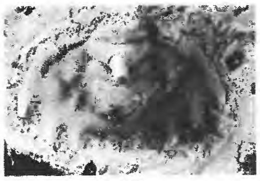
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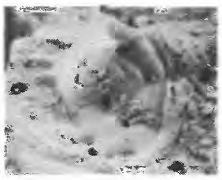
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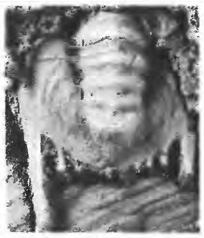
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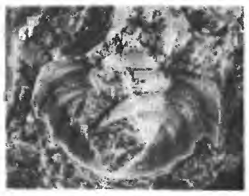
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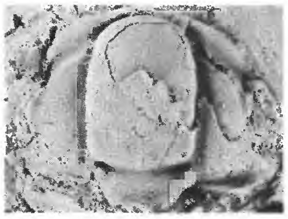
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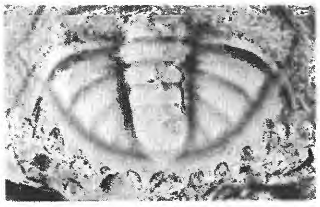
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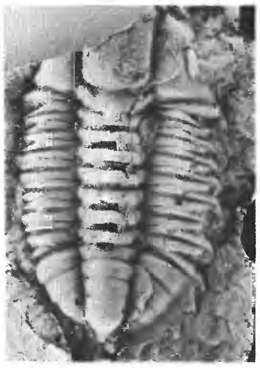
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ALBERTELLA ZONE

PLATE 12

ALBERTELLA ZONE

FIGURES

- 1–4. *Ogygopsis typicalis* (Resser) (p. 82).
  - 1. Complete individual, ×2, USNM 208173.
  - 2. Pygidium, ×1.5, USNM 208174.
  - 3. Latex cast of pygidium, ×2, USNM 208175.
  - 4. Hypostome, ×3, USNM 208176.
  - All from USGS colln. 4438–CO, Belted Range, Nev.
- 5. *Thoracocare idahoensis* (Resser) (p. 85).
  - Pygidium, ×15, USNM 208177, USGS colln. 4438–CO, Belted Range, Nev.
- 6. Oryctocephalid sp. undet. (p. 85).
  - Pygidium, ×3, USNM 208178, USGS colln. 4438–CO, Belted Range, Nev.
- 7. *Peronopsis*? sp. (p. 76).
  - Pygidium, ×10, USNM 208179, USGS colln. 4437–CO, Belted Range, Nev.
- 8, 12. *Macannaia maladensis* (Resser) (p. 76).
  - 8. Cranidium, ×20, USNM 208180.
  - 12. Pygidium, ×20, USNM 208181.
  - Both from USGS colln. 4436–CO, Belted Range, Nev.
- 9, 13. *Pagetia rugosa* (Rasetti) (p. 77).
  - 9. Cranidium, ×20, USNM 208182.
  - 13. Pygidium, ×20, USNM 208183.
  - Both from USGS colln. 4438–CO, Belted Range, Nev.
- 10, 14. *Pagetia* sp. (p. 77).
  - 10. Cranidium, ×20, USNM 208184.
  - 14. Pygidium, ×20, USNM 208185.
  - Both from USGS colln. 3766–CO, Nevada Test Site.
- 11, 15. *Peronopsis bonnerensis* (Resser) (p. 76).
  - 11. Cephalon, ×10, USNM 208186, USGS colln. 4437–CO.
  - 15. Latex cast of pygidium, ×10, USNM 208187, USGS colln. 4438–CO.
  - Both from Belted Range, Nev.
- 16–20, 23–26. *Pagetia resseri* (Kobayashi) (p. 77).
  - 16, 17. Immature cranidia, ×30, USNM 208188g, f.
  - 18. Immature pygidium, ×30, USNM 208188j.
  - 19. Small cranidium, ×15, USNM 208188e.
  - 20. Cranidium, ×15, USNM 208188b.
  - 23. Free cheek, ×30, USNM 208188a.
  - 24. Pygidium, ×15, USNM 208188h.
  - 25. Cranidium, ×20, USNM 208189.
  - 26. Pygidium, ×20, USNM 208190.
  - Figures 18–20, 23, 24 from USGS colln. 3547–CO; figures 25, 26, from USGS colln. 3766–CO; both from Nevada Test Site.
- 21, 22, 27. *Oryctocephalina maladensis* (Resser) (p. 83).
  - 21. Cranidium, ×4, USNM 208191.
  - 22. Cranidium, ×5, USNM 208192.
  - 27. Cranidium, ×5, USNM 208193.
  - All from USGS colln. 3766–CO, Nevada Test Site.


