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LATE CAMBRIAN AND EARLIEST ORDOVICIAN TRILOBITES WICHITA MOUNTAINS AREA, OKLAHOMA

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Title Page Illustration

Ink drawing by Roy D. Davis of unassigned pygidium L Wilson, showing the distinctive arrangement of pustules. This specimen, also illustrated on plate 2, was collected from the *Elvinia* Zone in the Reagan Sandstone of Late Cambrian age.

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LATE CAMBRIAN AND EARLIEST ORDOVICIAN TRILOBITES WICHITA MOUNTAINS AREA, OKLAHOMA

JAMES H. STITT[1]

Abstract—Upper Cambrian and Lower Ordovician rocks of the Timbered Hills and Arbuckle Groups crop out in the northwest-southeast-trending Blue Creek Canyon anticline, directly north of the Wichita Mountains in southwestern Oklahoma. Trilobites were collected from every fossiliferous bed in one complete section through the Reagan Sandstone and the Honey Creek Limestone (Timbered Hills Group) and the Fort Sill Limestone and the Signal Mountain Limestone (the lowest two formations in the Arbuckle Group). From more than 3,100 cleaned and prepared specimens, 98 species are identified and assigned to 66 genera, including 1 new genus and 2 new species. In addition, 7 taxa are generically identified but not assigned to any species, and 7 taxa are described and left in open nomenclature. Taxonomic descriptions are restricted either to new taxa not previously described from the Arbuckle Mountains (Stitt, 1971b) or to taxa for which new morphologic or biostratigraphic information is now available.

As in the Arbuckle Mountains, the oldest trilobites in the Wichita Mountains are assigned to the *Elvinia, Taenicephalus,* and *Saratogia* Zones of the Franconian Stage of the Upper Cambrian. Trilobites and brachiopods of the *Elvinia* Zone occur in the middle and upper parts of the scantily fossiliferous Reagan Sandstone, confirming a Franconian age for at least the upper half of the formation. The same taxa occur in the upper half of the Reagan Sandstone in the Wichita Mountains area that occur in the lower third of the Honey Creek Limestone in the Arbuckle Mountains to the east. This suggests the partial contemporaneity of these two rock units during deposition and perhaps an east-to-west invasion of the area by the Franconian sea. Similarly, the upper few feet of the Honey Creek Limestone in the Wichita Mountains area contains the same taxa that first occur several feet above the base of the Fort Sill Limestone in the Arbuckle Mountains. This suggests the original partial contemporaneity of these formations and an east-to-west depositional transgression of Franconian lithotopes.

Trilobites assigned to the *Saukia* Zone of the Trempealeauan Stage, the highest stage in the Upper Cambrian, occur in the upper third of the Fort Sill Limestone and the lower half of the Signal Mountain Limestone. Four subzones are recognized in the *Saukia* Zone: *Rasettia magna*, *Saukiella junia*, *Saukiella serotina*, and *Corbinia apopsis* (in ascending order). The Cambrian-Ordovician boundary occurs near the middle of the Signal Mountain Limestone, in an apparently conformable sequence of limestones.

The Royer and Butterly Dolomites of the Arbuckle Group are absent in the Chandler Creek section, in the Wichita Mountains area. Their absence is attributed to the basic difference between sedimentary environments in (1) the rapidly subsiding Southern Oklahoma geosyncline, where mostly limestone accumulated, and (2) the surrounding, more stable cratonic areas, in which carbonates accumulated that are now predominantly dolomite.

The abrupt mass extinctions of diverse trilobite faunas at the tops of the *Elvinia* and *Saukia* Zones define an extinction-bounded biostratigraphic unit called the Ptychaspid Biomere. Within this biomere, four stages are recognized in the adaptive radiation and evolutionary development of the trilobites. Speciation is common during the first two evolutionary stages, which were succeeded gradually by stage three, characterized by genera composed of normally nonoverlapping vertical successions of species. Stage four may represent an evolutionary attempt by the trilobites to meet rapidly changing environmental conditions which eventually killed all of the trilobites of the Ptychaspid Biomere.

A sudden global cooling of the climate is suggested as the mechanism that caused the extinction of the trilobites of the Ptychaspid and other biomeres. The spreading of cold polar water toward the equator might have caused a rise in the oceanic thermocline, enabling cold water to spread onto the warm, shallow-water shelf areas. This cold water might have killed trilobites adapted for life in warm water and simultaneously have triggered a replacement migration onto the shelf areas of oceanic trilobites living in the cold-water mass.

Trilobites from the upper half of the Signal Mountain Limestone constitute the faunas of the *Missisquoia* and *Symphysurina* Zones, the lowest two zones of the Lower Ordovician in North America. A *Missisquoia depressa* Subzone is recognized at the base of the *Missisquoia* Zone in the

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Wichita and Arbuckle Mountains, succeeded in both areas by the overlying *Missisquoia typicalis* Subzone. The fauna of the *M. typicalis* Subzone is widely distributed in North America and in many areas is the lowest Ordovician fauna. In Oklahoma and a few other areas, the *M. depressa* Subzone assemblage is the lowest Ordovician fauna, suggesting a possible small diachroneity in the *Missisquoia-Saukia* Zone boundary in North America.

The *Symphysurina* Zone contains a diverse and moderately abundant assemblage of trilobites and is correlated with the poorly known "A" Zone of Ross (1951) and the lower part of the *Symphysurina* (B) Zone of Hintze (1952). The fauna of this zone is more diverse and better preserved in the Chandler Creek section than in any other area where information has been published and establishes this area and the central Texas area (Winston and Nicholls, 1967) as the best reference areas in North America for this earliest Ordovician biostratigraphic interval.

If the base of the *Symphysurina* Zone is used for correlation, then the boundary between the Signal Mountain Limestone and the Butterly Dolomite in the westernmost Arbuckle Mountains correlates with an interval approximately 300 feet below the top of the Signal Mountain in the Chandler Creek section. The base of the McKenzie Hill Limestone in the westernmost Arbuckle Mountains can tentatively be correlated with an interval approximately 150 feet below the top of the Signal Mountain Limestone in the Chandler Creek section. Greater confidence in the latter correlation must await better knowledge of the faunas of the McKenzie Hill Limestone.

INTRODUCTION

In the fall of 1968, after I had completed a study of the trilobites of the Timbered Hills and lower Arbuckle Groups in the western Arbuckle Mountains, the late William E. Ham of the Oklahoma Geological Survey suggested that I study the same stratigraphic interval in the Wichita Mountains. He pointed out that with my familiarity with the trilobites of this age identification of the fauna would be relatively easy, and that taxonomic descriptions could be restricted to new taxa or to those not previously described from the western Arbuckle Mountains that might occur in the Wichita Mountains. The outcrop area had recently been mapped in detail by Harry Brookby, a master's-degree candidate working under Ham's supervision at The University of Oklahoma. Brookby (1969) found that the area was structurally less complicated than the intensely faulted Arbuckle Mountains, where unfaulted sections can be measured in only a few places. The interval I collected is entirely limestone in the Wichita Mountains (no Butterly or Royer Dolomite present), and I was able to collect a more complete fauna for the *Missisquoia* and *Symphysurina* Zones, which are partly unfossiliferous dolomite in the Arbuckle Mountains. The type sections for both the Fort Sill and Signal Mountain Limestones are located on the nearby Fort Sill military reservation, but neither formation is completely exposed at its type locality (Ham, 1969, oral communication). The Chandler Creek section that Ham suggested (fig. 1) is readily accessible, is well exposed, and should serve as a good reference section for the Upper Cambrian and Lower Ordovician rocks in the Wichita Mountains area.

I spent the summer of 1969 measuring the section and collecting fossils. The section was measured with a 5-foot Jacob's staff and a Brunton compass. Yellow stripes were painted on the outcrop every 5 feet, and numbered every 25 feet. Every exposed bed was sampled, and when fossils were recovered they were wrapped, bagged, and labeled with the footage above the base of the section. The fossils were cleaned and identified, and the new taxa were described at the University of Missouri—Columbia during the summers of 1970-73. The section was revisited for some additional collection in May 1973.

Acknowledgments

I want especially to thank the late William E. Ham of the Oklahoma Geological Survey, who suggested this project and followed with interest its progress until his death. Charles J. Mankin and the Oklahoma Geological Survey provided summer salary, vehicles, aerial photographs of the area, and various other vital support without which the project could not have been completed. The Geology Department at the University of Missouri—Columbia provided office space, microscopes and other necessary equipment, and secretarial help. W. H. Fritz and T. E. Bolton of the Geological Survey of Canada are thanked for the loan of requested type specimens.

Discussions with various geologists contributed many ideas during the course of this investigation, and exactly who contributed what is difficult if not impossible to remember now. The following geologists are especially thanked for their free exchange of ideas and unpublished data: J. R. Derby, J. F. Miller, A. R. Palmer, R. A. Robison, J. E. Shergold, and M. E. Taylor. Taylor, Derby, and Palmer carefully read and criticized the original manuscript, and they are thanked for many helpful comments and suggested improvements.

The ranchers in the area of the measured section were extremely cooperative in allowing me access to the outcrops.

Lois Huff, Beverly Sapp, and Claudia Johnson typed various versions of the original and revised manuscripts, and they are thanked for their careful work.

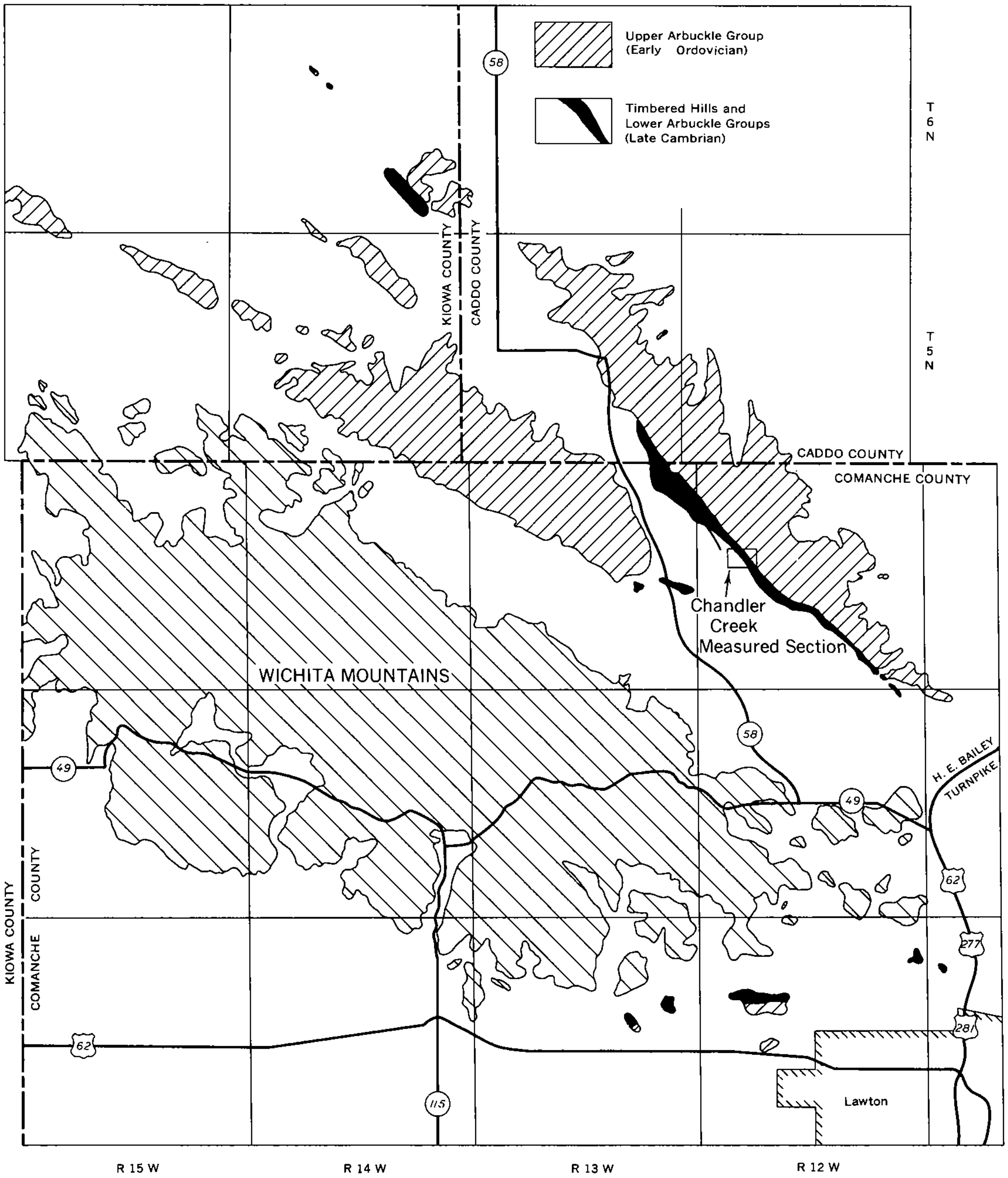

Figure 1. Index map showing area of Wichita Mountains, outcrop areas of Cambrian and Ordovician rocks, and location of Chandler Creek measured section.

LITHOSTRATIGRAPHY

Introduction

The nomenclatorial history of the Upper Cambrian and lowest Ordovician formations in the Arbuckle and Wichita Mountains has been briefly reviewed by Stitt (1971b, p. 5-7) and more extensively discussed by Frederickson (1956, p. 488-501) and will not be pursued further here. This section will concentrate on (1) a brief description of the regional tectonic elements that were established prior to deposition of these rocks, (2) lithologic descriptions of the rocks exposed in the Chandler Creek section and a comparison with the corresponding rocks in the western part of the Arbuckle Mountains, and (3) a discussion of the depositional history of the Upper Cambrian and lowest Ordovician rocks in the Wichita and Arbuckle Mountains.

Regional Setting

In their very important basement rock study, Ham and others (1964) delineated the boundaries of the northwest-trending Southern Oklahoma geosyncline, which cuts across the western part of the Arbuckle Mountains and includes the area of the Chandler Creek section. Underlain by the Carlton Rhyolite Group of Middle(?) Cambrian age and the older igneous and metasedimentary rocks of the Wichita province, this elongate intercratonic sag (Ham, 1969, fig. 1) was an area of active subsidence, having accumulated a total of 30,000 to 40,000 feet of Paleozoic sediments above the basement rocks before deposition ceased. The geosyncline is partly bounded by northwest-trending faults along which there has been repeated movement (Ham and others, 1964, p. 144-149). These faults include the Washita Valley fault in the Arbuckle Mountains (Ham and others, 1964, p. 9-10; Ham, 1969, p. 7, fig. 13), which separates the Arbuckle anticline and the southwestern Arbuckle Mountains from the remainder of the Arbuckles, and the Meers fault (Ham and others, 1964, pls. 1, 2, 5), which trends northwest subparallel to the Cambrian outcrop belt in the Wichita Mountains.

Northeast of the Washita Valley fault in the Arbuckle Mountains and in the immediately surrounding subsurface, Paleozoic sedimentary rocks are underlain by Precambrian granites of the Eastern Arbuckle province, which extend from the outcrop in the Arbuckles northward through Oklahoma, Kansas, and beyond (Ham and others, 1964, pl. 5; Ham, 1969, p. 7). Similar Precambrian granites, gabbros, and metasedimentary rocks flank the Southern Oklahoma geosyncline on the southwestern side and the western end, extending southward and westward into Texas (Muehlberger and others, 1967, p. 2364-2371, fig. 11). Ham and others concluded (p. 142-162) that the Precambrian areas surrounding the Southern Oklahoma geosyncline acted as a stable cratonic shelf of only moderate sediment accumulation that was periodically uplifted during the Paleozoic. Ham (1969, fig. 3) estimated that only about 10,000 feet of Late Cambrian through Permian sediment accumulated on the Texas and Oklahoma cratonic areas, whereas as much as 38,000 feet of sediment accumulated in the Southern Oklahoma geosyncline during the same time span.

The mostly Cambrian rocks of the Wichita province that crop out in the present Wichita Mountains were injected by various granite plutons and sills and converted to a rigid mass before Reagan deposition began. They formed a rigid mass that acted structurally like the adjacent Texas craton and that was probably welded to it (Ham and others, 1964, p. 159).

Thus the Southern Oklahoma geosyncline, an elongate area of rapid subsidence and accumulation, was surrounded by a stable cratonic mass that subsided slowly and was an area of slow accumulation. This contrast in structural history influenced the sedimentary pattern, as will be seen in the later discussion of the depositional history of the Timbered Hills and Arbuckle Groups.

Timbered Hills Group

The Timbered Hills Group consists of the Reagan Sandstone and the Honey Creek Limestone (Ham, 1955, p. 4).

REAGAN SANDSTONE

The Reagan Sandstone rests disconformably on rocks of the Carlton Rhyolite Group and is typically a reddish-brown to brown, medium- to fine-grained, glauconitic, feldspathic quartz sandstone. Several different units can be recognized in the Reagan in the vicinity of the Chandler Creek section. The lower 80 feet is mostly dark-reddish-brown, quartz-cemented, medium- to coarse-grained, cross-bedded, thick-bedded, very feldspathic quartz sandstone that forms a small scarp. Small pebbles and granules of Carlton Rhyolite are present in the basal beds. The upper part of this unit is quite hematitic, becoming locally almost a pelleted-hematite deposit. The hematite pellets are the same size and shape as glauconite pellets that are scattered through the Reagan and may have been derived from them. Just northwest of the line of section, hematite was mined at one time from this part of the Reagan. Remains of the old quarrying operation are still present.

The next approximately 140 feet of the Reagan forms a small valley in which actual outcrops are scarce. Perhaps this part of the Reagan was calcite cemented, with a covered interval having resulted from dissolution of the cement upon surface exposure. The Reagan commonly is calcite cemented in samples from the subsurface (W. E. Ham, 1967, oral communication).

The rest of the Reagan (191 feet in the line of section) is mostly very fine- to fine-grained, thin-bedded, glauconitic, feldspathic quartz sandstone. The lower half of this interval is strongly quartz cemented and makes a resistant, steep scarp face. Beginning about 15 feet above the base of this interval and scattered through it are thin to medium beds and lenses of limestone, many of which contain abundant trilobites and phosphatic brachiopods. These fossiliferous limestones weather easily and are usually difficult to trace laterally because of their recessive character. Sometimes they are cross-bedded, suggesting that the trilobite carapaces accumulated as current-sorted debris piles, having alternated on the sea floor with similarly sorted quartz grains.

Frederickson (1956, p. 491) assigned this 191-foot interval to the Honey Creek Limestone, and indeed the limestone beds are identical in lithology with those of the overlying Honey Creek. However, the limestone beds constitute at most only about 10-20 percent of the outcropping beds; the bulk of the beds are sandstone. Because this interval is predominantly sandstone I have mapped it with the Reagan Sandstone, and I have mapped as Honey Creek the overlying gray, glauconitic limestone interval that contains no sandstone beds.

The sandstone beds of the Reagan in the Wichita Mountains are very similar to those described in the Arbuckle Mountains (Ham, 1955; Stitt, 1971b), where a lower unit of coarse, hematitic sandstone containing rhyolite clasts grades upward into finer grained sandstone near the top. The most important difference is the absence of the trilobite-rich limestone beds and lenses in the upper half of the Reagan in the Arbuckle Mountains. Much of the upper part of the Reagan is covered in the vicinity of the Royer Ranch section (Stitt, 1971b, p. 65-67). Perhaps some of these covered intervals were originally limestone that has now completely weathered away.

The contact between the Reagan and the Honey Creek in the Chandler Creek section is conformable and rather sharp, although the Honey Creek contains a moderate amount of quartz sand that was undoubtedly derived from the same source area as the Reagan sand. A distinctive change in the vegetation at this formation boundary is visible on the ground and on aerial photographs and makes this boundary an easy one to map.

HONEY CREEK LIMESTONE

The Honey Creek Limestone consists of gray, thin-bedded, coarse-grained, glauconitic, pelmatozoan, trilobite biosparite and biomicrite. Quartz and feldspar sand and silt, ferroan dolomite, and phosphatic and calcitic brachiopods are common minor constituents. In the line of section the Honey Creek is only 52 feet thick, and this appears to be a fairly consistent thickness along the outcrop belt. The Honey Creek consists of the same lithologies in the western Arbuckle Mountains, where it is consistently about 100 feet thick (Stitt, 1971b, p. 5).

Trilobites become scarce toward the top of the Honey Creek and in the base of the overlying Fort Sill Limestone. The contact with the Fort Sill is conformable and gradational, with a gradual change from thin-bedded, medium-gray biomicrite, below, to thick-bedded, reddish-purple to light-gray, sparsely fossiliferous biomicrite, above. For mapping purposes, the base of the Fort Sill is drawn at the first thick, light-gray limestone bed in the transition.

Arbuckle Group

The Fort Sill and Signal Mountain Limestones, the two lowest formations of the Arbuckle Group, are examined in this investigation. The intervening Royer Dolomite and overlying Butterly Dolomite, which are present throughout much of the Arbuckle Mountains (Ham, 1955, fig. 2), do not occur in the Chandler Creek area (fig. 2) for reasons that are explained in the section on Depositional History.

FORT SILL LIMESTONE

The Fort Sill consists predominantly of light- to medium-gray, fine-grained, nonglauconitic limestone. Fossils are not nearly as abundant as in the underlying Honey Creek Limestone, although more than twice as many fossiliferous beds were discovered in the Fort Sill in the Chandler Creek section than were previously reported from the Joins Ranch section in the western Arbuckle Mountains (Stitt, 1971b, p. 62-64).

The lower 412 feet of the Fort Sill Limestone in the Chandler Creek section is mostly trilobite biomicrite and pelsparite, with scattered occurrences of biosparite and intrasparite. Minor constituents include very fine quartz sand; phosphatic, calcitic, and silicified brachiopods; ferroan dolomite; glauconite; and sponge spicules. These rocks are similar to those reported from the lower part of the Fort Sill in the Arbuckle Mountains (Stitt, 1971b, p. 5) and probably accumulated in the same type of environment.

Overlying the fine-grained interval is 64 feet of mostly thin-bedded, coarse-grained calcarenites, principally trilobite biosparites and intrasparites. These rocks are in turn overlain by 116 feet of predominantly thick-bedded, domal, algal-stromatolite biomicrite. Various lithologies ranging from oolitic intrasparite to trilobite biomicrite and pelsparite occur between the algal domes, which are best developed near the top of this unit.