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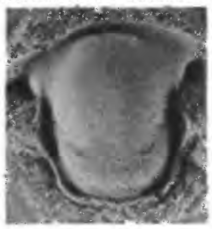
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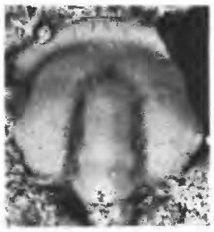
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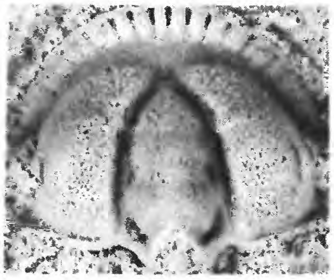
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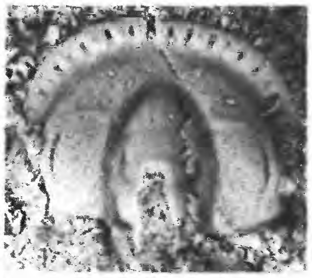
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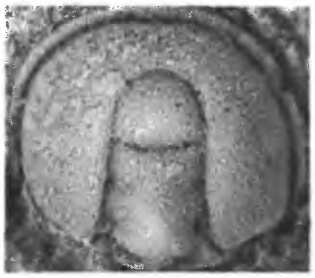
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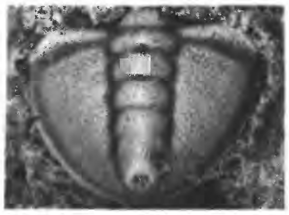
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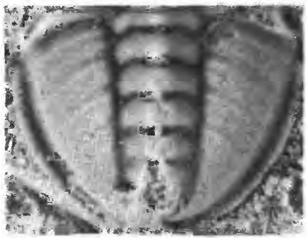
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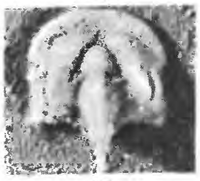
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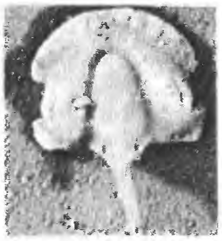
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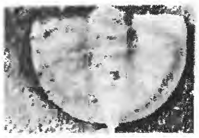
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ALBERTELLA ZONE

PLATE 13

ALBERTELLA ZONE

FIGURES 1–4. *Oryctocephalites typicalis* (Resser) (p. 84).

1. Cranidium with weak furrows, ×8, USNM 208194.
2. Typical cranidium, ×8, USNM 208195.
3. Small cranidium, ×8, USNM 208196.
4. Pygidium, ×8, USNM 208197.

All from USGS colln. 3766–CO, Nevada Test Site.

5, 9, 10. *Mexicella grandoculus* n. sp. (p. 109).

5, 9. Top and oblique views, holotype cranidium, ×6, USNM 208198.

10. Small cranidium, ×12, USNM 208199.

All from USGS colln. 4141–CO, Titanothere Canyon section, Grapevine Mountains, Calif.

6. *Caborcella pseudaulax* n. sp. (p. 102).

Holotype cranidium, composite photo, ×3, USNM 208200, USGS colln. 3547–CO, Nevada Test Site.

7, 8. *Caborcella reducta* n. sp. (p. 102).

7. Holotype cranidium, ×3, USNM 208201.
8. Cranidium, ×3, USNM 208202.

Both from USGS colln. 3547–CO, Nevada Test Site.

11, 12. *Chancia* cf. *C. venusta* (Resser) (p. 103).

11. Latex cast of cranidium, ×3, USNM 208203.
12. Small cranidium, ×6, USNM 208204.

Both from USGS colln. 3547–CO, Nevada Test Site.

13–21. *Mexicella mexicana* (Lochman) (p. 109).

13. Free cheek, ×4, USNM 208205.

14, 15. Top and oblique views of cranidium, ×8, USNM 208206.

16. Large cranidium, ×3, USNM 208207.
17. Free cheek, ×10, USNM 208208.
18. Large cranidium, ×2, USNM 208209.
19. Cranidium, ×6, USNM 208210.
20. Cranidium, ×10, USNM 208211.
21. Free cheek, ×10, USNM 208212.

Figures 13–17 from USGS colln. 7196–CO, Desert Range, Nev.; figures 18, 19, from USGS colln. 3543–CO, Desert Range, Nev.; figures 20, 21, from USGS colln. 4165–CO, Eagle Mountain, Calif.

22–25. *Plagiura minor* n. sp. (p. 114).

22. Cranidium, ×10, USNM 208213.
23. Free cheek, ×10, USNM 208214.
24. Holotype cranidium, ×10, USNM 208215.
25. Free cheek, ×10, USNM 208216.

Figures 22, 23 from USGS colln. 4165–CO, Eagle Mountain, Calif.; figures 24, 25 from USGS colln. 7196–CO, Desert Range, Nev.


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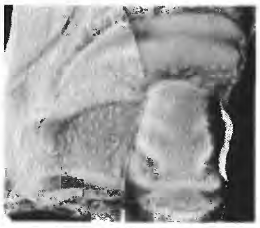
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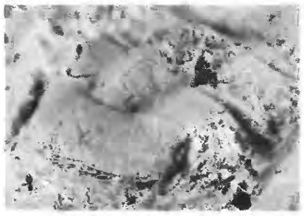
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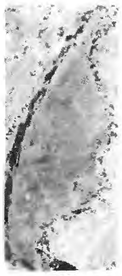
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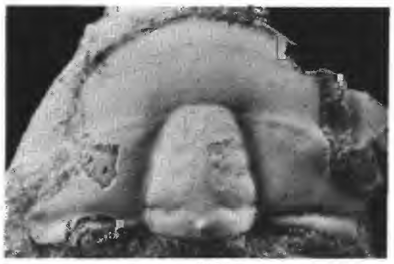
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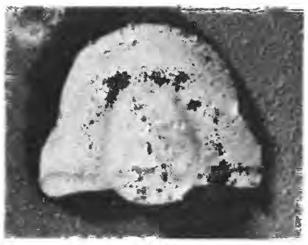
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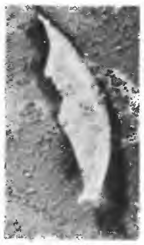
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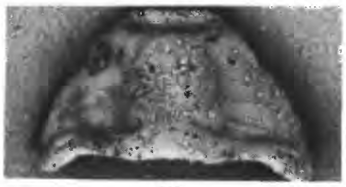
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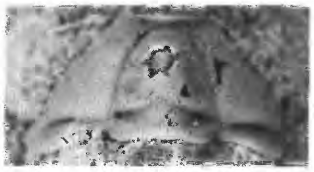
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ALBERTELLA ZONE

PLATE 14

ALBERTELLA ZONE

FIGURES

1–4. *Nyella clinolimbata* (Fritz) (p. 110).
  1,2. Top and oblique views of cranidium, ×6, USNM 208217.
  3. Cranidium, ×5, USNM 208218.
  4. Free cheek, ×4, USNM 208219.
  All from USGS colln. 3766–CO, Nevada Test Site.