The Fort Sill Limestone is conformably overlain by the Signal Mountain Limestone. The mapping boundary between these two formations in the Wichita Mountains is

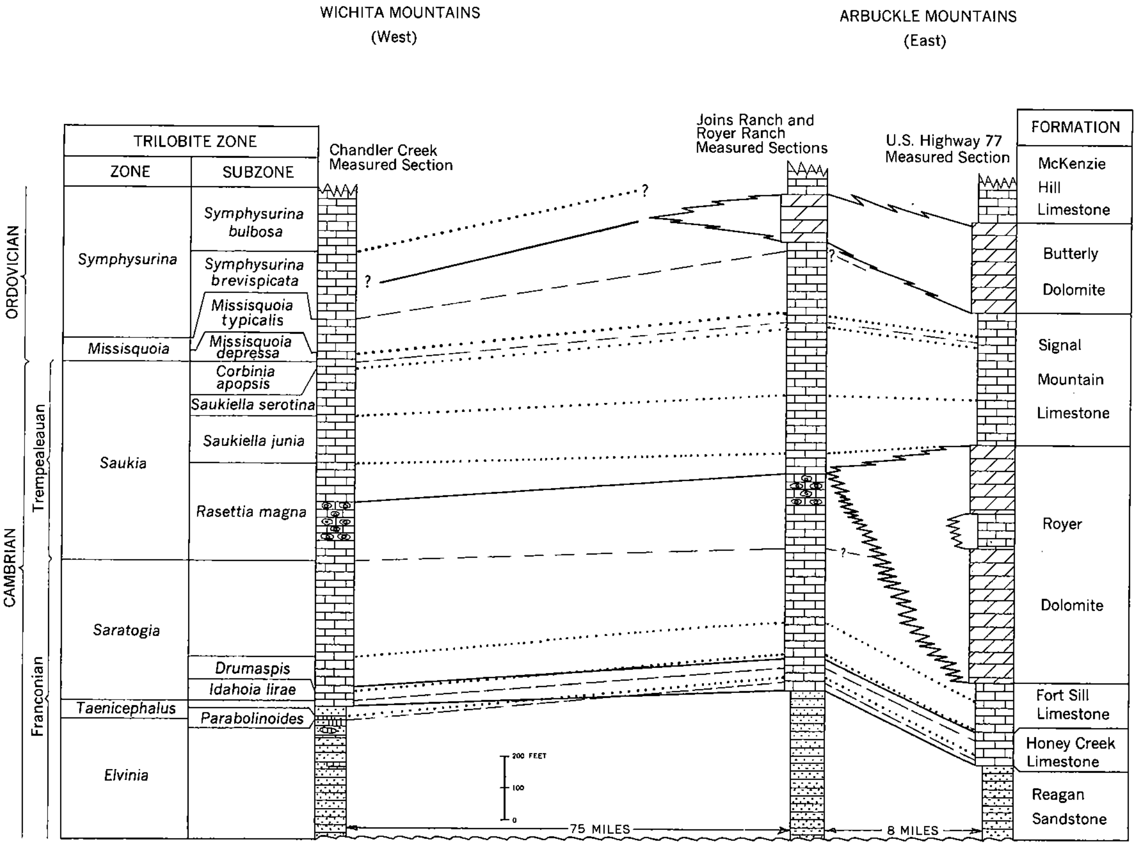

Figure 2. Diagram showing relationship between formations and trilobite zones of Late Cambrian and earliest Ordovician in Wichita and Arbuckle Mountains.

placed at the top of the thick interval of well-developed domal algal stromatolites. A similar horizon based on the same criterion was mapped as the boundary between these two formations in the western Arbuckle Mountains (W. E. Ham, oral communication, 1964; Stitt, 1971b, p. 6).

SIGNAL MOUNTAIN LIMESTONE

The Signal Mountain consists of intraclastic and oolitic limestones that commonly alternate with intervals of trilobite biomicrite and pelsparite. Minor constituents include fine to very fine quartz sand; ferroan dolomite; calcitic, silicified and phosphatic brachiopods; gastropods; and glauconite. Essentially the same lithologies occur in this formation in the Arbuckle Mountains (Stitt, 1971b, p. 6).

The lower 45 feet of the Signal Mountain in the Chandler Creek section contains a variety of lithologies (horizontally laminated stromatolitic algal biomicrite, scattered oncolites and ooliths, and intrasparite) similar to those in the upper part of the Fort Sill. Similar lithologies are present in the lower few feet of the Signal Mountain in the Joins Ranch section in the western Arbuckles.

This interval is succeeded by the more typical alternation of intervals of fine-grained limestone (trilobite biomicrite and pelsparite) with intervals of coarser grained limestone (intrasparite mostly, with lesser amounts of intramicrite, oosparite, biosparite, and oomicrite). Most of the intraclasts are pieces of unfossiliferous micrite, trilobite biomicrite, or pelsparite. This pattern occurs throughout the rest of the formation in both the Arbuckle and Wichita Mountains. The intervals of a particular lithology seldom persist vertically for more than a few feet, and scattered beds containing mixtures of lithologies occur.

The Signal Mountain is conformably overlain by the McKenzie Hill Limestone. The same basic limestone lithologies that are present in the upper part of the Signal Mountain also occur in the lower part of the McKenzie Hill. The principal difference is that many of the McKenzie Hill rocks are thick bedded, whereas those in the underlying Signal Mountain are thin to medium bedded. The lowest occurrence of these thick-bedded limestones was mapped as the boundary between these two formations.

Depositional History

The Arbuckle and Wichita Mountains area was apparently not covered by the widespread marine transgression that occurred during the Dresbachian Stage of early Late Cambrian age (see Lochman-Balk *in* Holland, 1971, p. 117-121, figs. 16, 17; Stitt, 1971b, p. 9). Marine waters did enter the area during the major transgression near the beginning of the succeeding Franconian Stage, and these waters reworked and deposited the weathered debris from the mostly igneous basement rocks, forming the arkose unit now called the Reagan Sandstone. The weathered pieces of Carlton Rhyolite found in the lower beds of the Reagan indicate the local nature of the source for the Reagan sediments. Although no recognizable fossils occur in the lower part of the Reagan, brachiopods and trilobites characteristic of the *Elvinia* Zone of the Franconian Stage do occur in the upper part of the Reagan in the Chandler Creek section, which helps to establish an approximate time for the marine transgression into this area (see discussion of the *Elvinia* Zone in the section on Biostratigraphy).

An important paleogeographic conclusion that is demonstrated for the first time in this report is that the upper half of the Reagan Sandstone in the Wichita Mountains is the same age as at least the upper quarter of the Reagan *and* the lower third of the overlying Honey Creek Limestone in the Arbuckle Mountains (fig. 2). The boundary between the *Elvinia* and *Taenicephalus* Zones occurs 47 feet *below* the base of the Honey Creek in the Wichita Mountains, whereas in the Royer Ranch section in the western end of the Arbuckle Mountains (Stitt, 1971b, p. 66, pl. 11) the same zonal boundary occurs 30 feet *above* the base of the Honey Creek (see fig. 2). Abundant trilobites and phosphatic brachiopods of the *Elvinia* Zone occur in the upper part of the Reagan in the Wichitas, whereas the same taxa occur abundantly in the lower part of the overlying Honey Creek in the western Arbuckles.

This information can be interpreted in at least two ways. One possibility is that the Franconian sea spread into southern Oklahoma from an easterly or southeasterly direction and the upper part of the Reagan Sandstone was deposited as a nearshore sand body in the Wichita Mountains area at the same time that the limestone of the Honey

Creek accumulated farther offshore in the Arbuckle Mountains. Another possibility is that sand-sized quartz and feldspar grains continued to be supplied to the Wichita Mountains area for some time after such sediments stopped being available to the Arbuckle Mountains area and that limestone began to accumulate in the latter area in the absence of terrigenous influx. Judging from Lochman-Balk's paleogeographic maps (figs. 18-24, p. 100-103, *in* Holland, 1971) the Cambrian rocks in the Wichita Mountains area were always closer to the Cambrian landmass than were the Cambrian rocks in the Arbuckle Mountains. Also, the Red River uplift (Barnes and others, 1959, p. 64-65, figs. 1, 4) may have been an additional source of sediments for the Wichita Mountains area as well as possible local granite islands known to have existed in other areas (Ham, 1969, p. 8). Whichever of these or other possible explanations is in fact correct, the faunal information now available clearly indicates that the change from sandstone to limestone deposition did not occur at the same time throughout the Southern Oklahoma geosyncline.

Eventually all sources of terrigenous detritus stopped supplying much sediment to the Arbuckle and Wichita Mountains areas, and the bioclastic Honey Creek Limestone accumulated over a broad area. Initially the sea floor was within the zone of moderate wave energy, and carbonate mud was winnowed away, resulting in the formation of the biosparites that are so common in the lower part of the Honey Creek. Gradually more and more carbonate mud began to accumulate along with the fossil debris, and the biomicrites of the upper part of the Honey Creek accumulated.

The upper few feet of the Honey Creek Limestone in the Wichita Mountains contains the same fossils as the lower part of the Fort Sill Limestone in the western Arbuckle Mountains (fig. 2), a further clue to the depositional history of the Upper Cambrian. Trilobites of the *Drumaspis* Subzone first occur 6 feet *below* the base of the Fort Sill in the Chandler Creek section. These same trilobites first appear in the Joins Ranch section in the Arbuckle Mountains 7 feet *above* the base of the Fort Sill (Stitt, 1971b, p. 10, 64, fig. 2, pl. 10). Thus at the same time that the last of the medium-gray, glauconitic biomicrites of the Honey Creek lithotope accumulated in the Wichita Mountains area the first of the light-gray, nonglauconitic, sparsely fossiliferous biomicrites of the Fort Sill lithotope began to accumulate in the western Arbuckle Mountains. After a short time the latter lithotope spread westward into the Wichita Mountains area, and accumulation of the thick Fort Sill Limestone occurred at a more or less uniform rate (fig. 2) throughout the region.

Regional-distribution patterns of the Fort Sill are useful in determining the probable depositional setting for this formation. In the Joins Ranch section in the western Arbuckle Mountains, the Fort Sill is 577 feet thick and is composed of limestones that are very similar to those exposed in the Chandler Creek section. However, just east of the Joins Ranch section the domal algal-stromatolite limestones that characterize the uppermost part of the Fort Sill are dolomitized, and from there eastward the dolomite thickens abruptly (Ham, 1955, fig. 2) until, at the Highway 77 section only 7 miles east, the dolomite (called the Royer Dolomite) is 752 feet thick and the Fort Sill has thinned to only 154 feet (Stitt, 1971b, fig. 2, p. 5-6). This progressive eastward dolomitization of the Fort Sill interval continues to the northeast across the Arbuckle Mountains and is accompanied by an overall thinning and dolomitization of the entire Upper Cambrian-Lower Ordovician sequence (Ham, 1955, p. 1, figs. 1, 2). As Ham pointed out (1955, p. 1; 1969, p. 7), sediments of the same age in the Southern Oklahoma geosyncline are thicker and predominantly limestone. In the Arbuckles, the Washita Valley fault is the approximate hinge across which this lateral lithologic change has taken place, although considerable interfingering of limestone and dolomite occurs across this hinge line (Ham, 1955, figs. 1, 2).

Chenoweth (1968, fig. 10) reconstructed the regional limestone-dolomite depositional pattern for the Fort Sill and correlative units in the midwest. Limestone deposition in Oklahoma was restricted to the approximate limits of the rapidly subsiding Southern Oklahoma geosyncline, with dolomite accumulation on the surrounding, more stable areas.

The sparsely fossiliferous biomicrites and pelsparites of the lower two-thirds of the Fort Sill probably accumulated in slightly deeper water along the central part of the steadily subsiding Southern Oklahoma geosyncline, surrounded on three sides by shallow-water carbonate tidal flats that were later dolomitized to form the Royer Dolomite. Some of the dolomite may have been primary, but at present most of the beds of the Royer have a medium- to coarsely crystalline texture, suggesting one or more stages of recrystallization.

Scattered limestone lenses in the Royer give some indication of the original lithology. One such lens in the Highway 77 section in the Arbuckles (Stitt, 1971b, p. 56) consists of fine to coarse intrasparite. The cleanly washed nature of the intrasparite suggests higher wave and current energies than are indicated by the laterally equivalent Fort Sill biomicrites and pelsparites; this suggests that the Royer accumulated in shallower, more agitated water than the Fort Sill.

Domal algal stromatolites may have been common in the shallow-water areas where the Royer was deposited. Ham (1967, oral communication) pointed out that many of the thicker beds in the Royer have the same weathering appearance as the domal algal stromatolites in the Fort Sill. Unfortunately, he was unable to find traces of algal filaments or even the characteristic stromatolitic layering on polished slabs or in thin sections of these beds. As mentioned previously, the coarseness of the dolomite has obliterated all traces of primary texture.

In the upper part of the Fort Sill, cleanly washed intrasparites and biosparites occur that indicate an increase in wave and current energy. This was probably the result of a gradual shallowing of the sea, perhaps when the rate of accumulation temporarily exceeded the rate of subsidence. This shallowing continued with the formation of the domal algal-stromatolite limestone in the upper 116 feet of the Fort Sill. These stromatolites probably formed in subtidal water, for they are most similar to those described by Gebelein (1969) from subtidal water in Bermuda.

Interdigitation of the limestone and dolomite facies along the margins of the Southern Oklahoma geosyncline has already been demonstrated in the Arbuckle Mountains (Ham, 1955, figs. 1, 2). The amount of intertonguing probably reflects variations in the rates of both subsidence and accumulation within the geosyncline and the surrounding craton and is probably very irregular in plan view along the geosynclinal margins. This probably accounts for the presence of the Royer Dolomite in the Kindblade Ranch area at the northwestern end of the Cambrian outcrop belt in the Wichita Mountains area (see Frederickson, 1956, locality 9 on fig. 5); here again, the Royer replaces the upper part of the Fort Sill, which just a few miles away is the domal-algal-stromatolitic facies. Ham and others (1964, p. 161) are certain that carbonate rocks of the Arbuckle Group were deposited in the area of the present Wichita Mountains and that they were uplifted by Pennsylvanian faulting and subsequently eroded away. The Royer in the Kindblade Ranch area is probably a tongue of dolomite extending from the craton across the western or southwestern margin of the geosyncline.

The basal beds of the Signal Mountain Limestone consist of horizontally laminated stromatolitic-algal biomicrite and intrasparite with scattered oncolites and ooliths. I interpret these beds as having formed under a continuation of the same type of shallow-water conditions that prevailed at the close of the deposition of the Fort Sill.

The rest of the Signal Mountain consists of alternations of principally trilobite biomicrite and intrasparite, with lesser amounts of other lithologies as described earlier. Perhaps this alternation resulted from a delicate balance between the rate of subsidence and the rate of accumulation. When subsidence exceeded accumulation the water deepened below the effective wave base for winnowing carbonate mud, and trilobite biomicrite and pelsparite accumulated. When accumulation exceeded subsidence, the sea floor built up within wave base, and currents, storm waves, and organic activities combined to disrupt the biomicrite substrate. Subsequent wave and current action rounded and sometimes sorted the micrite clasts, mixing in ooliths, trilobite carapaces, brachiopod valves, and other debris present on the sea floor. Constant variation and imbalance between the rates of subsidence and accumulation could account for the variety of lithologies observed (including unusual lithologies such as intramicrite) as well as the mixing of lithologies in a single bed.

Chenoweth (1968, p. 1681, fig. 11) reported a similar regional depositional picture for the Signal Mountain that was previously discussed for the Fort Sill. Limestones of the Signal Mountain accumulated in the rapidly subsiding Southern Oklahoma geosyncline while dolomites of the Butterly and equivalent formations accumulated in the more slowly subsiding and perhaps shallower water cratonic areas. The facies relationship of the Signal Mountain and Butterly was clearly demonstrated in the Arbuckle Mountains by Ham (1955, fig. 2), but the Butterly does not occur in surface outcrops in the Wichita Mountains area (Frederickson, 1956, p. 499-500, fig. 6).

BIOSTRATIGRAPHY

Introduction

The Franconian and Trempealeauan Stages of the Croixan Series of the Upper Cambrian are represented by trilobites recovered from the Reagan Sandstone, the Honey Creek and Fort Sill Limestones, and the lower half of the Signal Mountain Limestone. The lowermost two zones of the Canadian Series of the Lower Ordovician are represented by trilobites recovered from the upper half of the Signal Mountain Limestone (fig. 2, pl. 7). The Cambrian-Ordovician boundary thus falls within the Signal Mountain, in a sequence of conformable limestones, as was previously determined in the Arbuckle Mountains (Stitt, 1971b, p. 12-13).

In this paper, the words Cambrian and Ordovician are used in the traditional North American sense (see Taylor and Halley, 1974, p. 8, and the discussion of this problem in the section entitled Cambrian-Ordovician Boundary later in this paper). The hierarchy of other stratigraphic terms to be used in the following biostratigraphic discussion is shown in figure 3. The zonation established for the Chandler Creek section follows the philosophy and guidelines previously discussed (Stitt, 1971b, p. 7-8) and is essentially the same one that was recognized in the Arbuckle Mountains. One important change is that the base of the *Symphysurina* Zone is redefined, utilizing the better faunal data available in the Chandler Creek section.

Cambrian

FRANCONIAN STAGE

Trilobites from the Reagan Sandstone, the Honey Creek Limestone, and the lower two-thirds of the Fort Sill Limestone constitute the faunas of the *Elvinia, Taenicephalus* and *Saratogia* Zones of the Franconian Stage.

Elvinia Zone

The following assemblage of species characterizes the fauna of the *Elvinia* Zone in the Chandler Creek section (pl. 7), and all taxa except *Irvingella major* Ulrich and Resser and *Pseudagnostus communis* (Hall and Whitfield) are restricted to this zone.

Apachia trigonis Frederickson
Burnetiella ectypa (Resser)
Buttsia drabensis Wilson
Camaraspis convexa (Whitfield)
Camaraspis parabola Frederickson
Cheilocephalus wichitaensis Resser
Cliffia lataegenae (Wilson)
Comanchia amplooculata (Frederickson)
Deckera completa (Wilson)
Dellea suada (Walcott)
Dokimocephalus curtus (Resser)
Dokimocephalus intermedius (Resser)
Drabia cf. *D. menusa* Wilson
Elvinia roemeri (Shumard)
Homagnostus tumidosus (Hall and Whitfield)
Irvingella major Ulrich and Resser
Kindbladia wichitaensis (Resser)
Morosa? bothra Stitt
Morosa simplexa Stitt
Plataspella anatina (Resser)
Pseudagnostus communis (Hall and Whitfield)
Pseudosaratogia lata Wilson
Pterocephalia sanctisabae Roemer
Reaganaspis parva Stitt, n. sp.
Sulcocephalus cereus Stitt
Sulcocephalus latus (Frederickson)
Xenocheilos minutum Wilson

The *Elvinia* Zone in the Chandler Creek section occurs entirely within the Reagan Sandstone (fig. 2), in contrast to its occurrence in both the Reagan and the overlying Honey Creek Limestone in the Arbuckle Mountains. Unfortunately, in neither area are fossils found at or near the base of the Reagan. In the Chandler Creek section, the first trilobites (*Kindbladia wichitaensis* and *Irvingella major*) occur at 225 to 235 feet above the base of the Reagan; in the Royer Ranch section in the Arbuckle Mountains (Stitt, 1971b, p. 67, pl. 11), the lowest *Elvinia* Zone taxa occur even higher, within 46 feet of the top of the Reagan, which is approximately 460 feet thick there (Ham, 1955, p. 4, fig. 2).

Thus there is still no definitive way to determine whether the Reagan is entirely Franconian. Many badly crinkled phosphatic films that probably were once acrotretid brachiopods occur squashed between the quartz grains near the base of the Reagan, but these whitish smears are deformed beyond recognition. One complete, articu-

SYSTEM	SERIES	STAGE	ZONE	SUBZONE	BIOMERE
Ordovician	Canadian		*Symphysurina*	*Symphysurina bulbosa*	"hystricurid"
				Symphysurina brevispicata	
			Missisquoia	*Missisquoia typicalis*	
				Missisquoia depressa	
Cambrian	Croixan	Trempeal-eauan	*Saukia*	*Corbinia apopsis*	Ptychaspid
				Saukiella serotina	
				Saukiella junia	
				Rasettia magna	
		Franconian	*Saratogia*		
				Drumaspis	
				Idahoia lirae	
			Taenicephalus		
				Parabolinoides	
			Elvinia		Pterocephaliid

Figure 3. Diagram summarizing stratigraphic nomenclature used in this paper.

lated specimen of the acrotretid brachiopod *Linnarssonella girtyi* was discovered in a small, enclosed pocket in the Reagan at 220 feet above the base of the Chandler Creek section. At a spot locality 600 yards northwest of the Chandler Creek section, disarticulated fragments of *L. girtyi* occur 168 feet above the base of the Reagan. According to Bell and Ellinwood (1962, p. 410), this species is ubiquitous within and restricted to the *Elvinia* Zone in North America. This then confirms the presently recognizable base of the Franconian at slightly below the middle of the Reagan.

It would be tempting to say that the entire Reagan is Franconian, and that it was entirely deposited as the transgressing Franconian sea inundated the craton (see Lochman-Balk *in* Holland, 1971, p. 100, figs. 17, 18). From considerations of regional geology, Lochman-Balk (p. 119) has interpreted the Reagan in this fashion. However, the possibility that part of the lower half of the Reagan may have been deposited under nonmarine conditions, or during the previous Dresbachian transgression that reached nearby central Texas and southeastern Missouri, cannot be completely ruled out until Franconian fossils are discovered at or very near the base of the Reagan.

If the available range data from the Arbuckle and Wichita Mountains areas are combined, I believe that several subdivisions or subzones could be recognized within the *Elvinia* Zone, as earlier proposed by Wilson (1949, p. 30) in his study of this fauna in central Texas. In the lower part of the *Elvinia* Zone in both areas, the characteristic trilobites are *Kindbladia wichitaensis, Plataspella anatina, Sulcocephalus cereus,* and *Sulcocephalus latus* (see pl. 7; and Stitt, 1971b, pl. 11). The middle and upper parts of the *Elvinia* Zone are characterized by species of *Camaraspis, Cliffia, Dellea, Dokimocephalus, Morosa, Pseudosaratogia,* and *Pterocephalia,* although some of these genera can occur sparingly with the lower assemblage (pl. 7; and Stitt, 1971b, pl. 11). Species of *Burnetiella, Apachia, Xenocheilos,* and *Deckera* also occur consistently near the base of the *Dokimocephalus* assemblage. *Elvinia roemeri* and *Irvingella major* occur sparingly to abundantly throughout these two subzones.

Characteristically throughout much of North America, the top few feet of the *Elvinia* Zone can be recognized by the presence of coquinoid abundances of *Irvingella major, Comanchia amplooculata*, and *Sulcocephalus candidus*, which, along with several less abundant species, form what is usually called the *Irvingella major* coquina (Wilson and Frederickson, 1950). This coquina is present in the Arbuckle Mountains (Stitt, 1971b, p. 9) but not in the Chandler Creek section, although in the latter locality *I. major* and *C. amplooculata* do occur by themselves in the stratigraphically highest collections of the *Elvinia* Zone.

These three informal subzones contain essentially the same taxa in Oklahoma that Wilson recognized in Texas (compare the above listings with those given by Wilson, 1949, p. 30). Furthermore, these subzones provide an opportunity to take a closer look at the depositional history of the Reagan Sandstone and the overlying Honey Creek Limestone. The *Elvinia* Zone fauna occurs completely within the Reagan at the Chandler Creek section, but these same trilobites occur in both the upper part of the Reagan *and* in the lower part of the Honey Creek in the Arbuckle Mountains. This suggests that in a regional sense these two formations are at least partly contemporaneous, although in outcrop they always occur one above the other and cannot be shown by lateral tracing or by field relationships to be lateral equivalents. During the time of the *Kindbladia* assemblage, at least 82 feet of Reagan accumulated in the Chandler Creek section, while at the same time in the Royer Ranch section in the western Arbuckles the upper 46 feet of the Reagan *and* the lower 14 feet of the Honey Creek were accumulating. Put more directly, during this time the deposition of appreciable quantities of quartz sand ceased in the western Arbuckles, and, in the absence of terrigenous influx, limestone began to accumulate there; at the same time, quartz-sand accumulation continued with minor limestone-lens formation in the Wichitas. Further evidence that the Honey Creek Limestone in the Arbuckles accumulated much more slowly than did the contemporaneous and westward-encroaching Reagan Sandstone in the Wichitas comes from consideration of the stratigraphic interval of the *Dokimocephalus* assemblage. In the Highway 77 and Royer Ranch sections, Honey Creek deposition amounted to only 4.5 and 13 feet respectively, whereas in the Chandler Creek section 40 feet of Reagan was deposited during this time. Similar shoreward thickening of biostratigraphic intervals is reported from the Cambrian of the Upper Mississippi Valley by Bell and others (1956, p. 441).

Valves of the acrotretid brachiopod *Linnarssonella girtyi* occur abundantly in the limestone lenses and beds of the *Elvinia* Zone in the Chandler Creek section, as they do in the *Elvinia* Zone almost everywhere in North America. Valves of linguloid brachiopods, a few scattered valves of the articulate brachiopod *Huenella*, and numerous pelmatozoan fragments constitute the only other non-trilobite faunal elements from the *Elvinia* Zone.

Rowell and McBride (1972) numerically compared the trilobite faunas of the *Elvinia* Zone described from 12 areas in North America. They found that trilobites from the cratonic areas (west-central Appalachians, Minnesota, Oklahoma, Texas, Wyoming, and Montana) had a high degree of similarity at the generic level (Dice similarity value of .55 or higher) and probably could be considered to represent a single faunal province. Faunas from peripheral areas (New York, east-central Appalachians, the Great Basin, and Alaska) were rather heterogeneous, not being closely similar at the generic level either to each other or to the cratonic group.

One interesting fact emerges in comparing the diverse and well-described trilobites of the *Elvinia* Zone of the Great Basin (Palmer, 1965b) with those in Oklahoma and other decidedly cratonic sites. Certain genera that occur in both areas (*Cheilocephalus, Comanchia, Dokimocephalus, Iddingsia, Kindbladia, Pseudosaratogia,* and *Xenocheilos*) are represented by one or more particular species in the cratonic areas and by other, different species in the Great Basin. *Elvinia roemeri* and *Irvingella major* occur both in cratonic sites and in the Great Basin, but additional species of *Elvinia* and *Irvingella* are present in the Great Basin. As pointed out by Rowell and McBride (1972, p. 249-250), other common *Elvinia* Zone genera (*Burnetiella*, *Camaraspis*, *Cliffia*, *Deckera*, *Plataspella*, and *Sulcocephalus*) are apparently restricted to the cratonic areas.

Another item that the cratonic areas have in common is that all of these areas were no more than 200 to 500 kilometres from the Cambrian shoreline of that time (Lochman-Balk *in* Holland, 1971, p. 100, fig. 18). The present outcrops in these areas expose rocks of either the inner detrital belt or the nearshore half(?) of the carbonate belt (see Palmer, 1968, p. 16-17; 1972, p. 310-311). In contrast, the localities collected in the Great Basin by Palmer occur approximately 500 to 900 kilometres from the Cambrian shoreline (Lochman-Balk *in* Holland, 1971, p. 100, fig. 18) and, probably more importantly, were within 50-150 kilometres of the outer margin of the shelf (see Palmer *in* Holland, 1971, p. 68, and figs. 15D and 16H on p. 66-67), where the light-colored limestones of the carbonate belt give way to the dark limestones and shales of the outer detrital belt.

Thus it appears that in a regional sense there may have been a nearshore *Elvinia* Zone fauna living in the inner detrital belt and the inner part of the carbonate belt that had very few species in common with the *Elvinia* Zone fauna inhabiting the shelf margin and the outer part of the carbonate belt. Genera and species of the "*Burnetiella* group" listed previously were apparently restricted to the nearer shore area. Other genera, such as those of the "*Cheilocephalus* group" listed previously, inhabited the entire shelf but showed discrimination at the species level, with certain species preferring the nearer shore conditions and some favoring the more open ocean shelf-margin areas. Species such as *Elvinia roemeri*, *Irvingella major*, and *Pterocephalia sanctisabae* were flexible enough in their ecologic requirements so that they could live throughout the shelf. Along the carbonate belt—outer detrital belt boundary at the shelf edge in the Great Basin, a few taxa (e.g., *Sigmocheilos*, *Parahousia*, *Dunderbergia*, *Aphelotoxon*) that were probably at home in the outer detrital belt mingled with the shelf faunas.

The two shelf faunal provinces delineated in the preceding paragraph are not coincident in their distribution with the inner detrital and carbonate belts recognized by Palmer (1968; 1972), nor do they coincide with the sedimentary facies patterns suggested by Lochman-Balk (*in* Holland, 1971, p. 100, fig. 18) for the *Elvinia* Zone. Taylor (1976) delineated inner-shelf and outer-shelf trilobite faunas for the late Franconian of the western United States. He suggested that their distribution may have been related to cooler shelf conditions during the late Franconian, based on comparison with modern marine isopods and their temperature-related distribution. Perhaps similar conditions also prevailed during the early Franconian, which resulted in inner-shelf and outer-shelf trilobite faunas as outlined above.

Taenicephalus Zone

The following assemblage of species occurs in the *Taenicephalus* Zone in the Chandler Creek section (pl. 7), and those taxa that are restricted to this zone are indicated by an asterisk.

Conaspis cf. *C. tumida* Kurtz
Irvingella major Ulrich and Resser
Parabolinoides contractus Frederickson*
Parabolinoides granulosus Ellinwood*
Pseudagnostus communis (Hall and Whitfield)
Taenicephalus shumardi (Hall)*
Wilbernia expansa Frederickson

Unfortunately, most of this interval is unfossiliferous sandstone. Collections from CC 364, 373, and 374 contain numerous specimens of *Parabolinoides*, the definitive taxon of the basal *Parabolinoides* Subzone (see following section). Collections from CC 413, 415, and 418 contain specimens of *Taenicephalus*, *Conaspis*, *Wilbernia*, and *Pseudagnostus*, an assemblage characteristic of the upper part of this zone as developed in the Arbuckle Mountains (Stitt, 1971b, pls. 9, 11, 12).

The *Taenicephalus* Zone is the lowest zone of the Ptychaspid Biomere (Longacre, 1970, p. 2-3; Stitt, 1971a, 1971b, p. 13-14, 1975). This zone consists of trilobites that are different at the family level from those of the underlying *Elvinia* Zone, which is the highest zone in the Pterocephaliid Biomere (Palmer, 1965a, 1965b). Only the agnostid trilobite *Pseudagnostus communis* (Hall and

Whitfield) ranges from the *Elvinia* Zone below through the *Taenicephalus* Zone and on into the succeeding *Saratogia* Zone. The base of the *Taenicephalus* Zone (=top of the *Elvinia* Zone) thus marks one of the most significant extinction events in the history of Late Cambrian trilobites. Another such extinction event does not occur until the end of the *Saukia* Zone. A possible cause of these mass extinctions is discussed later in this paper.

The Reagan Sandstone is a part of the inner detrital sedimentary belt (Palmer, 1969, p. 140), and I am surprised not to find in the Chandler Creek section more specimens of *Conaspis*, which is abundant in the inner-detrital-belt sandstones in the Upper Mississippi Valley (Berg, 1953, p. 555-557, table 1). *Conaspis* is generally scarce in rocks of the carbonate belt such as the Honey Creek Limestone (Longacre, 1970, p. 7; Stitt, 1971b, p. 8-9), but I had expected to find it in the fine-grained sandstones of the inner detrital belt such as those in the uppermost part of the Reagan. The absence of fossiliferous beds in the middle two-thirds of the *Taenicephalus* Zone at Chandler Creek makes it impossible to determine the full extent of the preference by *Conaspis* for quartz-sand substrates such as those of the Reagan rather than carbonate substrates of contemporaneous formations such as the Honey Creek Limestone.

It should also be noted (fig. 2) that the top of the *Taenicephalus* Zone (=base of the *Idahoia lirae* Subzone of the *Saratogia* Zone) is 21 feet below the top of the Honey Creek Limestone in the Highway 77 section in the west-central Arbuckle Mountains and 27 feet below the top of the Honey Creek in the Royer Ranch section in the western Arbuckles; it has dropped farther down section to the west and is 41 feet below the top of the Honey Creek in the Chandler Creek section. This continues the trend of younger-to-the-west for the lithologic units and suggests the continued westward migration of lithotopes into the middle Franconian.

Parabolinoides Subzone.—This subzone occurs at the base of the *Taenicephalus* Zone and consists of abundant specimens of (1) the trilobite *Parabolinoides contractus*; (2) the articulate brachiopods *Eoorthis remnichia*, *Eoorthis indianola*, and *Billingsella coloradoensis*; and (3) the acrotretid phosphatic brachiopod *Angulotreta microscopica*. A single specimen of *Irvingella major* has been recovered from the basal bed in this subzone, and a single specimen of *Parabolinoides granulosus* occurs 2 feet above the base of the subzone.

This subzone is defined by the range of *Parabolinoides* and, as such, is 10 feet thick in the Chandler Creek section. As has been previously noted (Longacre, 1970, p. 10; Stitt, 1971b, p. 10), this subzonal assemblage is widely distributed across the Cambrian inner detrital and carbonate belts. A similar assemblage is also present in southeastern Missouri (Kurtz, 1975).

Saratogia Zone

The following assemblage of species occurs in the *Saratogia* Zone in the Chandler Creek section (pl. 7), and those taxa that are restricted to this zone are indicated by an asterisk.

Conaspis cf. *C. tumida* Kurtz
Dartonaspis wichitaensis (Resser)*
Drumaspis idahoensis Resser*
Drumaspis texana Resser*
Ellipsocephaloides silvestris Resser*
Geragnostus intermedius Palmer
Genus and species undet. no. 1*
Genus and species undet. no. 2*
Idahoia lirae (Frederickson)*
Leiocoryphe occipitalis Rasetti
Pseudagnostus communis (Hall and Whitfield)
Ptychaspis bullasa Lochman and Hu*
Ptychaspis sp. undet.*
Rasettia capax (Billings)
Saratogia americana (Lochman and Hu)*
Saratogia fria Lochman and Hu*
Saratogia modesta (Lochman and Hu)*
Stigmacephaloides curvabilis Ellinwood*
Stigmacephaloides verticalis Stitt, n. sp.*
Wilbernia diademata (Hall)*
Wilbernia expansa Frederickson
Wilbernia cf. *W. pero* (Walcott)*

Most of these species make their first appearance in this zone and are restricted to it. Exceptions are *Conaspis* cf. *C. tumida*, *Pseudagnostus communis*, and *Wilbernia expansa*, which also occur in the underlying *Taenicephalus* Zone, and *Leiocoryphe occipitalis*, *Geragnostus intermedius*, and *Rasettia capax*, which range into the overlying *Rasettia magna* Subzone of the *Saukia* Zone.

Leiocoryphe occipitalis makes an unusually low biostratigraphic appearance in the *Saratogia* Zone of Franconian age; it usually occurs only in the Trempealeauan (Bell and Ellinwood, 1962, p. 403; Longacre, 1970, p. 5, text-fig. 3; Stitt, 1971b, pls. 10, 12). Rasetti originally described this species as part of the *Hungaia magnifica* fauna of the Lévis Conglomerate, and he considered this fauna as probably being Late Trempealeauan (Rasetti, 1944, p. 229, 231). The occurrence of *Leiocoryphe occipitalis* in association with Franconian trilobites in the Chandler Creek section suggests that some of the *Hungaia magnifica* fauna may be late Franconian.

Trilobites of the *Saratogia* Zone occur in the upper four-fifths of the Honey Creek Formation and the lower two-thirds of the overlying Fort Sill Limestone. The base of the zone is defined on the first occurrence of *Idahoia lirae*, and the top of the zone is the base of the *Saukia* Zone. The upper 45 feet of the *Saratogia* Zone is very sparsely fossiliferous, as is true for this interval in the western Arbuckle Mountains (Stitt, 1971b, p. 10; pls. 10, 12) and in many places on the North American craton (Longacre, 1970, p. 11). This must have been a time of harsh environmental conditions for the trilobites; the Parabolinoididae became extinct, and when conditions became more favorable for habitation in the Trempealeauan the Ptychaspididae expanded and diversified rapidly and were joined by a variety of genera from the *Hungaia magnifica* fauna.

Two subzones are recognized in the lower third of the *Saratogia* Zone: the *Idahoia lirae* Subzone, at the base, and the overlying *Drumaspis* Subzone. The *Saratogia* Zone and its subzones have previously been correlated with other areas (Stitt, 1971b, p. 10), and no new correlations are suggested here.

Idahoia lirae Subzone.—This subzone occurs at the base of the *Saratogia* Zone, and its base is defined by the first occurrence of *Idahoia lirae* (pl. 7). The top of this subzone is the base of the overlying *Drumaspis* Subzone. Although various other taxa occur with *Idahoia lirae* (pl. 7; Longacre, 1970, text-fig. 2; Stitt, 1971b, pl. 12), only *Wilbernia diademata* appears to be restricted to this subzone.

Drumaspis Subzone.—This subzone is defined by the range of the genus *Drumaspis*, which in turn is defined in the Chandler Creek section by the overlapping ranges of *Drumaspis texana* and *Drumaspis idahoensis* (pl. 7). The base of this subzone in the Arbuckle Mountains occurs 11 feet above the base of the Fort Sill Limestone at the Highway 77 section and 7 feet above the base of the Fort Sill in the more westerly Joins Ranch section. In the Chandler Creek section, the first *Drumaspis texana* occurs 5.5 feet *below* the base of the Fort Sill (in the uppermost part of the Honey Creek Limestone), indicating the partial contemporaneity of these two formations on a regional basis. The trend of westward migration of sedimentary lithotopes documented for the lower and middle Franconian thus continues into the Upper Franconian.

TREMPEALEAUAN STAGE

Trilobites from the upper third of the Fort Sill Limestone and slightly more than the lower half of the overlying Signal Mountain Limestone constitute the faunas of the *Saukia* Zone of the Trempealeauan Stage.

Saukia Zone

Howell (1944) suggested a four-zone subdivision of the Trempealeauan Stage, based primarily on supposed faunal relationships in the Upper Mississippi Valley. His classification was later modified by Raasch (1952, p. 148-151), who, working in the same area, recognized a single zone, the *Saukia* Zone, with 14 proposed subdivisions and a lower base for the Trempealeauan Stage than that proposed by Howell. Nelson studied this interval again in the Upper Mississippi Valley and recommended (1956, p. 171-172) recognition of four zones, the uppermost one having two subzones. Nelson's classification is similar to Howell's. However, later that same year, Bell and others (1956, p. 441) suggested that faunal subdivisions of the Trempealeauan Stage should await additional detailed studies in areas outside the Upper Mississippi Valley. They advised recognizing only the *Saukia* Zone of Raasch, pending more data.

This was good advice, because, as studies in other areas now show, there is one nearly insurmountable problem in trying to recognize the more detailed zonations developed in the inner-detrital-belt sandstones of the Upper Mississippi Valley. Several of the key genera (e.g., *Osceolia*, *Dikelocephalus*, *Tellerina*) are scarce outside the Upper Mississippi Valley, and species of several other key genera (e.g., *Saukiella*, *Saukia*, *Calvinella*, *Rasettia*) that occur in the inner detrital belt are different from those that occur in the carbonate belt (compare, for example, the faunal lists for the Trempealeauan zones given by Nelson, 1951, p. 768-770, 1956, p. 171-172, with those of Winston and Nicholls, 1967, p. 69-70, Longacre, 1970, p. 11-12, text-fig. 3, and Stitt, 1971b, p. 11-12, pl. 12).

The next major attempt at subdivision of the *Saukia* Zone was based on the study of the Late Cambrian of central Texas by Winston and Nicholls (1967). Longacre (1970) subsequently updated and modified their four proposed subzones of the *Saukia* Zone with additional data and some revised taxonomy, and the same basic zonation with one different subzonal name is applicable in Oklahoma (Stitt, 1971b, and this paper). This quadripartite zonation appears to be widely recognizable in the carbonate rocks of the Trempealeauan, but the four subzones of the *Saukia* Zone are not individually correlative with the various zones proposed in the Upper Mississippi Valley. Taylor (1971; and in Taylor and Halley, 1974, p. 5, table 2) finds this zonation applicable in the Upper Cambrian carbonate rocks of the eastern part of the Great Basin but not usable in the outer-detrital-belt rocks of the central and western Great Basin. Some of these subzones were recognized in eastern New York (Taylor and Halley, 1974, p. 5) for the uppermost part of the Cambrian that has been collected there. Derby and others (1972, p. 505-509, fig. 3) similarly recognized the upper two subzones in their work in the Survey Peak Formation in Alberta, Canada, and the lower two subzones can also be delineated farther down in the section (personal collecting done at Sunwapta Pass, Alberta, Canada, during 24th International Geological Congress field trip, 1972). Thus it now appears that this subzonation has wide applicability in the carbonate belt. When the complete details of the studies now in progress are completed and published, these subzones can probably be raised to zonal status, and we will have a workable zonation with well-documented range data for this interval.

Correlations for the individual subzones of the *Saukia* Zone in the Arbuckle Mountains were discussed previously (Stitt, 1971b, p. 11-12), and the same correlations can be extended into the Wichita Mountains. Correlations with other areas whose biostratigraphic details have been published since 1971 are suggested wherever possible in the discussions of the individual subzones.

Rasettia magna Subzone.—The following assemblage of species occurs in this subzone in the Chandler Creek section (pl. 7), and those taxa that are restricted to this subzone are indicated by an asterisk.

Bayfieldia binodosa (Hall)
Bowmania pennsylvanica Rasetti
Bynumina vescula Stitt
Euptychaspis frontalis Longacre*
Eurekia granulosa Walcott*
Geragnostus intermedius Palmer
Heterocaryon tuberculatum Rasetti*
Idiomesus levisensis (Rasetti)
Keithiella scrupulosa Longacre*
Leiocoryphe occipitalis Rasetti
Monocheilus truncatus Ellinwood*
Plethometopus convergens (Raymond)
Plethometopus granulosus Stitt*
Rasettia capax (Billings)
Rasettia magna Ellinwood*
Stenopilus pronus Raymond*
Theodenisia microps (Rasetti)*
Triarthropsis marginata (Rasetti)
Triarthropsis sp. undet.*

This is the lowest of the four subzones of the *Saukia* Zone. Its base is defined by the lowest occurrence of *Rasettia magna*, *Monocheilus truncatus*, *Eurekia granulosa*, *Theodenisia microps*, and *Idiomesus levisensis*. Its top is the base of the overlying *Saukiella junia* Subzone.

About half of the species that occur in the *Rasettia magna* Subzone are restricted to it, a higher restriction percentage than in either of the next two overlying subzones. In addition, *Stenopilus pronus*, *Plethometopus granulosus*, and *Theodenisia microps* all have their highest occurrence at about the same level, and *Rasettia magna* occurs only once above this level. This extinction level is well below the top of the subzone (pl. 7) and occurs in the lower 9-12 feet of the Signal Mountain Limestone, just above the pronounced lithologic change from the well-developed domal stromatolites of the uppermost Fort Sill to the more intraclastic limestones that characterize the lower part of the Signal Mountain. In even more detail, the rocks in which these trilobites make their last appearance are an interbedded sequence of predominantly laminated algal biomicrite, intrasparite, and trilobite biomicrite. In the next lithologic unit higher in the section, where the rocks become more definitely intraclastic, *Bayfieldia binodosa* makes its first appearance and is rather abundant. The same situation as outlined above occurs in the Joins Ranch section in the western Arbuckle Mountains (Stitt, 1971b, p. 62, pls. 10, 12). This suggests that the commonest trilobites of the *Rasettia magna* Subzone probably were ecologically adapted for the conditions in, on, or around the domal algal stromatolites and the interdome sediments, and that the demise of these trilobites may be directly related to the change in sedimentary environments.

Correlation of the *Rasettia magna* Subzone with similar assemblages in the Mistaya Formation in the southern Rocky Mountains of Canada is discussed in the section on the *Saukiella junia* Subzone.

Saukiella junia Subzone.—The following assemblage of species occurs in this subzone in the Chandler Creek section (pl. 7), and those taxa that are restricted to this subzone are indicated by an asterisk.

Acheilops cf. *A. dilatus* Ulrich*
Bayfieldia binodosa (Hall)
Bayfieldia simata Winston and Nicholls
Bowmania pennsylvanica Rasetti
Bynumina vescula Stitt
Euptychaspis jugalis Winston and Nicholls
Euptychaspis typicalis Ulrich
Eurekia eos (Hall)
Idiomesus levisensis (Rasetti)
Leiocoryphe platycephala Kobayashi
Magnacephalus smilus Stitt*
Plethometopus convergens (Raymond)
Rasettia wichitaensis (Resser)
Saukia tumida Ulrich and Resser*
Saukiella junia (Walcott)*
Saukiella pepinensis (Owen)*
Stenopilus latus Ulrich
Triarthropsis marginata (Rasetti)

This is an assemblage zone in the truest sense, because new taxa are steadily introduced throughout the subzone and less than one-third of these taxa are restricted to the subzone. The base of the *Saukiella junia* Subzone is defined in the Chandler Creek section by the lowest occurrence of *Saukia tumida*, *Saukiella pepinensis*, *Euptychaspis typicalis*, and *Stenopilus latus*. Its top is the base of the overlying *Saukiella serotina* Subzone.

Correlation with southern Rocky Mountains of Canada.—During August 1972 I participated in Field Excursion A-19 (sponsored by the 24th International Geological Congress) and, aided by W. H. Fritz and V. E. Kurtz, collected some trilobites from six fossiliferous beds in the middle part of the Mistaya Formation in the southern Rocky Mountains of Canada. The collections were made on the east slope of Sunwapta Pass, opposite the scenic Athabasca Glacier. Identification of these trilobites enables some tentative correlations for the middle Mistaya that complement those made by Derby and others (1972) for the uppermost Mistaya and basal Survey Peak Formations. The footages given (below, left) are in feet above the base of the Mistaya, which is 360 feet thick at Sunwapta Pass (SP).

SP-258	*Euptychaspis jugalis* Winston and Nicholls *Euptychaspis typicalis* Ulrich *Idiomesus levisensis* (Rasetti)
SP-230	*Euptychaspis typicalis* Ulrich *Plethometopus convergens* (Raymond) *Triarthropsis limbata* Rasetti
SP-222	*Briscoia* sp. undet. *Prosaukia*, n. sp. *Saukia tumida* Ulrich and Resser
SP-202	*Plethometopus convergens* (Raymond)
SP-169	*Saukiella pyrene* (Walcott)
SP-131	*Bayfieldia binodosa* (Hall) *Plethometopus* cf. *P. granulosus* Stitt

Almost all of these species occur in Oklahoma and illustrate the wide geographic distribution of the trilobites of the carbonate belt. In addition, the beds of trilobite biomicrite and intraclastic limestone from which these trilobites were collected are very similar to the limestones of the Signal Mountain and probably formed in a similar environment.

Biostratigraphically, *Saukiella pyrene* (SP-169) is restricted to the *Rasettia magna* Subzone (Stitt, 1971b, p. 11, pl. 12) and its correlatives (Longacre, 1970, p. 11-12, text-fig. 2), and the presence of *Bayfieldia binodosa* (SP-131) suggests the upper part of this subzone (see pl. 7; Stitt, 1971b, pl. 12). The first occurrences of *Saukia tumida* (SP-222) and *Euptychaspis typicalis* (SP-230) are indicative of the base of the *Saukiella junia* Subzone in Oklahoma; the former is restricted to this subzone, whereas the latter ranges up into the base of the overlying *Saukiella serotina* Subzone (see pl. 7; also Longacre, 1970, text-fig. 3; Stitt, 1971b, pl. 12). *Plethometopus convergens* (SP-202) occurs in both the *Rasettia magna* and *Saukiella junia* Subzones (pl. 7; Longacre, 1970, text-fig. 3), and thus its occurrence is unfortunately not indicative of either subzone. I can say, however, that the base of the *Saukiella junia* Subzone occurs near the middle of the Mistaya Formation, no higher than 222 feet above the base of the formation and perhaps as much as 50 feet lower. Below SP-169 I would expect to find only trilobites of the *Rasettia magna* Subzone, and because this is a fairly thick subzone (pl. 7; Stitt, 1971b, pl. 12) it may extend to the base of the Mistaya or even below into the top of the underlying Bison Creek Formation.

Saukiella serotina Subzone.—The following assemblage of species occurs in this subzone in the Chandler Creek section (pl. 7), and those taxa that are restricted to this subzone are indicated by an asterisk.