5–10. *Nyella granosa* (Resser) (p. 111).
  5. Free cheek, ×5, USNM 208274.
  6. Cranidium, ×4, USNM 208275.
  7. Cranidium, ×8, USNM 208276.
  8. Pygidium, ×8, USNM 208277.
  9. Cranidium, ×4, USNM 208278.
  10. Cranidium, ×8, USNM 208279.
  Figures 5–8 from USGS colln. 3695–CO, Nevada Test Site; figure 9 from USGS colln. 4440–CO, Groom Range, Nev.; figure 10, from USGS colln. 3766–CO, Nevada Test Site.

11, 12. *Nyella immoderata* n. gen., n. sp. (p. 112).
  11. Holotype cranidium, ×6, USNM 208280.
  12. Cranidium, ×10, USNM 208281.
  Both from USGS colln. 3766–CO, Nevada Test Site.

13–16, 20. *Volocephalina contracta* n. gen., n. sp. (p. 117).
  13, 14. Top and oblique views, holotype cranidium; ×12, USNM 208282.
  15. Cranidium, ×10, USNM 208283.
  16. Cranidium, ×10, USNM 208220.
  20. Free cheek, ×10, USNM 208221.
  Figure 13–15 from USGS colln. 4158–CO, Pyramid Peak section; figures 16, 20 from USGS colln. 4149–CO, Echo Canyon section; both in the Funeral Mountains, Calif.

17, 18, 21, 22. *Volocephalina connexa* n. gen., n. sp. (p. 117).
  17, 18. Top and oblique views of holotype cranidium, ×8, USNM 208222.
  21. Latex cast of cranidium, ×10, USNM 208223.
  22. Cranidium, ×10, USNM 208224.
  Figures 17, 18, 21, from USGS colln. 3547–CO, Nevada Test Site; figure 22 from USGS colln. 4141–CO, Titanothere Canyon section, Grapevine Mountains, Calif.

19. Ptychopariid sp. undet. 9, (p. 119).
  Cranidium, ×5, USNM 208225, USGS colln. 4440–CO, Groom Range, Nev.

23. Ptychopariid pygidium undet. 1, (p. 121).
  Pygidium, ×8, USNM 208226, USGS colln. 3766–CO, Nevada Test Site.

24. Ptychopariid pygidium undet. 2, (p. 121).
  Pygidium, ×8, USNM 208227, USGS colln. 3766–CO, Nevada Test Site.


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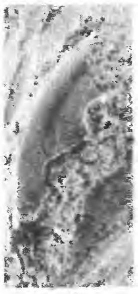
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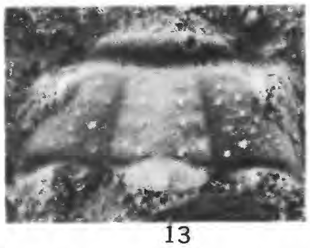
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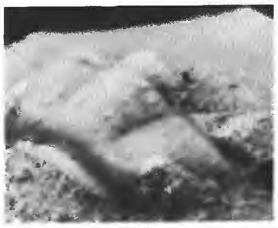
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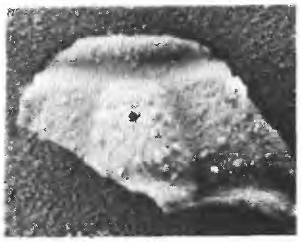
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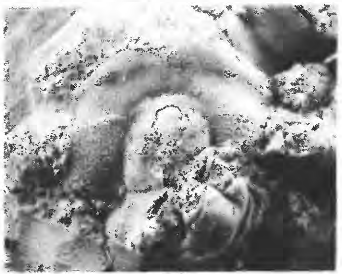
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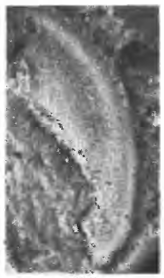
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ALBERTELLA ZONE

PLATE 15

ALBERTELLA ZONE

Figures 1–3. *Elrathina antiqua* n. sp. (p. 103).