Bayfieldia simata Winston and Nicholls
Bowmania sagitta Winston and Nicholls*
Bynumina vescula Stitt
Calvinella tenuisculpta Walcott*
Euptychaspis jugalis Winston and Nicholls
Euptychaspis kirki Kobayashi*
Euptychaspis typicalis Ulrich
Eurekia eos (Hall)
Idiomesus levisensis (Rasetti)
Leiocoryphe platycephala Kobayashi
Plethometopus convergens (Raymond)
Rasettia wichitaensis Resser
Saukiella serotina Longacre*
Stenopilus latus Ulrich
Triarthropsis limbata Rasetti

The base of this subzone in the Chandler Creek section is defined by the lowest occurrence of *Euptychaspis kirki*, with the first appearances of *Saukiella serotina* and *Calvinella tenuisculpta* coming slightly higher in the section (compare with Stitt, 1971b, pl. 12; Longacre, 1970, text-fig. 3). Further substantiating this base is the highest occurrence of *Saukiella junia* in the bed one foot below the first occurrence of *E. kirki*. The top of this subzone is the base of the overlying *Corbinia apopsis* Subzone. Most of this interval is covered, resulting in few collections and less apparent diversity to the fauna than was previously recorded from the Arbuckle Mountains.

The *Saukiella serotina* Subzone has recently been recognized in Alberta, Canada (Derby and others, 1972, p. 505-508, fig. 3), the eastern Great Basin (Taylor, 1971; and in Taylor and Halley, 1974, table 2), and eastern New York (Taylor and Halley, 1974, p. 5), as well as documented in earlier reports of this subzone from the Arbuckle Mountains, Oklahoma (Stitt, 1971b, p. 12), and where it was originally defined in central Texas (Winston and Nicholls, 1967, p. 69-70; Longacre, 1970, p. 12). This illustrates the widespread distribution of this fauna in the carbonate belt around the Transcontinental arch (Lochman-Balk, *in* Holland, 1971, p. 102-103, figs. 22-23).

Corbinia apopsis Subzone.—The following assemblage of species occurs in this subzone in the Chandler Creek section (pl. 7), and those taxa that are restricted to this subzone are indicated by an asterisk.

Acheilops masonensis Winston and Nicholls*
Apatokephaloides clivosus Raymond*
Corbinia apopsis Winston and Nicholls*
Idiomesus levisensis (Rasetti)
Leiobienvillia leonensis Winston and Nicholls*
Plethometopus obtusus Rasetti*
Triarthropsis limbata Rasetti

The base of this subzone is defined in the Chandler Creek section by the lowest occurrence of *Apatokephaloides clivosus* and *Acheilops masonensis*. Most of this interval is covered, but fortunately the exposed beds yielded fossils. The top of this subzone is the base of the *Missisquoia* Zone (Ordovician).

In addition to the original definition and refinement of this subzone in central Texas (Winston and Nicholls, 1967, p. 69; Longacre, 1970, p. 12) and its previous recognition in the Arbuckle Mountains (Stitt, 1971b, p. 12), this subzone has recently been recognized in Alberta, Canada (Derby and others, 1972, p. 509, fig. 3) and in the eastern Great Basin (Taylor, 1971; and in Taylor and Halley, 1974, table 2).

Apatokephaloides clivosus, a species restricted to this subzone in all of the previously mentioned areas, has also been reported from Vermont (Raymond, 1924, p. 425) and from the Lévis Conglomerate at Quebec (Rasetti, 1963, p. 1010), suggesting that this subzonal assemblage probably extended into that area also. Taylor and Halley (1974, p. 5) found fossils indicative of the underlying *Saukiella serotina* Subzone and the overlying *Missisquoia* Zone in the Whitehall Formation in eastern New York, but faunas of the *Corbinia apopsis* Subzone assemblage were not discovered.

Evolutionary Patterns within Ptychaspid Biomere

The boundary between the *Corbinia apopsis* Subzone (=top of the *Saukia* Zone) and the *Missisquoia* Zone is the currently accepted horizon of the Cambrian-Ordovician boundary in North America (fig. 3; Winston and Nicholls, 1967, p. 71; Stitt, 1971b, p. 12-13; Derby and others, 1972, p. 509; Taylor and Halley, 1974, p. 8). This boundary is also the top of the Ptychaspid Biomere (fig. 3; Longacre, 1970, p. 2-3; Stitt, 1971b, p. 13-14, 1975), which begins at the base of the *Taenicephalus* Zone. All of the diagnostic *Saukia* Zone trilobite genera and species in the Arbuckle and Wichita Mountains, including some abundant taxa with stratigraphic ranges of over 200 feet, become extinct either within a few feet of the base of the *Corbinia apopsis* Subzone, within the subzone, or at its top. None survive into the Ordovician. The abruptness with which the diverse Ptychaspid Biomere assemblage dies out is striking (pl. 7; Stitt, 1971b, pl. 12) and parallels the abrupt extinction of the *Elvinia* Zone trilobites at the top of the underlying Pterocephaliid Biomere.

A composite range chart for identified species of latest Middle Cambrian and Late Cambrian trilobites (fig. 4), drawn from several sources, clearly shows the extinction levels that form the boundaries for three biomeres (Palmer, 1965a) that are recognized in this interval. Each biomere contains a unique assemblage of trilobite families, with the exception of the Agnostidae, which occur in all three biomeres. Other animal groups such as articulate brachiopods and conodonts were not necessarily affected by the events that caused the extinction of the trilobites. As Palmer (1965a) noted, the initial replacement trilobites at the bases of the biomeres are very similar to each other, as though they were all descended from a common stock. Furthermore, the extinction and subsequent replacement was probably a diachronous event (Palmer, 1962, 1965a, 1965b) that began at the margins of the Cambrian shelf area and proceeded across the shelf toward the shoreline. Thus a dynamic repeating picture (fig. 5) emerges for these trilobites, beginning with the extinction of established, diversified shelf trilobites, followed quickly by invasion of replacements from a slowly evolving oceanic trilobite group, then diversification of these new trilobites on the shelf, much later extinction of these now diversified trilobites, and the replacement (again) by members of the oceanic group.

A four-stage evolutionary pattern has previously been described (Stitt, 1971a, 1975) for the trilobites of the Ptychaspid Biomere. The first stage begins with the trilobites of the *Taenicephalus* Zone. These trilobites are characterized by their low faunal diversity, marked intraspecific varia-

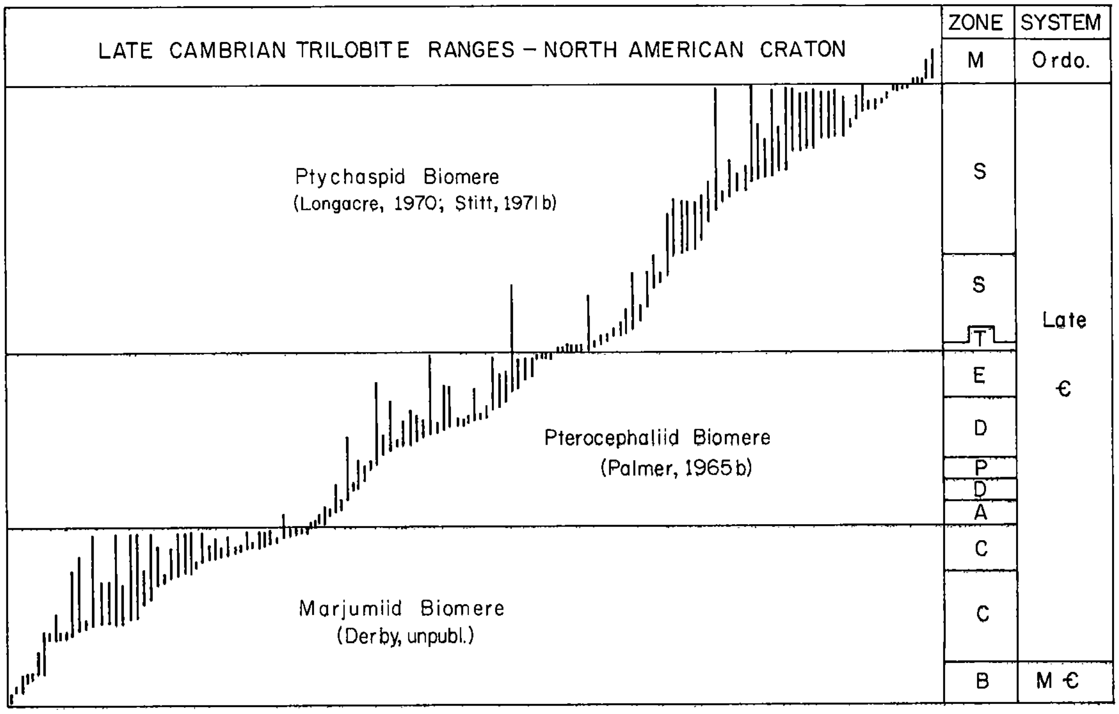

Figure 4. Composite range chart showing stratigraphic ranges of identified species of Late Cambrian trilobites.

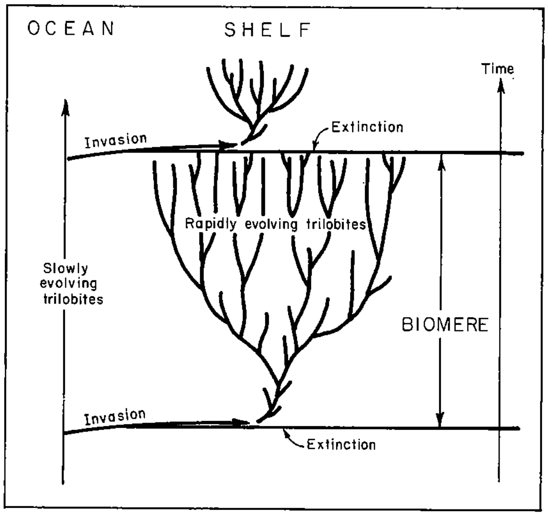

Figure 5. Diagrammatic representation of main characteristics and dynamics of biomeres.

bility, overall interspecific similarity of cranidial and pygidial shapes, and short stratigraphic ranges of individual taxa, which are evolving rapidly. This evolutionary stage continues into the overlying *Idahoia lirae* Subzone (fig. 3; pl. 7).

Evolutionary-stage 2 follows stage 1 and is characterized by a slight decrease in the amount of intraspecific variability and an increase in the interspecific variation in cranidial shapes. Diversity is still low, but the individual stratigraphic ranges are becoming longer, suggesting less rapid evolution of descendent forms. Stage 2 occurs in the *Saratogia* Zone (above the *I. lirae* Subzone) and its equivalents in the Ptychaspid Biomere (Stitt, 1971b, p. 10).

Stage 3 is characterized by its high species diversity, marked interspecific diversity in cranidial and pygidial shapes and sizes among the trilobites, long stratigraphic ranges for individual species, and the tendency toward decreased intraspecific variation, especially when compared with stage 1. Stage 3 occurs in the *Saukia* Zone (except the topmost *Corbinia apopsis* Subzone) in the Ptychaspid Biomere (fig. 3; pl. 7; Stitt, 1971b, pl. 12).

The main evolutionary style in stages 1 and 2 is speciation and adaptive radiation (fig. 6), stimulated by selection for those invading oceanic trilobites that could best adapt to life on the North American shelf. Lineages that successfully made the transition tended, as time passed, to become more efficient in their particular niche on the shelf. In stage 3, this is reflected by a change in the main evolutionary style from the diversification of speciation to a pattern in which genera consist of vertical successions of species (typically nonoverlapping; see fig. 7), and the introduction of new species apparently involved selection for relatively minor evolutionary adjustments and morphological refinements of basically sound adaptive plans. I believe that once the trilobite population had reached this plateau in its development, the various species became specialized enough so that they were susceptible to extinction if faced with the need to adapt rapidly to a geologically sudden change in their environment. When eventually such a change occurred, initial extinctions rapidly depopulated the shelf and initiated the final stage of evolution among the survivors.

Stage 4 is characterized by short stratigraphic ranges for the individual trilobite species and coquinoid abundances of at least one species that is clearly a member of one of the established trilobite families of stage 3. Apparently freed from the usual population restraints by the initial depopulation of the shelf area, this species rapidly multiplied to reach large population numbers. The well-known *Irvingella major* coquina (Wilson and Frederickson, 1950) at the top of the Pterocephaliid Biomere is probably the best development of this aspect of stage 4. Many of the other new species present in stage 4 are not clearly related to the established and long-ranging families of the biomere and may represent attempts at rapid adjustment to the environmental change. Mixed in with the above are a few olenid trilobites, usually occupants of open oceanic areas, that are apparently the first migrants into the shelf from the open-ocean replacement faunas.

Ultimately, however, the environmental change was either too rapid or too drastic, and even the adventurous trilobites of stage 4 became extinct. They are replaced within a very short stratigraphic interval by trilobites that look amazingly like those of the previous stage 1 (compare *Parabolinoides* and *Plethopeltis*, for example, in Stitt, 1971b, pl. 2, figs. 10-13, and pl. 8, figs. 10-15), and the cycle begins again.

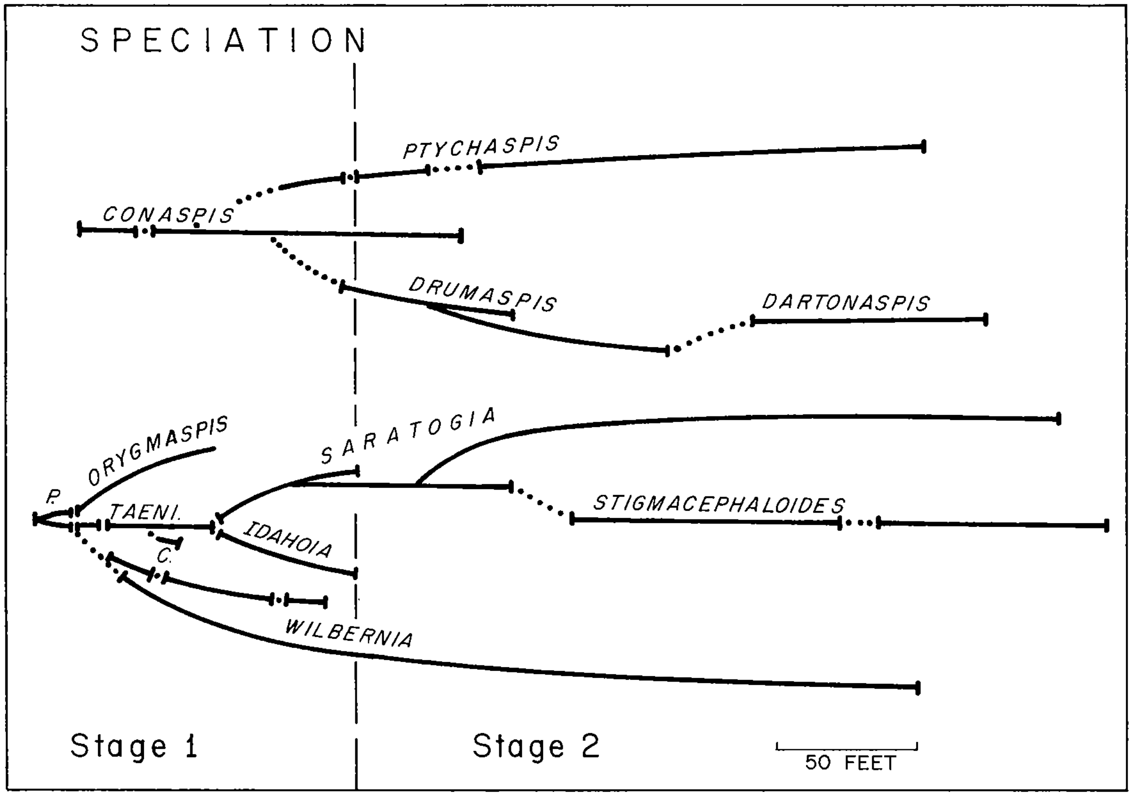

Figure 6. Diagram showing stratigraphic ranges of genera (labeled) and species (solid lines) of trilobites of *Taenicephalus* and *Saratogia* Zones of Ptychaspid Biomere from Oklahoma as well as probable evolutionary relationships of these taxa.

Possible Cause of Trilobite Extinctions at Biomere Boundaries

Any explanation of the mass extinction of these diversified and apparently well-adapted trilobites must simultaneously account for several different problems (Stitt, 1975). The extinctions are abrupt (pl. 7; Stitt, 1971b, pls. 9-11), and the horizons involved can be pinned down in measured sections to intervals as thin as 2 inches (in the Royer Ranch section, in the Arbuckle Mountains, a thin limestone bed contains the last trilobites of the Pterocephaliid Biomere along its underside and the first trilobites of the Ptychaspid Biomere on its top). Very little mixing of the adjacent faunas occurs at the biomere boundaries, with at most only a few specimens of *Irvingella major* of the Pterocephaliid Biomere occurring in the basal bed of the Ptychaspid Biomere. The sharp faunal changes at the base and top of the Ptychaspid Biomere are not related to unconformities or drastic lithologic changes (see discussion of the Cambrian-Ordovician boundary), and these horizons thus far cannot be located independently on sedimentological criteria.

The diverse trilobites of various holaspid sizes and shapes that become extinct are replaced by trilobites that are more uniform in holaspid size and shape (compare the trilobites of the *Elvinia* Zone at the top of the Pterocephaliid Biomere [pl. 1 and pl. 2, fig. 1; Stitt, 1971b, pl. 1 and pl. 2, figs. 1-9] with those of the *Taenicephalus* Zone at the base of the Ptychaspid Biomere [Stitt, 1971b, pl. 2, figs. 10-21]). The only trilobites to survive the extinction phenomenon are agnostid trilobites such as *Pseudagnostus* (pl. 7; Stitt, 1971b, pl. 2, figs. 4, 5, pl. 11). Robison (1972) concluded that agnostids were adapted to a pelagic mode of life and as such probably had rather different environmental require-

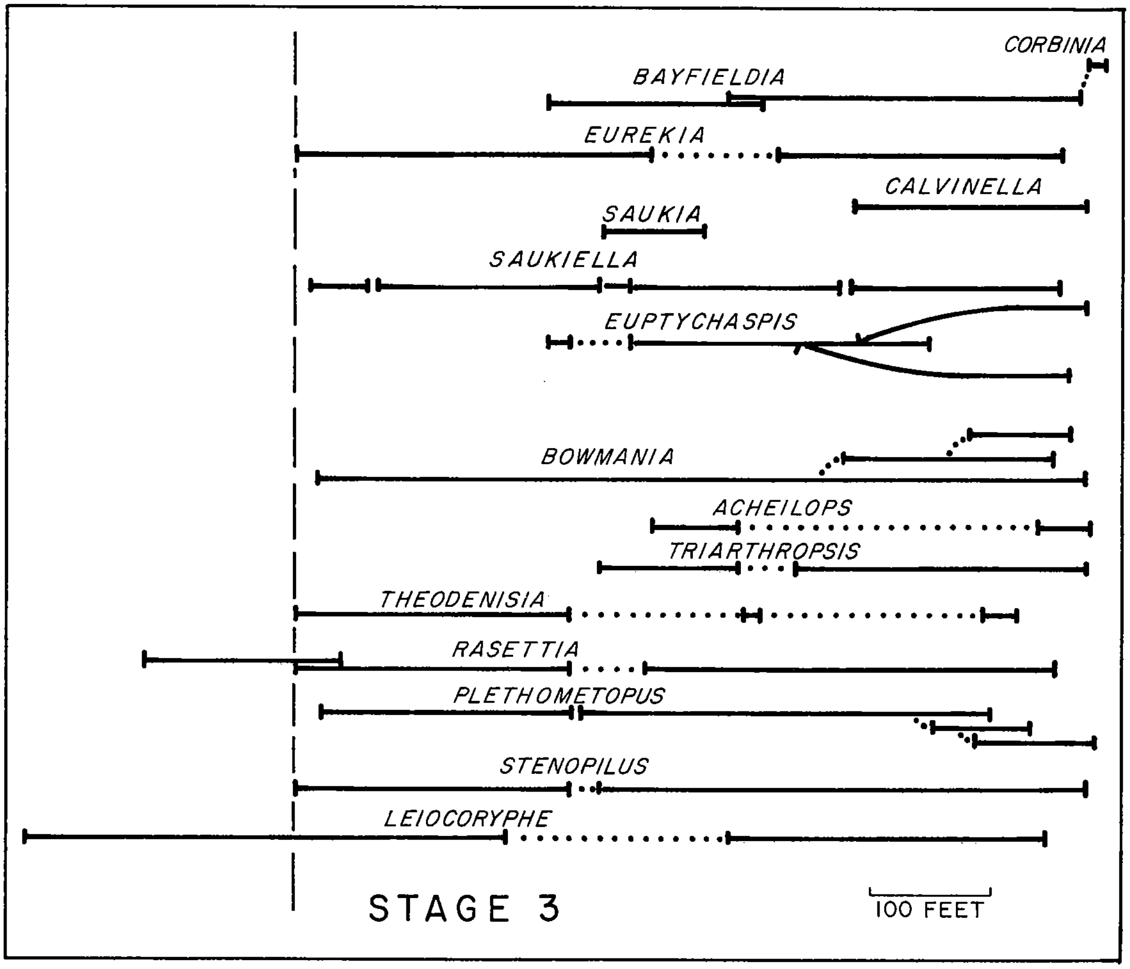

Figure 7. Diagram showing stratigraphic ranges of genera (labeled) and species (solid lines) of trilobites of *Saukia* Zone of Ptychaspid Biomere from Oklahoma as well as probable evolutionary relationships of these taxa.

ments and tolerances than the polymerid trilobites, which were probably adapted for a benthonic existence. Thus any proposed extinction mechanism must explain a phenomenon that started at the shelf margins and proceeded shoreward, that eliminated bottom-dwelling shelf trilobites while pelagic trilobites living in the water mass above survived, and that simultaneously killed one group of trilobites while making conditions favorable for the migration onto the shelf of replacement forms.

Palmer (1972, 1974) recently detailed what can be reasonably reconstructed of the Cambrian world. He outlines a world in which there were four major endemic groups of trilobites (North American, European, Siberian, and Chinese) that populated the shallow-water cratonic shelves. In the ocean basins there were widespread agnostid trilobites associated with two assemblages of oceanic polymerid trilobites. The distribution of the endemic cratonic trilobites is interpreted as being latitudinally controlled, with the North American group occurring in the middle latitudes. Olenid trilobites occur with the agnostids in the oceanic waters bordering North America (Wilson, 1957).

Öpik (1966) discussed the abrupt extinction of diverse shelf trilobites in both Australia and southeastern Asia. The extinctions he described are of the same type and magnitude as those that characterize biomere boundaries in North America. Interestingly enough, Palmer (1974, p. 224, fig. 10), in his most recent reconstruction of the Cambrian, located North American and Chinese endemic trilobite faunas at about 30° latitude, but on opposite sides of the equator. Thus trilobites susceptible to this drastic type of extinction may have lived in the middle latitudes in both hemispheres during the late Cambrian, and the events that led to these extinctions were probably global rather than local.

An important key to the understanding of what might have caused the extinctions may be to look at the possible paleoecology of the replacement faunas, since they seem to be favored by the change that killed the trilobites that they replaced. It seems highly likely that the replacement trilobites were derived from the olenid trilobites (Lochman, 1956; also compare, for example, *Parabolinoides contractus* [Stitt, 1971b, pl. 2, figs. 11-13] from the basal beds of the Ptychaspid Biomere with *Parabolina spinulosa* [Henningsmoen, 1957, pl. 3, chart 5, p. 293], which was living approximately contemporaneously in the nearly oceanic areas). In his study of the olenids, Henningsmoen (1957, p. 70-82) made several interpretations that are useful in the present context: (1) that the olenids in Scandinavia probably were living in shallow water but that olenids living along the North American shelf edge may have lived in deeper water (see also Wilson, 1957, and Taylor, 1976); (2) that the olenids were good swimmers, swimming above a stagnant ocean floor and descending to the ocean floor only long enough to feed on the organic debris accumulating there; (3) that the olenids did not move to more favorable conditions on the craton, perhaps because they were unable to compete with the more specialized forms that already occupied the cratonic-shelf sites.

Palmer (1972) suggested that western Europe was probably located in high latitudes during the Cambrian; if so, then the olenids living there must have been living in shallow but rather cold water. Taylor (1976) argued further that olenid trilobites around North America lived off the edge of the shelf, in deeper and presumably colder water than that on the shelf. Thus, Taylor concludes, the olenid trilobites may be analogous to the asellote isopods, which live today at all depths in the Antarctic area but only in cold water off of the shelf in the northwestern Atlantic Ocean and in the eastern Pacific Ocean opposite Peru.

Taylor (1976) also summarized data available on the distribution of modern isopods along a profile from North Carolina to Bermuda and pointed out the association of major changes in population composition (at the generic level) within the isopods with major changes in water temperature. Shelf isopods live in water that is warm but seasonally variable, whereas abyssal isopods live in cold water that varies in temperature only slightly during the year. Taylor then compared the changes in population composition of the trilobites of the Ptychaspid Biomere (along a basin-to-shore profile from western Nevada to Minnesota-Wisconsin) with the population changes in the isopods and found that the major changes in generic composition for both groups occur at the shelf edge and on the continental slope. Since the major isopod-population changes appear to be temperature related, Taylor postulated a similar temperature influence on Late Cambrian trilobites.

Utilizing these various diverse bits of information, perhaps what happened is as follows (see also Stitt, 1975). During most of the Late Cambrian, North American shelf trilobites probably enjoyed mild climates and warm, shallow waters and became well adapted for life under these conditions on the broad, shallow shelf areas that existed then. The deeper oceanic areas probably then as now contained water that was mostly much cooler (except near the surface) than the water covering the shelves. There may well have been (fig. 8A) two temperature regimes in the sea—a warm-water regime located over the temperate shelves and in the near-surface water over the oceanic areas, with endemic trilobites adapted for life on the various shelf areas, and a cold-water regime in the polar shelf areas and in the deeper water of the ocean basins, with olenids and some other polymerid trilobites adapted for life under these conditions. The boundary between these water masses may have been a rather sharp thermocline (fig. 8A, t_0), such as exists today between similar water masses in the oceans (Taylor, 1976).

If a geologically brief but pronounced climatic cooling had occurred, punctuating the normal warm climate, it would have caused a shift of the cold, polar-water masses toward the equator along the ocean floor. This shift would have caused a rise in the thermocline, eventually allowing cold water to move onto the shelves, encroaching along the bottom (fig. 8B) under the warmer, less dense shelf water. Benthonic shelf trilobites used to living in stable, warm conditions might have been killed rapidly by the cold water, starting at the shelf margin and moving landward. These same cold-water conditions would have been exactly what the olenids were already used to, and, with the progressive depopulation first at the shelf edge and then shoreward, a migration of olenids onto the shelf would have been a likely result, instigated by the same factor or factors that eliminated the shelf trilobites. Pelagic trilobites such as the agnostids (fig. 8A, B) probably survived this cool event by either living in the near-surface waters, which would have been still somewhat warm, or by simply being more tolerant of temperature extremes.

Once the replacement trilobites migrated onto the shelf, they began to evolve rapidly (stages 1 and 2) in response to the opportunities and selection pressures afforded by these broad, shallow-water areas. When the climate began to moderate and to return to the more normal warm conditions, these evolving trilobites did not return to the ocean basins but stayed on the shelf areas and continued to diversify. Apparently during their continued evolution they gradually lost their tolerance to cold-water conditions, because after a long time of success (stage 3) the entire diverse assemblage of shelf trilobites of the Ptychaspid Biomere was again eliminated at the end of the Cambrian.

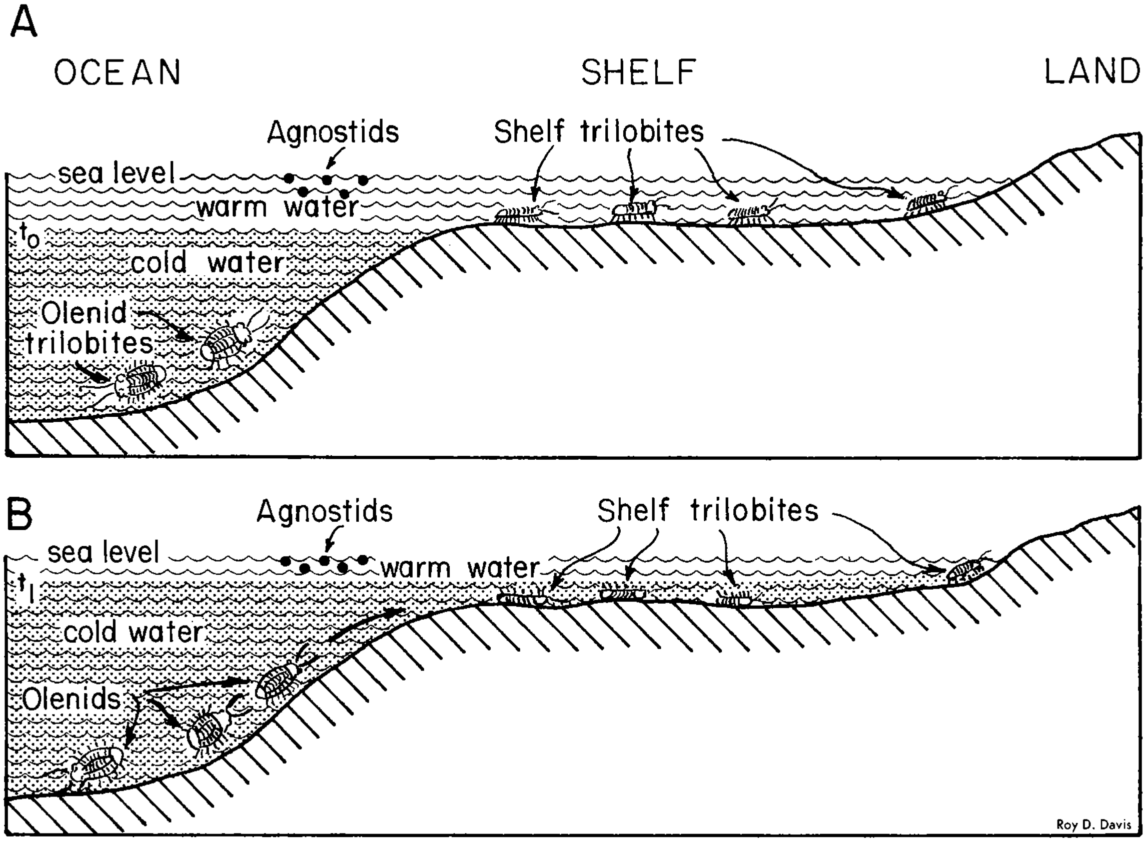

Figure 8. Interpretive diagram of trilobite extinctions.
A. Trilobite life and water mass relationships during stage 3 ("normal" times).
B. Shelf trilobites die and are replaced by migrating olenid trilobites as thermocline (t_1) rises and cold water invades shelf areas.

Cambrian-Ordovician Boundary

As in the Arbuckle Mountains (Stitt, 1971b, p. 12-13), the boundary between the *Saukia* Zone and the *Missisquoia* Zone is recognized as the Cambrian-Ordovician boundary in the Wichita Mountains. Once again, this horizon occurs near the middle of the Signal Mountain Limestone, in an apparently conformable limestone sequence.

Taylor and Halley (1974, p. 8) briefly summarized the criteria presently used to define the boundary between the Cambrian and Ordovician Systems in North America. As they point out, the position of this boundary in North America is probably different than its position where first defined in Great Britain. Henningsmoen (1973) discussed not only the uncertainties in trying to reconstruct exactly what Charles Lapworth had had in mind when he defined the base of the Ordovician System but also the problems involved in trying to correlate from the type area into adjacent areas in Europe such as Scandinavia. James F. Miller (Southwest Missouri State University, Springfield, oral communication, 1975) recently suggested that the Cambrian-Ordovician boundary as recognized in Scandinavia and Australia may correlate closely with the base of the *Corbinia apopsis* Subzone, if such correlations are based primarily on conodont distributions and ranges. The question of the exact position and correlation of the Cambrian-Ordovician boundary is presently being studied by a working subgroup of the International Stratigraphic Commission, in the hope that this knotty international problem can be brought to some agreement in the near future.

M. E. Taylor (1972, written communication) noted that at the Lava Dam South section in the southern House Range of western Utah the replacement of the *Saukiella serotina* Subzone assemblage by the *Corbinia apopsis* assemblage was accompanied by an abrupt change from trilobite biomicrite to oosparite. This prompted a detailed reexamination of the rocks that span the Cambrian-Ordovician boundary in the Chandler Creek section, and the better exposed Joins Ranch section in the Arbuckle Mountains, to see if a similar lithologic change occurred in the interval. In the Joins Ranch section, the rocks from 1,041 to 1,065 feet were carefully resampled and examined (base of *C. apopsis* Subzone at 1,046 feet; highest occurrence of *Corbinia apopsis* Subzone trilobites at 1,054 feet; lowest occurrence of *Missisquoia* Zone trilobites [=base of *Missisquoia* Zone] at 1,058 feet). All of the rocks are approximately the same color (about medium gray), and a summary of the lithology of the exposed beds is as follows:

Feet	
1,057.5-1,065	Trilobite biomicrite
1,056-1,057	Micrite with scarce intraclasts
1,055	Slightly glauconitic mixed micrite and intrasparite
1,054	Trilobite biomicrite
1,049.5-1,051	Oolitic intrasparite
1,047	Glauconitic mixed trilobite biomicrite and biosparite
1,041-1,046	Sparse trilobite biomicrite

This sequence contains the common lithologies of the Signal Mountain, and the mixture of lithologies in the *Corbinia apopsis* Subzone really does not represent a change from typical lithologic sequences below or above.

In the Chandler Creek section, fewer beds are exposed in this interval. They are again all about the same shade of medium gray, and a summary of the lithology of the exposed beds is as follows:

Feet	
1,499, 1,501	Sandy trilobite biomicrite
1,497	Pelmicrite
1,491	Sandy pelsparite
1,483	Sparse trilobite pelsparite
1,482.5	Glauconitic trilobite biosparite
1,479	Sandy pelsparite
1,469	Intrasparite

Again, most of the rocks are fine grained, and there is no drastic lithologic change at either the base of the *Corbinia apopsis* Subzone (1,479 feet) or the base of the *Missisquoia* Zone (1,497 feet). Whatever the environmental event was that caused the extinction of these trilobites, it did not leave an obvious record in the lithologies of the limestones. This suggests that at least some of the environmental factors that influenced the distribution and survival of these trilobites cannot be deduced readily by simple examination of the enclosing rocks. Perhaps Bergström (1973, p. 47) was right when he said, "One of the possible complications is that the animal's choice of a sediment may not correspond to the sedimentologist's idea of a lithology."

One other important aspect of the abrupt faunal change at the base of the *Missisquoia*

Zone is discussed in the section on the *Missisquoia depressa* Subzone.

Ordovician

Trilobites collected from the upper half of the Signal Mountain Limestone in the Chandler Creek section are assigned to the *Missisquoia* and *Symphysurina* Zones of the Canadian Series (Lower Ordovician) (fig. 3). At the start of this project the base of the overlying McKenzie Hill Limestone was selected as an arbitrary top for the biostratigraphic analysis, so that the interval studied in the Wichita Mountains would then approximate the interval previously studied in the Arbuckle Mountains (Stitt, 1971b). This assumed that the Signal Mountain—McKenzie Hill contact in the Wichita Mountains was about the same horizon as the Butterly Dolomite—McKenzie Hill contact in the western end of the Arbuckle Mountains (fig. 2). This correlation is explored in more depth in the discussion of the *Symphysurina* Zone.

Lower Ordovician rocks are dolomitized over most of the Midcontinent, from the Upper Mississippi Valley through Missouri to Texas (see, for example, Chenoweth, 1968, p. 1682-1683, fig. 12). Faunal information from these dolomites is spotty, being restricted mostly to float collections and a few, widely scattered, *in situ* collections of molds preserved either in the dolomite or in chert nodules in the dolomite. In this vast area the only surface outcrops of a complete, uninterrupted, fossiliferous limestone sequence for the lowest Ordovician are in Oklahoma, and especially in the Wichita Mountains. In the western Arbuckles, the Butterly Dolomite intervenes to obliterate what turns out to be a very important 150 feet of strata in the *Symphysurina* Zone. Hence the information from Oklahoma and especially this section, plus that reported by Winston and Nicholls (1967) from central Texas, forms the best basis for correlations between the Midcontinent region and the Utah-Nevada area, which has become the effective reference area for the Lower Ordovician of North America since the biostratigraphic studies of Ross (1951) and Hintze (1952).

Missisquoia Zone

The following assemblage of species occurs in the *Missisquoia* Zone in the Chandler Creek section (pl. 7), and those taxa that are restricted to this zone are indicated by an asterisk.

Apoplanias rejectus Lochman
Highgatella sp. undet.*
Homagnostus reductus Winston and Nicholls
Missisquoia depressa Stitt*
Missisquoia typicalis Shaw
Plethopeltis arbucklensis Stitt*
Ptychopleurites brevifrons (Kobayashi)*
Symphysurina cf. *S. cleora* (Walcott)*

The base of this zone is defined in the Chandler Creek section on the lowest occurrence of *Missisquoia depressa, Plethopeltis arbucklensis,* and *Ptychopleurites brevifrons*. This unique assemblage at the base of the zone is recognized as a new subzone, the *Missisquoia depressa* Subzone, both here and in the Arbuckle Mountains.

The association of *Missisquoia typicalis* and *Apoplanias rejectus* in the middle and upper parts of the *Missisquoia* Zone is also recognized as a new subzone, the *Missisquoia typicalis* Subzone. This subzone is also recognized in the Arbuckle Mountains. The top of the *Missisquoia* Zone is the base of the overlying *Symphysurina* Zone.

The *Missisquoia* Zone, with its low diversity and generally short-ranging taxa that are abundant, shares these characteristics with the lowest zone in each of the underlying Ptychaspid and Pterocephaliid Biomeres (fig. 3). This abundant but low-diversity fauna has been called stage 1 in the development of the trilobites of the Late Cambrian biomeres (Stitt, 1971a) and has been interpreted as the initial phase of an adaptive radiation. Whether the *Missisquoia* Zone trilobites represent the beginning of an Ordovician "hystricurid" biomere or not is unknown at present, for no abrupt extinction event that would have signaled the end of such a biomere was encountered in the overlying rocks studied in this project.

Silicified valves of the orthid brachiopod *Apheoorthis* occur abundantly on bedding surfaces starting usually about 30-50 feet above the base of the *Missisquoia* Zone. These silicified shells are easy to spot, and their lowest occurrence can be used as a field aid for locating the *Missisquoia* Zone and the vicinity of the Cambrian-Ordovician boundary. Ham (1955, fig. 1, 1969, fig. 24) used the zone of these silicified *Apheoorthis* valves as an aid in mapping and correlating in the Arbuckle Mountains.

Missisquoia depressa Subzone.—This subzone is delineated here for the first time. It is characterized by the association of *Missisquoia depressa*, *Plethopeltis arbucklensis*, and *Ptychopleurites brevifrons*, all of which are restricted to this subzone (pl. 7). *Homagnostus reductus* makes its lowest appearance in this subzone but is not restricted to it. *Plethopeltis arbucklensis* is the most abundant of the three diagnostic taxa, reaching coquinoid abundances in some beds.

This subzone is also recognized at the base of the *Missisquoia* Zone in the western Arbuckle Mountains. The occurrence of *Missisquoia depressa* and *Plethopeltis arbucklensis* at the base of the *Missisquoia* Zone has previously been documented (Stitt, 1971b, p. 13, pls. 9, 10, 12), and *Ptychopleurites brevifrons* can now be added to that association (see fig. 9 and the occurrence data for *Ptychopleurites* in the Arbuckle Mountains that are listed for that taxon later in this report in the section on Systematic Paleontology).

The top of the *Missisquoia depressa* Subzone is the base of the overlying *Missisquoia typicalis* Subzone, which is defined by the first occurrence of either *M. typicalis* or *Apoplanias rejectus*. In the Joins Ranch section in the Arbuckle Mountains, the highest occurrence of *Plethopeltis arbucklensis* and the lowest occurrence of *Apoplanias rejectus* are in the same bed (Stitt, 1971b, p. 59), which is probably the best representation of the real situation. In the Chandler Creek section, a mostly covered interval of 16.5 feet separates the highest occurrence of *P. arbucklensis* and *P. brevifrons* from the lowest occurrence of *M. typicalis* and *A. rejectus*. In the Highway 77 section in the Arbuckle Mountains, this interval is not very fossiliferous (see Stitt, 1971b, p. 55), and a barren interval of 49 feet separates the highest occurrence of *P. arbucklensis* from the lowest occurrence of *M. typicalis*.

I prefer to assign the assemblage of the *Missisquoia depressa* Subzone to the earliest Ordovician *Missisquoia* Zone rather than to the latest Cambrian *Saukia* Zone for three reasons. First, none of the trilobite genera or species that have been found in the *Saukia* Zone in either the Arbuckle or Wichita Mountains range upward into the *M. depressa* Subzone. Several of the long-

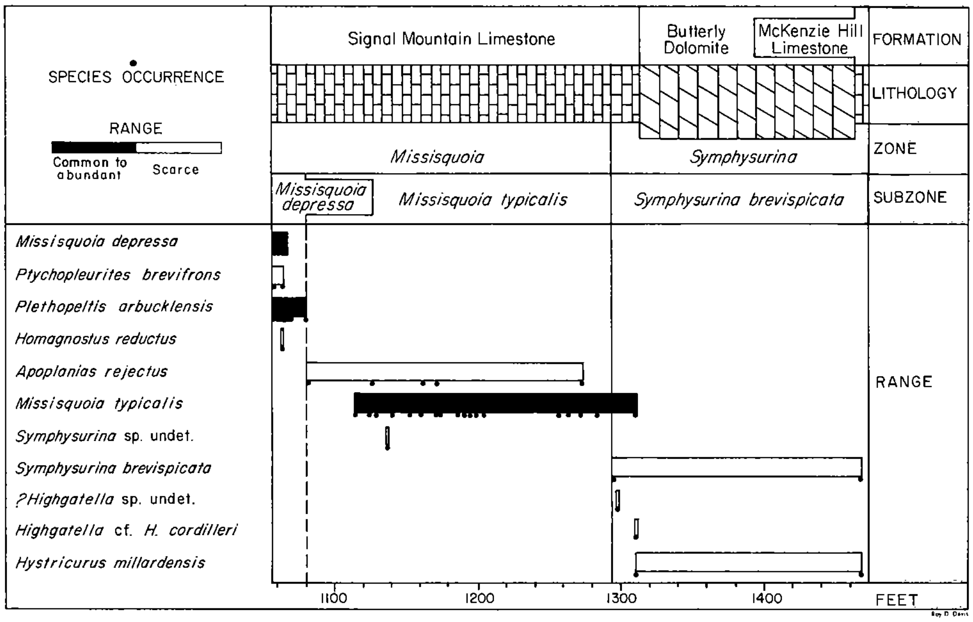

Figure 9. Diagram showing revised stratigraphic occurrences and ranges of identified Ordovician trilobites, Joins Ranch measured section, western Arbuckle Mountains.

ranging species of the *Saukia* Zone do occur with the assemblage of the *Corbinia apopsis* Subzone, indicating its affinities with the other *Saukia* subzones and its position as the latest Cambrian assemblage.

A second reason is that *Missisquoia depressa* is the apparent ancestor of *Missisquoia typicalis*. *M. typicalis* occurs with various species of *Symphysurina* (pl. 7; Stitt, 1971b, pl. 12), a genus that has been traditionally recognized as an indicator of lowest Ordovician rocks since the work of Ross (1951) and Hintze (1952). This association of *Missisquoia* and *Symphysurina* led earlier workers (Winston and Nicholls, 1967, p. 72; Taylor, 1971; Stitt, 1971b, p. 13; Taylor and Halley, 1974, p. 6-8) to consider the *Missisquoia* Zone, and therefore species of *Missisquoia*, to be indicators of lowest Ordovician rocks also. Therefore, it seems more logical to me to include the *Missisquoia depressa* assemblage with the Ordovician *Missisquoia* Zone rather than with the underlying *Saukia* Zone.

A third reason for considering the *M. depressa* assemblage as Ordovician rather than Cambrian is the presence of *Ptychopleurites brevifrons*. Kobayashi (1936a) originally described this taxon and considered it to be part of a Late Cambrian assemblage. Palmer (1968, p. B104) noted that *P. brevifrons* comes from a single collection that is "about 50 feet above the highest undoubted Cambrian collection and it lies above a collection that yielded only small brachiopods resembling *Nanorthis*, a characteristic Early Ordovician form." Palmer excluded *P. brevifrons* from his study of Cambrian trilobites from Alaska and considered the taxon to be Ordovician (Palmer, 1968, fig. 2). This further substantiates my belief that the *M. depressa* assemblage should be associated with the Ordovician *Missisquoia* Zone.

On the other hand, the most abundant species in the *M. depressa* assemblage is *Plethopeltis arbucklensis*, and the genus *Plethopeltis* is usually considered to be restricted to the Trempealeauan (see, for example, Lochman-Balk, 1971, p. 91, fig. 7). However, I believe that a closer examination of the occurrences of *Plethopeltis* raises doubt about the restriction of this taxon to the uppermost Cambrian. As I noted previously, *P. arbucklensis* occurs in Oklahoma with other trilobites that are best considered to be Ordovician. Longacre (1970, p. 19-20) recently reviewed the nomenclatorial history of *Plethopeltis*. The original specimens, described from Hoyt's Quarry west of Saratoga Springs, New York, are preserved in a dark limestone and have generally small- to medium-sized cranidia (5-14 mm long) with some kind of granular ornament (Longacre, 1970, p. 20). Correlation of the Hoyt Limestone fauna is difficult; the only species in common with Oklahoma or Texas collections is *Briscoia hartii* (=*Dikelocephalus hartii* in Fisher's faunal list, 1956, p. 333), which is scarce high in the *Saukiella junia* Subzone in Texas (Longacre, 1970, p. 16, text-fig. 3) and scarce low in the *Saukiella serotina* Subzone in the Arbuckle Mountains (Stitt, 1971b, p. 17, pls. 9, 12). This correlation is tenuous at best, but it suggests a Trempealeauan age for this fauna. Taylor and Halley (1974, p. 16-17) wrestled with this same correlation problem and suggested that the uniqueness of the Hoyt Limestone fauna may be the result of original environmental differences during the Late Cambrian between the Hoyt and other coeval carbonate areas in North America.

In Texas, four poorly preserved specimens from the dolomitic facies of the San Saba Limestone Member of the Wilberns Formation are assigned to *Plethopeltis* (Longacre, 1970, pl. 4, figs. 7, 8). They resemble the species of *Plethopeltis* based on Walcott's collections from the Hoyt Limestone, and they occur in the *Saukiella pyrene* Subzone, which would perhaps make them a little older biostratigraphically than Walcott's species. However, they occur in dolomite, and Longacre (p. 21) stated that curiously enough none had ever been found in limestone in central Texas.

In Missouri, *Plethopeltis* occurs in a fauna described as highest Cambrian in Bridge (1930, p. 95). Most if not all of these specimens are preserved in chert nodules that usually occur as float, weathering out of the Eminence Dolomite. This mode of occurrence raises two problems that I want to consider. First, the specimens I have seen are much larger than the type material from the Hoyt Limestone, and their mode of preservation left no trace of any granules if such were present originally. Also, the pygidium associated with *Plethopeltis* in Missouri looks more like a *Plethometopus* pygidium than a *Plethopeltis* pygidium. It is possible that what is called *Plethopeltis* in Missouri is really *Plethometopus* that has undergone chertification and dolomitization, thus preserving in bolder relief the very, very faint anterior outline of the glabella that is present on some species of *Plethometopus* (see, for example, *Plethometopus obtusus* Rasetti, 1959, pl. 53, fig. 12; Stitt, 1971b, pl. 6, fig. 16).