1. Holotype, nearly complete individual, ×4, USNM 208228.
2. Cranidium, ×6, USNM 208229.
3. Free cheek, ×6, USNM 208230.

Figure 1 from USGS colln. 4437–CO; figures 2, 3 from USGS colln. 4438–CO; both from Belted Range, Nev.

4. *Chancia*? *maladensis* (Resser) (p. 103).

Cranidium, ×4, USNM 208231, USGS colln. 4438–CO, Belted Range, Nev.

5. Ptychopariid sp. undet. 5 (p. 118).

Cranidium, ×10, USNM 208232, USGS colln. 3547–CO, Nevada Test Site.

6. Ptychopariid sp. undet. 6 (p. 119).

Cranidium, ×12, USNM 208233, USGS colln. 3766–CO, Nevada Test Site.

7. Ptychopariid sp. undet. 7 (p. 119).

Cranidium, ×6, USNM 208234, USGS colln. 3695–CO, Nevada Test Site.

8. *Pachyaspis gallagari* (Fritz) (p. 112).

Complete individual, ×4, USNM 208235, USGS colln. 3692–CO, Groom Range, Nev.

GLOSSOPLEURA ZONE

9–14. *Alokistocarella*? cf. *A. brighamensis* (Resser) (p. 100).

9. Free cheek, ×4, USNM 208236.
10. Cranidium, ×3, USNM 208237.
11. Cranidium, ×5, USNM 208238.
12. Pygidium, ×4, USNM 208239.
13. Cranidium, ×3, USNM 208240.
14. Free cheek, ×3, USNM 208241.

Figures 9–12 from USGS colln. 4155–CO, Echo Canyon section, Funeral Mountains, Calif.; figures 13, 14 from USGS colln. 3690–CO, Striped Hills, Nev.

15. Ptychopariid sp. undet. 10 (p. 120).

Cranidium, ×5, USNM 208242, USGS colln. 4155–CO, Echo Canyon section, Funeral Mountains, Calif.

16. Ptychopariid sp. undet. 11 (p. 120).

Cranidium, ×8, USNM 208243, USGS colln. 4155–CO, Echo Canyon section, Funeral Mountains, Calif.

17, 21. *Alokistocarella*? sp. (p. 101).

17. Latex cast of cranidium, ×5, USNM 208244, USGS colln. 3545–CO, Nevada Test Site.

21. Cranidium, ×6, USNM 208245 USGS colln. 3767, Nevada Test Site.

18. *Alokistocare* sp. 1 (p. 99).

Latex cast of cranidium, ×4, USNM 208246, USGS colln. 7198–CO, Eagle Mountain, Calif.

19, 20. Ptychopariid sp. undet. 12 (p. 120).

19, 20. Top and oblique views, cranidium, ×8, USNM 208247, USGS colln. 7199–CO, Striped Hills, Nev.

22. *Alokistocare* sp. 2 (p. 100).

Latex cast of cranidium, ×4, USNM 208248, USGS colln. 7199–CO, Striped Hills, Nev.


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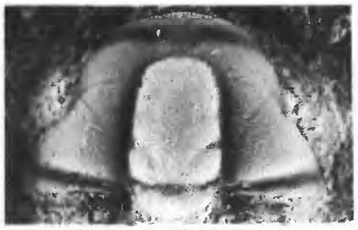
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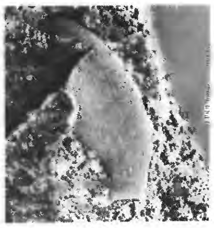
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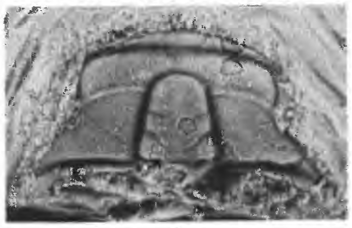
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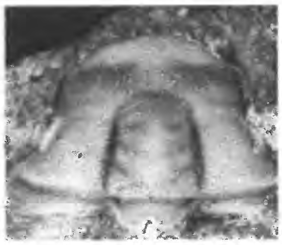
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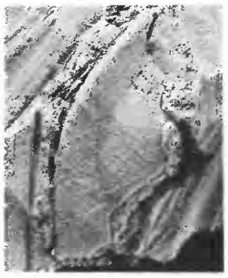
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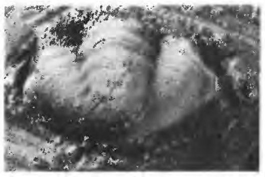
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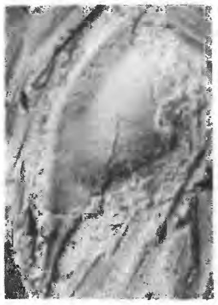
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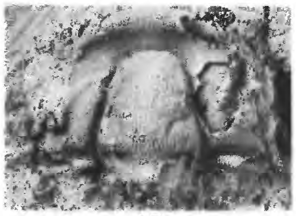
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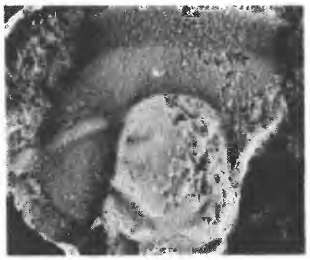
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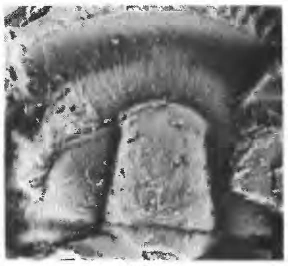
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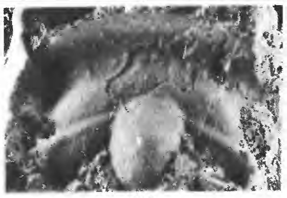
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ALBERTELLA AND *GLOSSOPLEURA* ZONES

PLATE 16

GLOSSOPLEURA ZONE

FIGURES 1–5, 9, 10. *Glossopleura lodensis* (Clark) (p. 78).
1. Free cheek, ×2, USNM 208249.
2. Cranidium, ×2, USNM 208250.
3. Cranidium, ×4, USNM 208251.
4. Pygidium, ×4, USNM 208252.
5. Pygidia,×3,USNM 208253.
9. Pygidium, ×3, USNM 208254.
10. Pygidium, ×4, USNM 208255.

All from USGS colln. 7198–CO, Eagle Mountain, Calif.

6–8, 11–19. *Glossopleura walcotti* C. Poulsen (p. 79).
6. Cranidium, ×3, USNM 208256.
7. Free cheek, ×5, USNM 208257.
8. Small cranidium, ×6, USNM 208258.
11. Hypostome, ×6, USNM 208259.
12. Hypostome, ×5, USNM 208260.
13. Pygidium, ×1.5, USNM 208261.
14. Pygidium, ×4, USNM 208262.
15. Small pygidium, ×6, USNM 208263.
16. Free cheek, ×5, USNM 208264.
17. Cranidium, ×2, USNM 208265.
18. Pygidium, ×2, USNM 208266.
19. Pygidium, ×4, USNM 208267.