The second problem with the Missouri occurrence of *Plethopeltis* concerns the reliability of the Late Cambrian age assigned to this taxon. Bridge (1930, p. 94) discussed the problems of reconstructing biostratigraphic zones when most of the fossils occur as float, with only a few scattered occurrences that are actually *in situ*. *Plethopeltis* occurs with *Entomaspis* (Bridge, 1930, p. 95), apparently above a completely different fauna that resembles a *Saukiella serotina* or *Saukiella junia* subzonal assemblage (compare the faunal list given in Bridge, 1930, p. 95, with Longacre, 1970, text-fig. 3, and Stitt, 1971b, pl. 12). Rasetti (1952, p. 801) redescribed the facial sutures of *Entomaspis* and noted that the only other trilobite with similarly unusual facial sutures was a Lower Ordovician taxon. I have collected a few float samples of *Plethopeltis* in Missouri myself and have yet to find *Plethopeltis* occurring with known Upper Cambrian trilobites on the same piece of chert. The *Missisquoia* Zone fauna and its significance was unknown to Bridge and Ulrich, and the abruptness of the change at the boundary between the *Missisquoia* Zone and the *Saukia* Zone was also documented after their work. I believe that the actual age of the *Plethopeltis* fauna in Missouri remains to be proved and will only be resolved when *in situ* specimens can be collected in a known biostratigraphic context. Once again, *Plethopeltis* occurs in biostratigraphic uncertainty.

Howell (1944) recognized a *Plethopeltis* Zone as the highest Cambrian zone in North America. The data for this zone are generally (e.g., Bell and others, 1956, p. 440) attributed solely to Raasch, who published (1952, p. 148) a list of genera associated with *Plethopeltis* in the Sunset Point Sandstone, all of which are *Saukia* Zone trilobites and suggest a *Saukiella serotina* Subzone association. Unfortunately, Raasch never did publish descriptions or illustrations of his *Plethopeltis* Zone fauna. Stauffer (1940, p. 54) commented on the difficulty of working with fossils from the friable uppermost Cambrian sandstones when he described and illustrated the trilobites from the Van Oser beds in the upper part of the Jordan Sandstone in Minnesota. The Van Oser fauna included a few specimens attributed to *Plethopeltis* sp. (p. 55-56, pl. 6, figs. 11-15). Later, Miller (1970a) reported Ordovician conodonts from the Van Oser and overlying Sunset Point Members of the Jordan Sandstone in Wisconsin. He was not able to find any trilobites where he collected his conodonts. The entire Jordan Sandstone was previously considered to be latest Cambrian in age (Bell and others, 1956, p. 431, pl. 1; Miller, 1970a). This apparent age conflict for the Van Oser and Sunset Point Members of the Jordan raises an interesting possibility. The faunal change across the Cambrian-Ordovician boundary takes place very abruptly, with the highest Cambrian collection as little as 1 foot below the lowest Ordovician collection (Winston and Nicholls, 1967, p. 71; Derby and others, 1972, p. 505-506, fig. 3). Unless the trilobite collecting in the Van Oser and Sunset Point was done very carefully, mixing of Ordovician and Cambrian fossils could have occurred. If Miller's collections come from the Ordovician part of the Sunset Point, confusion as to the location of the Cambrian-Ordovician boundary in the area is the result, and once again *Plethopeltis* occurs in biostratigraphic confusion. The Sunset Point should be re-collected for both trilobites and conodonts so this problem could be resolved.

I think the preceding discussion suggests that the genus *Plethopeltis* is not restricted to the Trempealeauan but that it ranges upward into the basal Canadian, certainly in Oklahoma and perhaps also in southeastern Missouri and the Minnesota-Wisconsin area.

Missisquoia typicalis Subzone.—The base of this subzone is defined by the lowest occurrence of *Missisquoia typicalis* or *Apoplanias rejectus*, the two trilobite taxa that characterize this subzone. *A. rejectus* is restricted to this subzone, whereas the much more abundant *M. typicalis* ranges into the overlying *Symphysurina* Zone (pl. 7). *Symphysurina* cf. *S. cleora* apparently is also restricted to this subzone, marking the lowest biostratigraphic occurrence of this genus in the Wichita Mountains. The top of this subzone is the base of the overlying *Symphysurina* Zone.

The *M. typicalis* Subzone is also recognized in the upper part of the *Missisquoia* Zone in the Arbuckle Mountains, based on the association of abundant specimens of *M.*

typicalis and the scarcer occurrence of *A. rejectus* (Stitt, 1971b, pls. 10, 12). The latter taxon is again restricted to this subzone (fig. 9). *Symphysurina* again makes its lowest appearance in this subzone, but a slight change in taxonomy is in order. The collection of JoR 1137 yielded two cranidia that were originally assigned to *Symphysurina brevispicata* Hintze (Stitt, 1971b, p. 59). After studying the larger collections of this genus from the Chandler Creek section, I have become aware that species of *Symphysurina* cannot usually be identified from collections of cranidia alone. This is particularly true of *S. brevispicata* (see the discussion of *Symphysurina* sp. A Ross in the section on Systematic Paleontology later in this report). I re-collected this bed but was unable to find any additional fossils. In the absence of the critical librigenae and pygidia needed for confident specific identification, I suggest that the collection from JoR 1137 is best referred to as *Symphysurina* sp. undet.

The fauna of the *Missisquoia typicalis* Subzone can be expanded to include information on brachiopods and conodonts. The orthid brachiopod *Apheoorthis ornata* Ulrich and Cooper makes its lowest appearance at the base of this subzone (Stitt, unpublished data), and its distinctive silicified valves are abundantly scattered on bedding surfaces in this interval. Miller (1970b and subsequent oral communication) found that the lowest occurrence of the common conodont taxa *Clavohamulus primitus*, *Acodus housensis*, and *Acontiodus nogamii* coincided with the lowest occurrence of *M. typicalis* and *A. rejectus* in the Chandler Creek section. The conodont genus *Fryxellodontus* is restricted to the *Missisquoia* Zone. The significance of this trilobite-brachiopod-conodont assemblage in the *M. typicalis* Subzone is discussed in the section on correlation of the *Missisquoia* Zone.

Correlation of *Missisquoia* Zone.—Taylor and Halley (1974, p. 6-8) recently discussed the widespread occurrences in North America of the *Missisquoia* Zone faunal assemblage, which can be identified in outcrops in (1) Alberta and British Columbia, Canada (Derby and others, 1972, p. 509); (2) the subsurface Williston Basin in Montana and North Dakota (*Apoplanias rejectus* faunule of Lochman, 1964a, p. 41); (3) the Great Basin of Utah and Nevada (Taylor, 1971; Taylor and Halley, 1974, p. 8); (4) central Texas (Winston and Nicholls, 1967, p. 72); (5) Oklahoma (this paper and Stitt, 1971b, p. 13); and (6) eastern New York (Taylor and Halley, 1974, p. 6-8). *Missisquoia* was originally described from the Highgate Formation in Vermont (Shaw, 1951, p. 108-109), which is as far to the northeast as this fauna is presently known. Thus, in recently published detailed studies of fossiliferous strata spanning the Cambrian-Ordovician boundary, the faunal assemblage of the *Missisquoia* Zone occurs at the base of the Ordovician on both eastern and western sides of the Transcontinental arch.

Attempts to correlate the two subzones of the *Missisquoia* Zone yield slightly different and interesting results. The three diagnostic species of the *M. depressa* Subzone (*M. depressa*, *Plethopeltis arbucklensis*, and *Ptychopleurites brevifrons*) have not been reported together from anywhere else. *M. depressa* is known only from Oklahoma. *P. brevifrons* Kobayashi, 1936a) is known from the shelf-edge Jones Ridge Limestone (Palmer, 1968, p. B19) in the Alaska-Yukon boundary area, but its precise biostratigraphic position in the lower Ordovician is unclear (Palmer, 1968, p. B104). Taylor (1975, written communication) reported a collection of *Ptychopleurites*, *Plethopeltis*, and *Parabolinella* from the deep-water, continental-slope Hales Limestone in the Hot Creek Range in south-central Nevada. This collection occurs approximately 245 feet *above* a collection containing *Eurekia* (a diagnostic *Saukia* Zone taxon) and approximately 210 feet *below* a collection consisting of *Symphysurina*, *Highgatella*, *Missisquoia*, *Parabolinella*, and *Leiobienvillia* (probably a *Symphysurina brevispicata* Subzone assemblage—see pl. 7). This *Ptychopleurites*-*Plethopeltis* collection is interpreted as earliest Ordovician, based on the occurrence of these taxa in Oklahoma.

Personal examination of the Amoco Oil Co. collections from Mount Wilson, Alberta, Canada, reveals that *Plethopeltis arbucklensis* is present in collections AM-9, 10, and 11 from this outer-shelf section described by Derby and others (1972, p. 507, fig. 3). This establishes the presence of the *M. depressa* Subzone at Mount Wilson, beginning 3 feet above a good *Corbinia apopsis* Subzone collection (AM-8) and ending 6 feet higher with the first *Apoplanias rejectus*—*Apheoorthis ornata* collection (AM-13) that marks the base of the *M. typicalis* Subzone.

The only other trilobite that occurs in the *M. depressa* Subzone, *Homagnostus reductus*, is known from Oklahoma (pl. 7; Stitt, 1971b, pls. 10, 12) and central Texas (Winston and Nicholls, 1967, text-fig. 3), but it is a long-ranging agnostid taxon and is not diagnostic of the *Missisquoia* Zone. No orthid brachiopods or conodonts occur in the *M. depressa* Subzone that have not already made their first appearance in the underlying *Corbinia apopsis* Subzone, including such widespread taxa as the brachiopod *Nanorthis* and the conodont *Cordylodus* (Winston and Nicholls, 1967, text-fig. 3; Miller, 1970b; Derby and others, 1972, p. 507, fig. 3).

Thus the assemblage of the *M. depressa* Subzone is known from only four places—the subsiding Southern Oklahoma geosyncline, the shelf-edge Jones Ridge Limestone in the Alaska-Yukon boundary area, the outer-shelf Survey Peak Formation at Mount Wilson, and the deep-water Hales Limestone in Nevada.

Individual trilobite taxa of the *M. typicalis* Subzone are widely distributed and are known from all of the areas listed in the first paragraph of this section (see preceding). The best correlations using trilobites, brachiopods, and conodonts can be made with the Alberta, Canada, and central Texas areas. In the section at Mount Wilson, Alberta (Derby and others, 1972, p. 507, fig. 3), *Apoplanias rejectus*, *Apheoorthis ornata*, *Palaeostrophia* cf. *P. elax*, and *Fryxellodontus inornatus* all have their lowest occurrence together in collection AM-13, at the base of what can now be called the *M. typicalis* Subzone. All of these taxa are also restricted to this subzone in this section. *M. typicalis*, *Acodus housensis*, and a species of *Acontiodus* make their initial appearance somewhat above the base of the zone.

In central Texas, the most fossiliferous section for this biostratigraphic interval is the Threadgill Creek section (Winston and Nicholls, 1967, text-fig. 2). In this section, *M. typicalis*, *A. ornata*, and *F. inornatus* all have their lowest occurrences within 3 feet of each other at the base of the *Missisquoia* Zone (Winston and Nicholls, 1967, p. 88-89; 92; Miller, 1970b), beginning 3.5 feet above the highest occurrence of *Corbinia apopsis*. *A. rejectus* has not been reported from central Texas.

None of the taxa of the *M. depressa* Subzone have been recovered from the Threadgill Creek section, despite the fact that the section and surrounding area have been sampled in detail by many collectors including myself. Also, the fauna of the *M. depressa* subzone has not been reported from the other shelf localities listed earlier where the *M. typicalis* Subzone assemblage is present.

The sporadic occurrence of the *M. depressa* Subzone assemblage is anomalous, especially when compared with the close similarity of the trilobite, brachiopod, and conodont assemblages in the underlying *C. apopsis* Subzone and in the overlying *M. typicalis* Subzone. Several explanations might be suggested to explain this anomaly; two of these have been briefly discussed by Derby (1973).

One possibility is that the fauna of the *M. depressa* Subzone is actually present in all of these various areas and this thin subzone has simply been missed during collecting because the critical interval is covered or nonfossiliferous at these particular outcrops or because of some other problem. It is hoped that future investigators in other areas will be aware of the need for extremely detailed collecting in the vicinity of the Cambrian-Ordovician boundary, and perhaps this subzonal assemblage will be discovered in these other areas, too.

A second possibility is that there was a hiatus at the base of the *Missisquoia* Zone over most of the North American shelf area, during which time the *M. depressa* assemblage moved into Oklahoma and the western shelf-edge localities and flourished there. Deposition continued uninterrupted in these latter areas into *M. typicalis* Subzone time, when deposition resumed over the entire shelf. The problem with this explanation is that no one has noticed any physical evidence of erosion or sedimentary bypassing in this interval in the various areas where this could have been occurring.

A third possibility is that the base of the *Missisquoia* Zone is a diachronous horizon. This horizon may be the base of an incompletely defined Lower Ordovician "hystricurid" biomere, whose top horizon is not known at present. Palmer (1962, 1965a) has cited good evidence that the base of the Pterocephaliid Biomere is diachronous. In the model developed earlier to explain trilobite extinctions at biomere boundaries, the *M. depressa* assemblage may have been simply the first migrants of the "hystricurid" biomere to reach the cratonic shelf. These forms could have migrated from the open ocean into favorable ecologic sites along the western shelf edge and in the center of the subsiding Southern Oklahoma geosyncline, thus being contemporaneous with the latest *Corbinia apopsis* Subzone fauna still inhabiting other areas in North America. At some later time, the *M. typicalis* fauna evolved and spread across the entire North American shelf, replacing elsewhere the *Corbinia apopsis* fauna, and in Oklahoma and the western shelf-edge localities being at least partly descended from the *M. depressa* fauna.

If this last explanation is true, I would expect to find younger taxa at the very top of the *Corbinia apopsis* Subzone that evolved and lived in the areas where the *M. depressa* Subzone assemblage is not present. To date this has not been demonstrated in the areas involved.

These hypotheses should be tested by detailed data that are presently being gathered in other areas in North America. The base of the *Missisquoia* Zone is presently considered to be the base of the Ordovician System as defined in North America (Winston and Nicholls, 1967, p. 71-72; Stitt, 1971b, p. 12-13; Taylor and Halley, 1974, p. 8). If this boundary is in fact shown to be diachronous, then a new systemic boundary should be chosen so that the problems in logic and semantics that would result from having a diachronous systemic boundary could be avoided.

Symphysurina Zone

The following assemblage of species occurs in the *Symphysurina* Zone in the Chandler Creek section (pl. 7). *Apoplanius rejectus*, *Missisquoia typicalis*, and *Homagnostus reductus* also occur in the underlying *Missisquoia* Zone. Because the location of the top of the *Symphysurina* Zone is unknown at present (see the following discussion), I am unable at this time to determine which taxa that have their lowest occurrence in this zone are restricted to it.

Apoplanius rejectus Lochman
Clelandia texana Winston and Nicholls
Genus and species undet. no. 3
Highgatella cordilleri (Lochman)
Homagnostus reductus Winston and Nicholls
Hystricurus millardensis Hintze
Missisquoia typicalis Shaw
Symphysurina brevispicata Hintze
Symphysurina bubops Winston and Nicholls
Symphysurina bulbosa Lochman
Symphysurina pygidium no. 1
Symphysurina sp. A. Ross
Unassigned pygidium no. 1
Unassigned pygidium no. 2

The base of this zone is defined by the lowest occurrence of *Symphysurina brevispicata*, *Highgatella cordilleri*, and *Symphysurina* sp. A. The top of this zone apparently occurs in the overlying McKenzie Hill Limestone, because none of the diagnostic trilobites of the *Bellefontia-Xenostegium* Zone (Zone B of Ross, 1951) were found in the Signal Mountain Limestone. My next project will be to continue upsection and describe the trilobites of the McKenzie Hill Limestone.

Two subzones, a lower *Symphysurina brevispicata* Subzone and an overlying *Symphysurina bulbosa* Subzone, are recognized in the part of the *Symphysurina* Zone that occurs in the Signal Mountain Limestone (pl. 7).

Symphysurina brevispicata Subzone.—The base of this subzone is defined by the lowest occurrence of *Symphysurina brevispicata*, *Highgatella cordilleri*, and *Symphysurina* sp. A (pl. 7). The latter two taxa are restricted to this subzone, but *S. brevispicata* ranges into the overlying *Symphysurina bulbosa* Subzone. Other common taxa in the *S. brevispicata* Subzone include *Missisquoia typicalis* (abundant in the lower part of the subzone) and *Hystricurus millardensis* (common except in the lowest and highest parts of the subzone). Scarce taxa in this subzone include *Apoplanias rejectus*, *Homagnostus reductus*, genus and species undet. no. 3, *Symphysurina bubops*, *Symphysurina* pygidium no. 1, and *Clelandia texana*.

Symphysurina bulbosa Subzone.—The base of this subzone is defined by the lowest occurrence of *Symphysurina* bulbosa, which is present in moderate abundance in the upper 60 feet of the Signal Mountain Limestone. Scarce taxa that make their lowest appearance in this subzone include unassigned pygidia nos. 1 and 2. *S. brevispicata* ranges into this subzone from the underlying *S. brevispicata* Subzone. Preliminary collecting into the basal part of the overlying McKenzie Hill Limestone indicates that *S. bulbosa* continues to be an abundant taxon for at least another 100 feet above the top of the Signal Mountain. Thus the top of this subzone probably lies somewhere in the lower part of the McKenzie Hill.

Revised *Symphysurina* Zone in Arbuckle Mountains.—In the western Arbuckle Mountains, the biostratigraphic interval of the upper part of the *Missisquoia* Zone and the lower part of the *Symphysurina* Zone is occupied by the unfossiliferous Butterly Dolomite. In the Highway 77 section, the Butterly cuts out all but the lowest part of the range of *Missisquoia typicalis* (Stitt, 1971b, pl. 9). In the more westerly Joins Ranch section, the Butterly is much thinner (Stitt, 1971b, p. 6-7, fig. 2), and a much better representation of the fauna of the *M. typicalis* Subzone is preserved (Stitt, 1971b, pl. 10). However, in this section the upper 55 feet of the Signal Mountain did not yield any fossils when initially collected (Stitt, 1971b, p. 59), and the top of the *Missisquoia* Zone was believed to lie somewhere in the Butterly Dolomite. The upper 55 feet of the Signal Mountain in the Joins Ranch section was recollected in May 1973, using a slightly different traverse, and this time taxa indicative of the *Symphysurina brevispicata* Subzone of the *Symphysurina* Zone were recovered from the upper 19 feet of the Signal Mountain. The occurrence of *S. brevispicata* at JoR-1293 defines the base of the subzone, and the presence of *Highgatella cordilleri* and *Hystricurus millardensis* in succeeding beds corroborates the presence of this zone and subzone. If the base of the *Symphysurina* Zone is used for correlation, then the uppermost beds of the Signal Mountain Limestone and the base of the Butterly Dolomite in the Joins Ranch section correlate with an interval about 300 feet below the top of the Signal Mountain in the Chandler Creek section (see fig. 2).

The supplementary faunal data are given below and are combined with the earlier information in a new range chart (fig. 9) for this interval. The section code and footage data are presented as before (Stitt, 1971b, p. 58-64), and the numbering system used after the taxa names is the same one that is used and explained for the Chandler Creek occurrence data at the end of this report.

Symphysurina Zone

Symphysurina brevispicata Subzone

JoR-1311	*Highgatella* cf. *H. cordilleri* (0-0-1) *Hystricurus* cf. *H. millardensis* (1-0-0) *Missisquoia* cf. *M. typicalis* (1-0-0)
JoR-1298	?*Highgatella* sp. undet. (1-0-0)
JoR-1294	unassignable hystricurid fragments
JoR-1293	*Symphysurina brevispicata* (1-1-0)

Missisquoia Zone

Missisquoia typicalis Subzone

JoR-1284	*Missisquoia typicalis* (1-0-0)
JoR-1274	*Apoplanias rejectus* (1-0-1) *Missisquoia typicalis* (12-2-0)
JoR-1263	*Missisquoia typicalis* (2-0-2)

The unfossiliferous Butterly Dolomite in the Joins Ranch section appears to obliterate most of the middle part of the *Symphysurina brevispicata* Subzone, which is characterized by common to abundant *S. brevispicata* and *Hystricurus millardensis* (pl. 7). A coquina of these two species is present in the Joins Ranch section, 5 feet above the base of the McKenzie Hill Limestone (Stitt, 1971b, p. 59), suggesting but not proving that the horizon of the Butterly—McKenzie Hill contact in the Joins Ranch section probably falls about 150 feet below the top of the Signal Mountain in the Chandler Creek section (fig. 2).

In the Highway 77 section in the Arbuckle Mountains, the base of the *Symphysurina* Zone as used in this paper apparently falls in the lower part of the Butterly Dolomite (fig. 2). Ordovician fossils are so scarce in the Highway 77 section that accurate correlations are difficult to make in this part of the section.

Even with the new data from the Joins Ranch section, by far the greatest diversity of *Symphysurina* Zone taxa occurs in the Chandler Creek section, making it the best section to use in correlations from Oklahoma to other areas where similar faunas have been reported.

Correlation of *Symphysurina* Zone. —Most of the fossiliferous sections with which correlations in this part of the section can be made occur in western North America. In the Midcontinent and the Appalachian Mountains, this interval is mostly dolomitized, and the faunal data are not sufficiently detailed to be useful. Bridge (1930) and Sando (1957) discussed the scarcity of fossils and the biostratigraphic problems of working in these dolomites.

The *Symphysurina* Zone as presently defined in Oklahoma can be correlated with the *Symphysurina* Zone recognized by Derby and others (1972, fig. 3) in this section at Mount Wilson in Alberta, Canada. They used the lowest occurrence of *Symphysurina brevispicata* and *Highgatella cordilleri* to define the base of the *Symphysurina* Zone, which is the same biostratigraphic horizon used to define the base of this zone in Oklahoma. The only other trilobite in this zone that is common to both areas is *Clelandia texana*, which occurs at Mount Wilson in their highest collection. In the Chandler Creek section, this taxon occurs at the top of the *S. brevispicata* Subzone (pl. 7). This suggests that the interval that Derby and others called the *Symphysurina* Zone is perhaps more precisely correlative with the *S. brevispicata* Subzone of the *Symphysurina* Zone in Oklahoma.

This same subzone is apparently present in the subsurface Deadwood Formation of the Williston basin. Lochman (1964b, p. 456-458) identified *S. brevispicata* and *H. cordilleri* (=*Euloma cordilleri*) in core samples from the Southwest Richey Unit 32-33B well. In these samples, *H. cordilleri* has its lowest occurrence 5 feet below the lowest occurrence of *S. brevispicata*, and both taxa occur together in a collection 4-8 feet above the lowest occurrence of *S. brevispicata*. In this well, the lowest occurrence of trilobites of the *Bellefontia-Xenostegium* Zone (Zone B of Ross, 1951) is 60 feet above the highest collection of *S. brevispicata* and *H. cordilleri*. In another well (Pine field Unit 43-22A), *Symphysurina bulbosa* occurs in core samples 30 feet below the lowest trilobites of the *Bellefontia-Xenostegium* Zone. This information suggests the presence of the faunas of both the *S. brevispicata* and the *S. bulbosa* Subzones of the *Symphysurina* Zone in the Deadwood Formation in the subsurface of the Williston basin.

In central Texas, Winston and Nicholls (1967, p. 72, text-fig. 3) described a *Symphysurina* Zone fauna that is similar to that reported from Oklahoma, Alberta, and the Williston basin. Their range chart (text-fig. 3) is generalized, and I have used the actual occurrence data that they listed for the individual species to construct a more detailed relative-range chart (fig. 10) for their taxa. They (p. 72) defined the base of the *Symphysurina* Zone on the first occurrence of *Jujuyaspis keideli*, *Hystricurus millardensis*, and *Clelandia texana*, which make their lowest appearance at approximately the same level (fig. 10). They also stated (p. 72) that the *Symphysurina* Zone (as they defined it) was actually "characterized by abundant specimens of *Symphysurina brevispicata*, a species not restricted to it [the *Symphysurina* Zone]." In the Chandler Creek section, *Jujuyaspis keideli* has not been found, and the lowest occurrence of *H. millardensis* is 214 feet below the lowest occurrence of *Clelandia texana*. Furthermore, the interval of abundant *S. brevispicata* begins (in the Chandler Creek

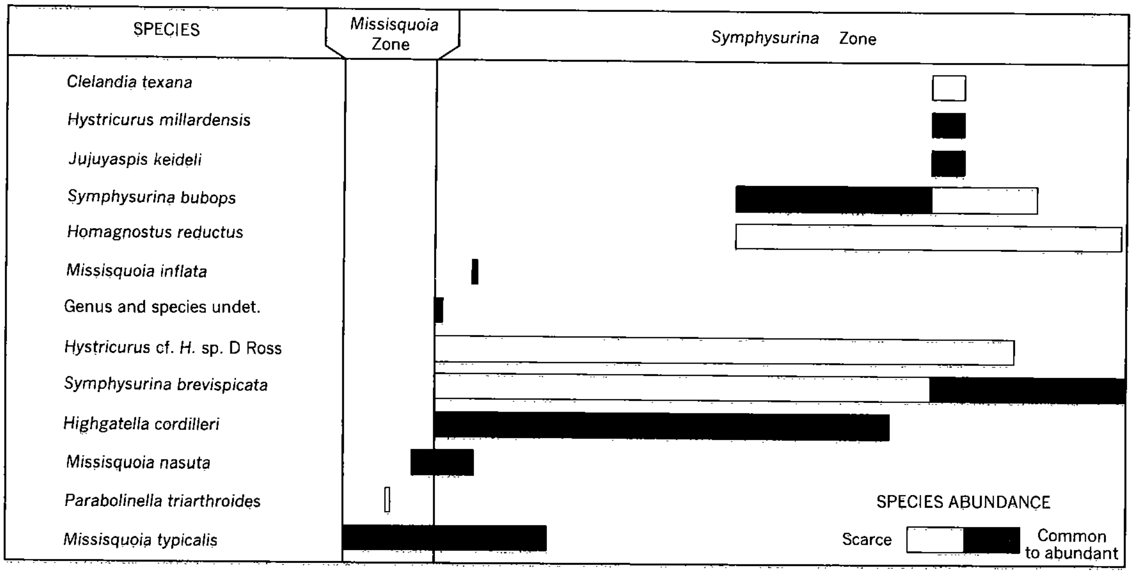

Figure 10. Diagram showing approximate relative ranges of earliest Ordovician trilobites from central Texas (redrafted from Winston and Nicholls, 1967), with base of *Symphysurina* Zone defined as in Oklahoma.

section) considerably above the lowest occurrence of *H. millardensis* and much below the lowest occurrence of *C. texana* (pl. 7). Similar difficulties arise when trying to correlate this interval from central Texas to Alberta (Derby and others, 1972, fig. 3) or to the subsurface of the Williston basin (Lochman, 1964b, p. 456-458).

The same biostratigraphic horizon that is used to define the base of the *Symphysurina* Zone in Oklahoma and these other areas is also recognizable in central Texas. *Symphysurina brevispicata* and *Highgatella cordilleri* have their lowest occurrences close together in central Texas (fig. 10), just as they do in the Chandler Creek and Joins Ranch sections in Oklahoma and at Mount Wilson in Alberta. In central Texas, these two taxa are joined in their lowest occurrence by *Hystricurus* cf. *H.* sp. D Ross, whereas in the Chandler Creek section *Symphysurina* sp. A Ross makes its lowest occurrence with *S. brevispicata* and *H. cordilleri.* I believe that the base of the *Symphysurina* Zone in central Texas should be redefined on the first occurrence of *S. brevispicata* and *H. cordilleri.* This change would make the lower boundary and faunal content of this zone in central Texas similar to those in Oklahoma and other areas and would greatly facilitate correlations in this biostratigraphic interval.

It should be noted that in both Oklahoma and Texas the range of *Missisquoia* overlaps the range of *Symphysurina* (fig. 10, pl. 7). Thus it is impossible in these two areas to define succeeding zones in which each of these taxa occurs only in the zone that bears its name. This is not true in Alberta (Derby and others, 1972, fig. 3), where species of *Missisquoia* and species of *Symphysurina* occur only in their respective named zones. *Missisquoia* occurs in only two collections in the Mount Wilson section, and I suspect that the range data for these two taxa from that section are not representative of the real situation.

The problem of overlapping ranges of *Missisquoia typicalis* and *Hystricurus millardensis* puzzled Taylor and Halley (1974, p. 8) in discussing the proper zonal assignment for sample H-2 that contained these two taxa from the upper part of the Whitehall Formation in eastern New York. The ranges of these two taxa overlap in the Chandler Creek section in the lower half of the *Symphysurina brevispicata* Subzone of the *Symphysurina* Zone (pl. 7), suggesting that this subzone can also be recognized in the Whitehall Formation.

Correlations with the trilobite assemblages reported from Utah and Nevada by Ross (1951) and Hintze (1952) are hampered by nomenclatorial problems. The fauna that Ross (1951, p. 29) reported for his Zone A has never been found anywhere else. Lochman (1964b, p. 457) discussed this problem but then described a "Zone A" fauna that has only one genus (*Symphysurina*) and no species in common with Ross' Zone A fauna. I think her correlation is probably correct but mostly because she reports an underlying *Missisquoia* Zone fauna (her *Apoplanias rejectus* faunule) and an overlying fauna (1964b, p. 455, 458-460), including species of *Bellefontia, Xenostegium,* and *Clelandia utahensis*, that correlates well with Ross' Zone B assemblage (Ross, 1951, p. 29). In other words, Lochman's "Zone A" fauna is in the correct stratigraphic interval but has little in common with Ross' Zone A fauna. An easier correlation can be made between her Williston basin Zone A fauna and the *Symphysurina* Zone fauna from Oklahoma, Texas, and Alberta, based on the common occurrences of *Symphysurina brevispicata* and *Highgatella cordilleri* (=Lochman's *Euloma cordilleri*) as previously discussed.

Ross' Zone A fauna can be correlated rather tenuously with the *Symphysurina* Zone as recognized in Oklahoma and Texas. *Hystricurus* sp. D (Ross, 1951, p. 29) occurs in Zone A and in the *Symphysurina* Zone in central Texas (fig. 10). *Symphysurina* sp. A (Ross, 151, p. 29) occurs in Zone A and in the lower and middle parts of the *Symphysurina* Zone in the Chandler Creek section (pl. 7).

I think it would be best to abandon the use of the term "Zone A" for this fauna and instead call this biostratigraphic interval the *Symphysurina* Zone, as Winston and Nicholls (1967) and Derby and others (1972) have done. The trilobites of this zone are well preserved and are apparently most diverse in Oklahoma and Texas, and the occurrence of the various species and genera is well documented in these areas. As long as we try to use "Zone A," we inevitably have to correlate back to the Garden City Formation of Utah and Idaho, where this fauna is not well preserved. *Symphysurina* is abundant and is represented by several different species in this zone, and the name has long been synonymous with the lower part of the Lower Ordovician. Although this taxon ranges into higher zones (Ross, 1951, p. 29; Lochman, 1964b, p. 459), other genera and species are more characteristic at these levels. Thus I believe that calling this biostratigraphic interval the *Symphysurina* Zone would appropriately incorporate the name of a diagnostic taxon into our Lower Ordovician zonal terminology.

Norford (1969, p. 2) suggested that the *Symphysurina* (B) Zone recognized by Hintze (1952, p. 6-8) included both the A and B Zones of Ross (1951), and I agree. As Hintze pointed out (p. 7-8; see also Ibex A and B section faunal occurrences, p. 24-26), *Symphysurina brevispicata* and *Hystricurus millardensis* occur in the lower part of his *Symphysurina* (B) Zone, well below the first occurrences of genera or species such as *Bellefontia*, *Xenostegium*, *Clelandia utahensis*, *Hystricurus genalatus*, and *Hystricurus politus*, all characteristic of the B Zone of Ross (1951, p. 29). *S. brevispicata* and *H. millardensis* are now known to be indicative of the *Symphysurina* Zone of Oklahoma and Texas, which can be correlated with Ross' A Zone. Thus Hintze was right (1952, p. 6, 8) when he suggested that the low occurrence of *S. brevispicata* and *H. millardensis* might be useful in further zonation and that unknown to him their occurrence corresponded to Ross' A Zone.

SYSTEMATIC PALEONTOLOGY

The systematic descriptions that follow are intended to supplement those recently published (Stitt, 1971b) for the trilobites of the same stratigraphic interval in the Arbuckle Mountains. New taxa that were not recovered during the Arbuckle Mountains investigation are included, as are a few taxa for which either better specimens or additional range data are now available. Trilobites assigned to 12 families, 25 genera (1 new), and 27 species (2 new) are described and illustrated. In addition, 7 taxa that cannot be generically assigned and 7 taxa that cannot be specifically assigned are described and illustrated. Families are listed alphabetically under each order, genera alphabetically under each family, and species alphabetically under each genus.

Morphological terms used in the trilobite descriptions are those defined in Part O of the *Treatise on Invertebrate Paleontology* (Harrington and others, 1959, p. 117-126).

The abundance and occurrence of each taxon are listed after the taxonomic discussion as well as in the measured-section description following this portion of the report. Numbers given correspond to footages above the base of the section.

All figured specimens except the holotype of *Ptychopleurites brevifrons* (Kobayashi) are stored with the School of Geology and Geophysics at The University of Oklahoma (OU). The rest of the fossils recovered in this investigation will ultimately be stored at The University of Oklahoma when I have completed my studies of the faunas of the Arbuckle Group. The holotype of *Ptychopleurites brevifrons* was borrowed from the Geological Survey of Canada (GSC) and is reillustrated here with permission.

Phylum ARTHROPODA Siebold and Stannius 1845

Class TRILOBITA Walch, 1771
Order AGNOSTIDA Kobayashi, 1935
Family AGNOSTIDAE McCoy, 1849
Genus **Geragnostus** Howell, 1935
Geragnostus intermedius Palmer

Pl. 3, fig. 1

Geragnostus intermedius PALMER, 1968, p. 24, pl. 12, figs. 1, 2; ROBISON and PANTOJA-ALOR, 1968, p. 776, pl. 97, figs. 1-10.

Remarks.—This species has been carefully described by Palmer and by Robison and Pantoja-Alor. Pygidia are characterized by the tripartite subdivision of the first axial segment and can be further distinguished from pygidia of *Homagnostus tumidosus* by the greater length of the pleural field between the end of the axis and the border furrow. Some cranidia have a short, incomplete preglabellar axial furrow, which is distinctive among species assigned to *Geragnostus*.

Occurrence.—Scarce in the *Drumaspis* Subzone at CC 477, 481. Scarce in the *Rasettia magna* Subzone at CC 868, 893.

Order PTYCHOPARIIDA Swinnerton, 1915
Family ASAPHIDAE Burmeister, 1843
Subfamily SYMPHYSURININAE Kobayashi 1955
Genus **Symphysurina** Ulrich *in* Walcott 1924

Symphysurina ULRICH *in* Walcott, 1924, p. 37; WALCOTT, 1925, p. 108-112; POULSEN, 1937, p. 35-37; ROSS, 1951, p. 114-115; HINTZE, 1953, p. 230-232; KOBAYASHI, 1955, p. 429-430; HARRINGTON and others, 1959, p. O353.

Type species.—Symphysurina woosteri ULRICH *in* Walcott, 1925, p. 109, 115-116, pl. 21, figs. 1-11.

Remarks.—Specimens assigned to this genus conform to the concept of *Symphysurina* given in Harrington and others (1959, p. O353).

Symphysurina brevispicata Hintze

Pl. 4, fig. 10

Symphysurina brevispicata HINTZE, 1952, p. 236, pl. 3, figs. 9-17; STITT, 1971b, p. 15, pl. 8, figs. 19-21 (synonymy to date).

Remarks.—No librigena was illustrated in the previous recording of this species in Oklahoma (Stitt, 1971b, p. 15, pl. 8, figs. 19-21), and one is shown here to document the description given earlier (Stitt, 1971b, p. 15). Librigenae of *Symphysurina brevispicata* found in the Arbuckle and Wichita Mountains have the same broad, smooth, slightly convex shape and the short genal spine described originally by Hintze (1952, p. 236, pl. 3, figs. 10, 12, 13). This species is abundant in the *Symphysurina* Zone.

Occurrence.—Scarce in the lower part of the *Symphysurina brevispicata* Subzone at CC 1604, 1682, 1773; abundant in the middle and upper parts of this subzone at CC 1781, 1794, 1811, 1813, 1814, 1820, 1823, 1823.5, 1827.7, 1849, 1856, 1860, 1861, 1863. Abundant in the *Symphysurina bulbosa* Subzone at 1866, 1870, 1874, 1887, 1888, 1891, 1898, 1916.

Symphysurina bubops Winston and Nicholls

Pl. 5, fig. 7

Symphysurina bubops WINSTON and NICHOLLS, 1967, p. 87, pl. 12, figs. 13, 16, 17, 19.

Remarks.—Two specimens from one collection have strongly anteriorly convex cranidia and palpebral areas located anterior of the glabeller midlength, which are the diagnostic features of *Symphysurina bubops* as described and illustrated by Winston and Nicholls. The best specimen is illustrated.

Occurrence.—Scarce in the *Symphysurina brevispicata* Subzone at CC 1749.

Symphysurina bulbosa Lochman

Pl. 5, figs. 1-6

Symphysurina bulbosa LOCHMAN, 1964b, p. 470-471, pl. 66, figs. 4-8.

Remarks.—Lochman described this species from fragmentary material from the Williston basin. The most directly distinctive feature of this species is the punctation of the exoskeleton, which is most noticeable on internal molds. The pygidium of *Symphysurina bulbosa* is broadly triangular (length varies from slightly more than one-half to two-thirds of width) with a broad axis and rather convex pygidial margin. The area directly posterior of the axis is slightly inflated, and Lochman (p. 471) suggested that this may represent "an incipient tendency to produce an axial spine" that never developed.

The gently convex librigenae bear rather broad, medium-length genal spines. The cranidium is rather featureless aside from the punctation, with all furrows either extremely faint or absent. The anterior end is broadly rounded and has at most only a narrow rim. The anterior course of the facial sutures is slightly divergent directly anterior of the palpebral lobes; from there it curves axially, giving the anterior end of the cranidium a broad, fan shape.

The punctation, the broadly spined librigenae, and the triangular pygidium make this species readily distinguishable from *Symphysurina brevispicata*, which occurs with *S. bulbosa*.

Occurrence.—Common in the *Symphysurina bulbosa* Subzone at CC 1866, 1873, 1874, 1876, 1891, 1899, 1906, 1916.

Symphysurina cf. **S. cleora** (Walcott)

Pl. 5, fig. 8

Tsinania cleora WALCOTT, 1914, p. 43; 1916, p. 227-228, pl. 36, fig. 9, 9a-b (*not* 9c, 9c′—probably *Symphysurina brevispicata*).

Symphysurina cf. *S. cleora* (Walcott) HINTZE, 1952, p. 234-236, pl. 2, figs. 8-11.

Remarks.—As pointed out by Hintze (1952, p. 234), this species is most easily recognized by its broad, rounded librigenae, which lack a genal spine. One librigena that fits this description is illustrated and tentatively assigned to this species. An associated cranidium is too fragmentary for other than a generic assignment.

Occurrence.—Scarce in the *Missisquoia typicalis* Subzone at CC 1578.

Symphysurina sp. A Ross

Pl. 5, fig. 9

Symphysurina sp. A Ross, 1951, p. 115-116, pl. 26, fig. 17; pl. 28, figs. 29, 31-36.

Remarks.—The most easily distinguishable characteristic of this species is the librigena, which is moderately convex, lacks a genal spine, has a thickened rim (covered by terrace lines) that is broadest laterally opposite the eye, and is rather sharply rounded at the genal angle. This librigena is narrower, much more convex, and has a more prominent rim than that of *Symphysurina cleora*. It can also be easily distinguished from the librigena of the stratigraphically associated *Symphysurina brevispicata* (pl. 4, fig. 10), which has a genal spine.

I find it impossible to distinguish the cranidium of *S.* sp. A from that of the stratigraphically associated *S. brevispicata*. Measurement of cranidial length and width (fig. 11) for the specimens that occur in the interval of stratigraphic overlap does not suggest two different cranidia. On all specimens examined, a faint axial furrow extends to nearly the anterior end of the cranidium on exfoliated specimens. The palpebral lobes are uniformly located just posterior of the glabellar midlength, and the overall cranidial shape, convexity, and course of the anterior facial sutures do not suggest two different cranidia.

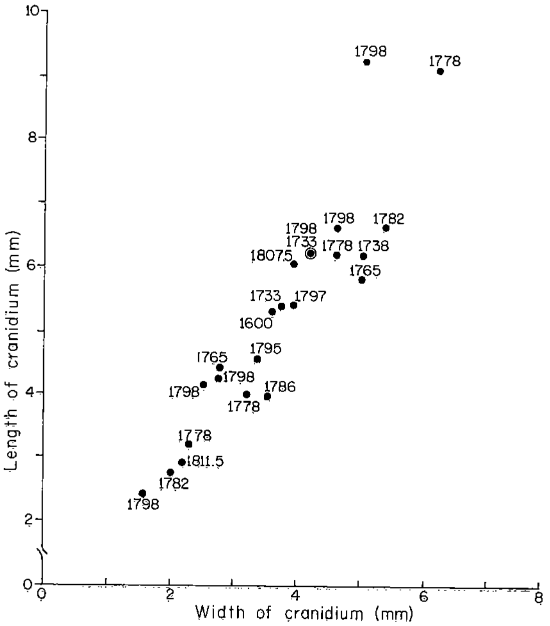

Figure 11. Graph of cranidial length versus width for cranidia of *Symphysurina* that occur between CC 1605 and CC 1820, with footage indicated for each datum point.

Cranidial discrimination is a problem in this genus. Hintze (1952, p. 236) noted that the cranidium of *S. brevispicata* is indistinguishable from the cranidium of the type species, *Symphysurina woosteri*. Thus, if a collection contains only cranidia, they cannot be assigned confidently at the species level, and such collections are classified *Symphysurina* sp. undet.

Occurrence.—Scarce in the *Symphysurina brevispicata* Subzone at CC 1605, 1718, 1792, 1798, 1813, 1814, 1820.

Symphysurina pygidium no. 1

Pl. 6, fig. 6

Remarks.—Associated with *Symphysurina* sp. A and with the wide, spineless pygidia of *Symphysurina brevispicata* are three pygidia that (1) are less than twice as wide as they are long, and (2) bear a spine. The spine is broken on all three specimens, but it was apparently very short, judging from the impression left on the rock by the illustrated pygidium. These pygidia have a subdued axial region, giving them a smoother overall appearance than the pygidia of *S. brevispicata*. Both *S. cleora* and *S.* sp. A are supposed to have spineless pygidia, although Hintze (1952, p. 236) suggested that the pygidium attributed to *S. cleora* by Walcott may in fact belong to *S. brevispicata*. The specific assignment of these spined pygidia will have to await the discovery of a complete specimen.

Occurrence.—Scarce in the *Symphysurina brevispicata* Subzone at CC 1792, 1794.

Family CATILLICEPHALIDAE Raymond, 1938

Genus **Acheilops** Ulrich *in* Bridge, 1930

Acheilops cf. **A. dilatus** Ulrich

Pl. 3, fig. 10

Acheilops dilatus ULRICH *in* Bridge, 1930, p. 219, pl. 19, figs. 20-22.

Remarks.—The characteristics of

Acheilops have been recently summarized by Winston and Nicholls (1967, p. 77). Two fragmentary cranidia (one from the Arbuckle Mountains) are assignable to this genus on the basis of their lack of anterior fixigenae and frontal areas; their prominent, palpebral lobes located posterior of the glabellar midpoint; and their anteriorly expanded glabellae. They are tentatively assigned to *A. dilatus* Ulrich on the basis of their anteriorly rounded glabellae and the continued posterior taper of the glabellae posterior to the anterior edge of the palpebral lobes. The best specimen is illustrated.

The specimen from the Arbuckle Mountains was previously (Stitt, 1971b, p. 15-16) assigned to *Acheilops masonensis*. Corrected range data are given below.

Occurrence.—In the Arbuckle Mountains, scarce in the *Saukiella junia* Subzone at HS 1120. In the Wichita Mountains, scarce in the *Saukiella junia* Subzone at CC 1204.

Genus **Buttsia** Wilson, 1951

Buttsia drabensis Wilson

Pl. 1, fig. 7

Buttsia drabensis WILSON, 1951, p. 626-628, pl. 89, figs. 12, 19-24; RASETTI, 1954, p. 606, fig. 2-c.

Remarks.—This species has been well described by Wilson (1951) and Rasetti (1954). One cranidium from the Wichita Mountains is assigned to this species. It differs in possessing deeper glabellar furrows, especially the posterior pair, but otherwise falls within the species concept of Wilson.

Occurrence.—Scarce in the *Elvinia* Zone at CC 351.

Genus **Triarthropsis** Ulrich *in* Bridge, 1930

Triarthropsis sp. undet.

Pl. 3, figs. 8, 9

Remarks.—Seven small fragmentary cranidia from three collections can be assigned to *Triarthropsis* because they possess a frontal area, but they cannot be assigned to any of the established species in the genus. These cranidia differ principally in possessing a tall, cylindrical glabella, which appears to be a unique feature in the genus. The frontal area is narrow and is overhung slightly by the glabella. Scattered granules occur on the cranidium. The two best specimens are illustrated.

Occurrence.—Scarce in the *Rasettia magna* Subzone at CC 901, 1010, 1030.

Family CHEILOCEPHALIDAE Shaw, 1956

Genus **Cheilocephalus** Berkey, 1898

Cheilocephalus wichitaensis Resser

Pl. 1, figs. 4, 5

Cheilocephalus wichitaensis RESSER, 1942, p. 35, pl. 5, fig. 39.

Remarks.—Palmer (1965b, p. 29) recently summarized the diagnostic features of this genus. Resser's original description of the cranidium appears adequate, with the exception that on the one specimen I found (which is mostly exfoliated) the external surface and the internal mold are ornamented by very low, medium-sized granules, giving the surface a roughened appearance.

The illustrated pygidium (pl. 1, fig. 5), from the same bed as the cranidium, has a broad, low axial region with six axial rings separated by shallow axial furrows and gently convex pleural fields that merge into the broad, convex border. Only the first pleural furrow is distinctly impressed across the pleural fields and the border outlining a laterally expanded first pleural segment; all other pleural furrows are extremely faint and do not reach the border. As such, the pygidium possesses the diagnostic generic characteristics and is assigned to *C. wichitaensis*. The axis, pleural fields, and anterior pleural segment are covered by the same external ornamentation of low, medium-sized granules as the cranidium; the border is smooth.

C. wichitaensis differs from *Cheilocephalus brachyops* Palmer (Palmer, 1965b, p. 30, pl. 1, figs. 12-15, 17), which also occurs in the *Elvinia* Zone, by the combination of a relatively wider glabella; an entirely concave frontal area; the larger, more posteriorly located palpebral areas; and more axial rings and a slightly narrower border on the pygidium.

Occurrence.—Scarce in the *Elvinia* Zone at CC 317.

Family DIKELOCEPHALIDAE Miller, 1889

Genus **Briscoia** Walcott, 1925

Briscoia sp. undet.