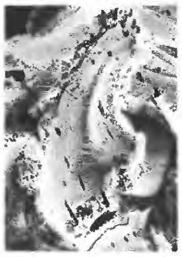
Figures 6–8, 12–15 from USGS colln.4156–CO, Echo Canyon section, Funeral Mountains, Calif,; figures 11, 16–19 from USGS colln. 4142-CO, Titanothere Canyon section, Grapevine Mountains, Calif.

20, 25. Corynexochid cranidium undet. 1 (p. 98).
20. Latex cast of cranidium, ×5, USNM 208268.
25. Small cranidium, ×6, USNM 208269.

Both from USGS colln. 7199–CO, Striped Hills, Nev.

21–24. *Glossopleura tuta* (Resser) (p. 78).
21. Latex cast of fragmentary cranidium, ×4, USNM 208270.
22. Free cheek, ×2, USNM 208271.
23. Pygidium, ×1.5, USNM 208272.
24. Pygidium, ×3, USNM 208273.

All from USGS colln. 7199–CO, Striped Hills, Nev.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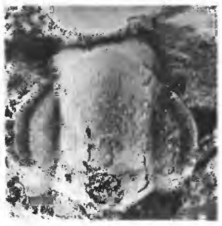
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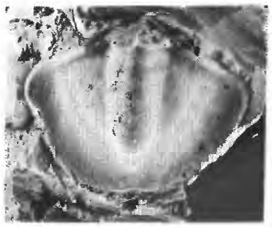
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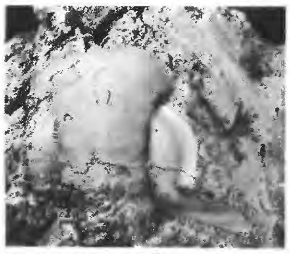
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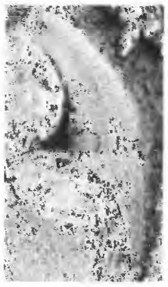
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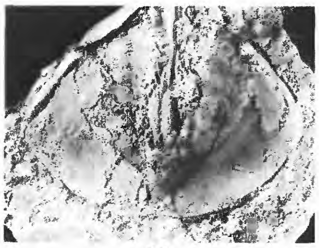
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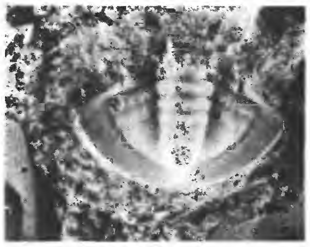
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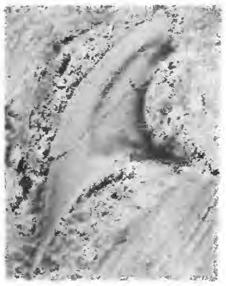
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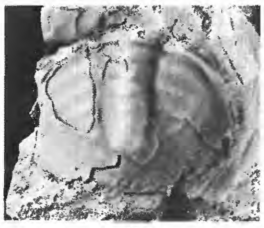
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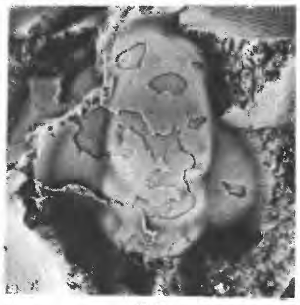
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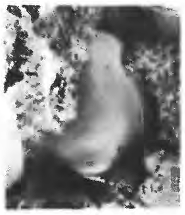
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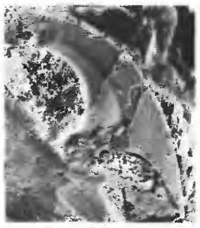
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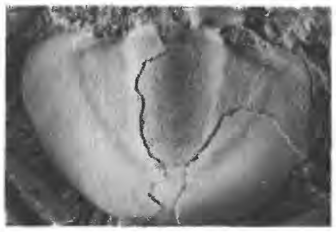
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GLOSSOPLEURA ZONE

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