Pl. 3, fig. 2

Remarks.—Harrington and others (1959,

p. O254), summarized the characteristics of *Briscoia*. One fragmentary cranidium is assigned to this genus on the basis of its convex, tapered, anteriorly rounded glabella, concave frontal area with a poorly defined anterior border furrow, and upturned, concave border. The specimen is similar to one illustrated by Bell and Ellinwood (1962, p. 390, pl. 52, fig. 5) that they assigned to *Briscoia* sp.

As usual with dikelocephalids, material is scarce and fragmentary; no associated pygidia or librigenae were recovered. A pygidium tentatively assigned to *Briscoia* (Stitt, 1971b, p. 17, pl. 3, fig. 21) from approximately the same stratigraphic level in the Arbuckle Mountains might be conspecific with the Wichita Mountains cranidium.

Occurrence.—Scarce in the upper *Saratogia* Zone at CC 742.

Family ELVINIIDAE Kobayashi, 1935 (as emended by Palmer, 1962)

Subfamily DOKIMOCEPHALINAE Kobayashi 1935

Genus **Pseudosaratogia** Wilson, 1951

Pseudosaratogia lata Wilson

Pl. 1, figs. 1-3

Pseudosaratogia lata WILSON, 1951, p. 648-649, pl. 94, figs. 19-21.

Remarks.—Palmer (1965b, p. 38) gave a recent diagnosis of the genus, and Wilson (1951) adequately described and illustrated this species. Specimens from the Wichita Mountains have the flared frontal area, prominent glabella, and narrow fixigenae with large palpebral lobes that are characteristic of *Pseudosaratogia.* In addition, the glabella is more rounded than truncate, the glabellar furrows are straight and oblique, the brim/border ratio ranges from 1.2 to 1.6, and the fixigenae are horizontal rather than upsloping—all characteristic of *P. lata,* according to Wilson. On many specimens, shallow, slotlike fossulae are present at the anterolateral corners of the glabella.

Ornamentation is somewhat variable; most commonly the glabella, the occipital ring, the palpebral and posterior areas of the fixigenae, and the anterior border are covered with medium-sized granules, and the brim is covered by low, anastomosing ridges running down toward the border. On some cranidia the entire surface is covered by granules. This ornamentation is strongest on the external surface and more subdued on molds.

Small domal swellings are present on the posterior fixigenae just anterior of the posterior border furrow. Similar swellings can be seen on Wilson's (1951, pl. 94, figs. 20, 21) illustrations of *Pseudosaratogia lata* and Palmer's (1965b, pl. 2, fig. 18) stereo pair of *Pseudosaratogia leptogranulata*, so this is perhaps a generic characteristic.

A librigena is illustrated for the first time for *P. lata*. It is crescentic in shape and medium sized. The slope below the eye is moderately convex and covered with fine caecal ridges. The lateral border furrow is well impressed, shallowing slightly toward the genal spine as the lateral border gradually widens. The posterior border furrow is well impressed and broader than the lateral border furrow. The genal spine tapers abruptly to a slender width, is of medium length, and contains a small groove that extends from the intersection of the posterior and lateral border furrows nearly to the tip of the spine. The lateral and posterior borders and the genal spine are covered by small- to medium-sized granules.

One fragmentary cranidium previously unidentified from the *Elvinia* Zone in the Arbuckle Mountains is assigned to this species.

Occurrence.—Abundant in the *Elvinia* Zone at CC 317, 319, 322, 329, 332, 337, 341. Scarce in the *Elvinia* Zone in the Arbuckle Mountains at HS 37.

Family HETEROCARYONTIDAE Hupé, 1953 (as emended by Clark and Shaw, 1968)

Genus **Bowmania** Walcott, 1925

Bowmania sagitta Winston and Nicholls

Pl. 4, fig. 1

Bowmania sagitta WINSTON and NICHOLLS, 1967, p. 89, pl. 10, figs. 19, 20; LONGACRE, 1970, p. 56.

Remarks.—This species has been well described and illustrated by Winston and Nicholls and by Longacre. Two specimens from the Wichita Mountains are assigned to this species. Winston and Nicholls (p. 89) emphasized the differences between *B. sagitta* and *Bowmania americana*. *B. sagitta* differs most obviously from *Bowmania pennsylvanica* by the much larger preglabellar field, more prominent eye ridges, and the generally triangular shape of the cranidium. The illustrated specimen from the Wichita

Mountains has the vermiform ridge pattern on the preglabellar field and anterior fixigenae described by Longacre (1970, p. 56). The anterior border is ornamented by a row of pustules. I agree with Winston and Nicholls' suggestion that *B. sagitta* is probably the species of *Bowmania* most closely related to *Entomaspis radiatus* Ulrich (compare with Rasetti, 1952, pl. 117, figs. 1-5).

Occurrence.—Scarce in the *Saukiella serotina* Subzone at CC 1414, 1469.

Family PARABOLINOIDIDAE Lochman, 1956 (as emended by Longacre, 1970)

Genus **Idahoia** Walcott, 1924

Idahoia? sp. undet.

Pl. 2, fig. 3

Remarks.—Four fragmentary cranidia represent a species that is tentatively assigned to this genus because of its general idahoiid characteristics. Specifically, the frontal area is greater than one-half the length of the glabella plus the occipital ring, the glabellar furrows are faint, and the anterior facial sutures are widely divergent. The brim/border ratio is approximately 3:2, which would suggest *Idahoia wisconsensis*, following Grant's (1965, p. 118) criteria. However, the brim slopes down fairly steeply, the border is slightly upturned, the anterior fixigenae are narrow, and the palpebral lobes are located more posteriorly than usual with *Idahoia wisconsensis*. Also, there are scattered pustules on the brim as well as a characteristic row of pustules that transversely cross the brim just anterior of the midlength (sag.).

The slightly upturned border, the narrow anterior fixigenae, and the ornamentation of the pustules are characteristic of species of *Saratogia* (Grant, 1965, p. 121). Hence, even the generic assignment of this taxon is uncertain. The best specimen is illustrated.

Occurrence.—Scarce in the *Drumaspis* Subzone at CC 534. Scarce in the upper part of the *Saratogia* Zone at CC 621.

Genus **Saratogia** Walcott, 1916

Saratogia americana Lochman and Hu

Pl. 2, fig. 2

Minkella americana LOCHMAN and HU, 1959, p. 414, pl. 58, figs. 1-20.

Saratogia americana (Lochman and Hu) BELL and ELLINWOOD, 1962, p. 393, pl. 54, figs. 1-5; LONGACRE, 1970, p. 29-30.

Remarks.—This species has been well described and illustrated by Lochman and Hu, Bell and Ellinwood, and Longacre. Five specimens from two collections are assigned to this species; they add nothing new to the description of the species.

Occurrence.—Scarce in the *Idahoia lirae* Subzone at CC 435. Scarce in the *Drumaspis* Subzone at CC 457.5.

Genus **Stigmacephaloides** Ellinwood *in* Bell and Ellinwood, 1962

Stigmacephaloides curvabilis Ellinwood

Pl. 2, fig. 6

Stigmacephaloides curvabilis ELLINWOOD, *in* Bell and Ellinwood, 1962, p. 401, pl. 56, figs. 2-5; GRANT, 1965, p. 135, pl. 14, fig. 21; LONGACRE, 1970, p. 31.

NOT *Stigmacephaloides curvabilis* STITT, 1971b, p. 31, pl. 3, figs. 16, 17.

Remarks.—Bell and Ellinwood, Grant, and Longacre have summarized the characteristics of this species, but my previous identification of this species in the Arbuckle Mountains needs revision. The material from the Arbuckle Mountains consists of 24 cranidia, many of which are incomplete. Comparison with more abundant and much better preserved material from the Wichita Mountains makes it clear that the small specimens with the extremely sharply downsloping anterior part of the cranidium that I previously illustrated (Stitt, 1971b, pl. 3, figs. 16, 17) are not small specimens of *S. curvabilis* as I had originally believed but are in fact a separate and stratigraphically higher species, *Stigmacephaloides verticalis* Stitt, n. sp. Revised range data for *S. curvabilis* from the Arbuckle Mountains are included with the range data from the Wichitas, and a representative specimen of this species from the Wichita Mountains is illustrated.

Occurrence.—In the Arbuckle Mountains, scarce in the upper part of the *Saratogia* Zone at HS 251, 257, 258, 268; JoR 142, 169. In the Wichita Mountains, common in the upper part of the *Drumaspis* Subzone at CC 555, 560, 563; common in the upper part of the *Saratogia* Zone at CC 611, 613, 621, 657.5, 661, 687.

Stigmacephaloides verticalis Stitt, n. sp.

Pl. 2, figs. 7-9

Available material.—85 cranidia, mostly well preserved.

Description.—Cranidium small, rectangular, strongly convex longitudinally and transversely. Glabella strongly convex longitudinally and transversely; basal glabellar width approximately equal to glabellar length; tapered, anteriorly rounded. Glabellar furrows absent. Axial furrow moderately impressed, preglabellar furrow faint. Occipital furrow moderately impressed along axis, but fades rapidly laterally and does not reach axial furrow; occipital ring is thus defined only near axis. Frontal area one-tenth or less of glabellar length. Preglabellar field nearly vertical, narrowest along axis, widens laterally. Anterior border usually broken off, but when preserved is straplike, sharply upsloping, and of subequal width to preglabellar field. Anterior border furrow troughlike, curving slightly forward and down laterally. Fixigenae narrow, flat to slightly convex. Palpebral lobes prominent, furrowless, centered at about glabellar midlength. Posterior areas narrowly triangular, posterior border furrow moderately impressed. Anterior course of facial sutures slightly divergent.

External and internal surfaces of carapace smooth.

Associated and tentatively assigned librigena slopes down sharply from eye to border furrow and has long genal spine. External surface is smooth.

Pygidium unknown.

Holotype.—UT 13997, Stitt, 1971b, plate 3, figure 16.

Paratypes.—OU 8215, plate 2, figure 7; OU 8216, plate 2, figure 8; OU 8217, plate 2, figure 9.

Etymology.—*Verticalis*, L., upright, vertical; referring to vertical to near-vertical frontal area on this species.

Remarks.—The species is assigned to *Stigmacephaloides* on the basis of its smooth cranidium, furrowless glabella, strong convexity, similar palpebral lobes, incomplete occipital furrow, and anteriorly curved anterior border furrow. It differs from *S. curvabilis* by its even more pronounced anterior convexity, its upsloping anterior border, and smaller size. The tentatively assigned librigena differs from that assigned to *S. curvabilis* in being much less broad and in possessing a long genal spine.

Some specimens from the Arbuckle Mountains now assigned to this species were originally assigned to *S. curvabilis*. Revised range data for *S. verticalis* in the Arbuckle Mountains are given below.

No additional specimens with a coarsely pitted ornament (Stitt, 1971b, p. 31, pl. 3, fig. 17) that occur at the top of the range of *S. verticalis* in the Arbuckle Mountains were recovered in the Wichita Mountains. These three specimens are included in *S. verticalis* until more material is available.

Occurrence.—In the Arbuckle Mountains, scarce in the upper *Saratogia* Zone at JoR 180, 183, 217, 271, 274, 281, 283, 294. In the Wichita Mountains, common in the upper *Saratogia* Zone at CC 708, 709, 714, 720, 728, 730, 734, 742, 743, 768, 772, 777, 782, 784, 790, 791, 794, 797, 800, 807, 809.

Genus **Wilbernia** Walcott, 1924

Wilbernia cf **W. pero** (Walcott)

Pl. 2, fig. 10

Conocephalites diadematus Hall, 1863 (part), pl. 8, fig. 18.
Ptychoparia pero Walcott, 1891, p. 274, pl. 21, fig. 6.
Wilbernia pero (Walcott) Walcott, 1924, p. 60, pl. 13, fig. 4; Longacre, 1970, p. 33 (synonymy to date).

Remarks.—One fragmentary cranidium is assigned to this species on the basis of its parallel-sided glabella and its convex anterior border that is more than twice the length (sag.) of the preglabellar field. The border, preglabellar field, and anterior fixigenae are ornamented by fine terrace lines that run transversely on the border as described by Longacre (1970, p. 33).

Occurrence.—Scarce in the *Drumaspis* Subzone at CC 484.

Family PLETHOPELTIDAE Raymond, 1925

Genus **Leiocoryphe** Clark, 1924

Leiocoryphe occipitalis Rasetti

Pl. 3, fig. 3

Leiocoryphe occipitalis Rasetti, 1944, p. 245, pl. 38, fig. 4; Longacre, 1970, p. 18; Stitt, 1971b, p. 33, pl. 4, fig. 13 (synonymy to date).

Remarks.—This species is characterized by a small, convex, smooth cranidium, a lack of palpebral lobes, and the presence of an occipital furrow. *L. occipitalis* was previously reported from basal Trempealeauan strata in central Texas and the Arbuckle Mountains of Oklahoma (see Longacre, 1970, p. 18, text-fig. 3; Stitt, 1971b, p. 33, pls. 10, 12). Rasetti (1944, p. 245, table 1) reported *L. occipitalis* from several boulders in the Lévis Conglomerate, associated with a variety of trilobites, some of which (*Keithia* and *Keithiella*, for example) are characteristic of the Trempealeauan.

In the Wichita Mountains, specimens of *L. occipitalis* occur in the upper two-thirds of the *Saratogia* Zone (highest Franconian) as well as in the lower half of the *Rasettia magna* Subzone (lowest Trempealeauan). Lochman-Balk (1971, p. 88) observed that *Leiocoryphe* is known from the *Hungaia* fauna in extracratonic sites during the late Franconian and Trempealeauan but does not occur in cratonic sites until the Trempealeauan. This report is the first documentation of *Leiocoryphe* from Franconian cratonic strata.

Occurrence.—Scarce in the *Drumaspis* Subzone at CC 563. Scarce in the upper *Saratogia* Zone at CC 613, 702, 705, 728, 795, 820. Scarce in the *Rasettia magna* Subzone at CC 865, 901, 935, 998, 1017, 1030.

Family PTEROCEPHALIIDAE Kobayashi, 1935 (as emended by Palmer, 1962)

Subfamily PTEROCEPHALIINAE Kobayashi 1935

Genus **Camaraspis** Ulrich and Resser *in* Ulrich, 1924

Camaraspis parabola Frederickson

Pl. 1, fig. 10

Camaraspis parabola FREDERICKSON, 1948, p. 799-800, pl. 123, figs. 16-19.

Remarks.—Frederickson (1948, p. 799-800, pl. 123, figs. 16-19) adequately described and illustrated this unusual species, which is characterized by its strong cranidial convexity, the absence of an occipital furrow, and its poorly defined glabella. The convexity is greatest near the posterior end of the cranidium, and the axial profile of *C. parabola* (Frederickson, 1948, pl. 123, fig. 18) is very similar to that of the Trempealeauan genus *Stenopilus*. Perhaps both were adapted for similar modes of life.

Only seven cranidia of *C. parabola* were recovered from a single bed, and no librigena or pygidium can be associated with the cranidia. As such, *C. parabola* appears to be a divergent evolutionary dead end off of the main line of *Camaraspis convexa*, which is abundant and ranges higher in the *Elvinia* Zone.

Occurrence.—Scarce in the *Elvinia* Zone at CC 317.

Family PTYCHASPIDIDAE Raymond, 1924 (as emended by Longacre, 1970)

Subfamily PTYCHASPIDINAE Longacre, 1970

Genus **Euptychaspis** Ulrich *in* Bridge, 1930

Euptychaspis frontalis Longacre

Pl. 3, fig. 6

Euptychaspis frontalis LONGACRE, 1970, p. 41, pl. 3, figs. 2-5.

Remarks.—This species has been well described and illustrated by Longacre. One specimen from the Wichita Mountains is assigned to this species on the basis of its parallel-sided, flattened glabella; the presence of a well-defined preglabellar field; the medially constricted cranidial outline; and the elongate, triangular posterior fixigenae. I follow Longacre in the generic assignment of this species, which is the apparent ancestor to the stratigraphically higher species of *Euptychaspis*.

Occurrence.—Scarce in the *Rasettia magna* Subzone at CC 1148.

Genus **Keithiella** Rasetti, 1944

Keithiella scrupulosa Ellinwood

Pl. 3, fig. 7

Keithiella scrupulosa ELLINWOOD *in* Bell and Ellinwood, 1962, p. 405, pl. 58, figs. 19-21; LONGACRE, 1970, p. 43-44.

Remarks.—Longacre (1970, p. 42) recently updated the diagnosis of this genus, and Bell and Ellinwood carefully described and illustrated this species. Ten specimens from eight collections are assigned to this species because they match closely the description given in Bell and Ellinwood (1962, p. 405), differing only in that the specimens from the Wichita Mountains are more strongly and uniformly pustulose than those from central Texas. The specimen that shows this feature best is illustrated.

Occurrence.—Scarce in the *Rasettia magna* Subzone at CC 868, 875, 884, 897, 898, 901, 910, 935.

Genus **Ptychaspis** Hall, 1863

Ptychaspis bullasa Lochman and Hu

Pl. 2, fig. 4

Ptychaspis bullasa LOCHMAN and HU, 1959, p. 422, pl. 58, figs. 21-42; LONGACRE, 1970, p. 44, pl. 2, figs. 4, 5 (synonymy to date).

Remarks.—One incomplete cranidium is assigned to this species on the basis of its almost parallel-sided glabella that stands above the fixigenae and the granular ornamentation that is distributed on the glabella and the fixigenae posterior to the ocular ridges, but not on the anterior fixigenae and the frontal area, which are covered with faint transverse ridges. As such, this specimen falls within the range of variation described for this species by Lochman and Hu and summarized recently by Longacre.

Occurrence.—Scarce in the *Idahoia lirae* Subzone at CC 447.

Ptychaspis sp. undet.

Pl. 2, fig. 5

Remarks.—Six fragmentary cranidia are assigned to this genus on the basis of their prominent cylindrical glabellae, the lack of an anterior border furrow, anteriorly located palpebral areas, upsloping fixigenae, and the granular ornament. They most resemble *Ptychaspis* sp. Longacre (1970, p. 44-45, pl. 2, figs. 12-14) not only in appearance but in stratigraphic occurrence. Longacre had 14 fragmentary cranidia and several librigenae but felt her material was not complete enough to merit describing it as a new species, although she summarized the differences between her material and other similar species of *Ptychaspis*. My material is even more fragmentary (the best one is illustrated), so I am reluctant to do more than make a generic assignment.

Occurrence.—Scarce in the *Drumaspis* Subzone at CC 517, 521, 613, 648, 657.5.

Subfamily SAUKIINAE Ulrich and Resser 1933

Genus **Saukiella** Ulrich and Resser, 1933

Saukiella junia (Walcott)

Pl. 4, figs. 3-5

Saukia junia WALCOTT, 1914, p. 378, text-fig. 17.
Saukiella junia (Walcott) RESSER, 1938, p. 43; LONGACRE, 1970, p. 50-51, pl. 5, figs. 12-21 (synonymy to date).

Remarks.—Winston and Nicholls (1967, p. 81-82, pl. 9, figs. 8, 10, 12, 14, 22) and Longacre (1970) recently redescribed and illustrated this species. Four cranidia and eight fragmentary pygidia that fall within the range of variation described for this species are assigned to it; the two best cranidia and the best pygidium are illustrated.

Pygidia low in the stratigraphic range of the species (CC 1200 to CC 1270) have deep furrows and unequally divided pleurae characteristic of *S. junia* var. B (see pl. 4, fig. 4; Longacre, p. 51); associated cranidia are poorly preserved (pl. 4, fig. 3) but are generally similar to those assigned to *S. junia* var. B by Winston and Nicholls (pl. 9, figs. 8, 14) and Longacre (pl. 5, figs. 12-17). The cranidia from CC 1322 have the anteriorly rounded glabella and longer frontal area characteristic of *S. junia* var. A (compare pl. 4, fig. 5, with Winston and Nicholls, p. 82, pl. 9, figs. 10, 12; Longacre, p. 50, pl. 5, figs. 19, 20). If these assignments are correct, it means that the same stratigraphic pattern in the evolution of *S. junia* can be recognized in the Wichita Mountains that was first documented in the much better Texas collections.

Occurrence.—Scarce in the *Saukiella junia* Subzone at CC 1200, 1215, 1216, 1235, 1270, 1322.

Saukiella pepinensis (Owen)

Pl. 4, fig. 2

Dikelocephalus pepinensis OWEN, 1852, p. 574, pl. 1, figs. 9, 9a, 9b.
Saukiella pepinensis (Owen) ULRICH and RESSER, 1933, p. 202, pl. 33, figs. 22-24; LONGACRE, 1970, p. 51, pl. 5, figs. 9-11 (synonymy to date).

Remarks.—Four fragmentary cranidia are assigned to this species on the basis of their narrow to nonexistent preglabellar field, deep cranidial furrows, and anterior border of intermediate length that is distinctly raised above the preglabellar field. Longacre (1970, p. 51) summarized the differences between *S. pepinensis* and the stratigraphically lower *Saukiella pyrene* and the stratigraphically higher *Saukiella junia*. Two fragmentary pygidia associated with the cranidia of *S. pepinensis* are assigned to this species; they have the nearly equal subdivision of the pleurae by the pleural furrows that distinguishes pygidia of *S. pepinensis* from pygidia of *S. junia*. The best cranidium is illustrated.

Occurrence.—Scarce in the lower part of the *Saukiella junia* Subzone at CC 1171, 1172.

Family PTYCHOPARIIDAE Matthew, 1887

Genus **Highgatella** Shaw, 1955

Highgatella cordilleri (Lochman)

Pl. 6, figs. 1, 2

Euloma cordilleri LOCHMAN, 1964b, p. 464, pl. 63, figs. 27-38.

Highgatella cordilleri (Lochman) WINSTON and NICHOLLS, 1967, p. 73, pl. 13, figs. 8, 11, 13.

Remarks.—Three fragmentary cranidia are assigned to this species, based on the criteria listed by Winston and Nicholls (1967, p. 73) and comparison of my specimens with their illustrations and those of Lochman. Lochman (1964b, p. 464) mentioned that the medial bulge on the preglabellar field is not well developed on smaller (1.25 to 3.5 mm) specimens, and this is true on my smallest specimen (pl. 6, fig. 1), although it is slightly larger (approximately 5 mm long) than Lochman's. A larger, broken cranidium (pl. 6, fig. 2) has the characteristic pitted anterior border and bulging preglabellar field ornamented by caecal ridges.

Lochman (p. 464) described the ornamentation as dense, fine granules. On my smallest specimen (pl. 6, fig. 1) the posterior areas and part of the palpebral areas nearest the axial furrow are not granulated but rather densely and deeply pitted.

Occurrence.—Scarce in the *Symphysurina brevispicata* Subzone at CC 1605, 1612, 1733.

Highgatella? sp. undet.

Pl. 6, fig. 3

Remarks.—One incomplete cranidium from the *Missisquoia* Zone is tentatively assigned to this genus. Distinctive features include (1) a prominent, tapered, anteriorly rounded glabella of low convexity that contains two pairs of slitlike glabellar furrows that do not reach the axial furrow; (2) narrow, upsloping, elevated palpebral areas with the crescentic palpebral lobes connected to the eye ridges; (3) anterior fixigenae and a preglabellar field that form a broad, slightly to moderately downsloping fan covered by genal caeca, the amount of downslope increasing abaxially; (4) the anterior border furrow, which is really a string of slitlike depressions; and (5) the occipital ring, which is broken in the center but contains an enlarged area that is probably the base for a node or spine.

This specimen has the isolated glabellar furrows, genal caeca, pitted border furrow, eye ridges, and high palpebral lobes characteristic of *Highgatella*, whose generic characteristics were most recently summarized by Winston and Nicholls (1967, p. 73), and it is questionably assigned to *Highgatella* on this basis. It also has the enlarged area on the occipital ring shown on specimens of *H. gelasinata* (Shaw, 1951, pl. 21, figs. 7, 8, especially). It differs from described species of *Highgatella* principally in lacking the bulging preglabellar field characteristic of *Highgatella*, and the glabellar furrows appear to be farther from the axial furrow than is usual in *Highgatella*.

Occurrence.—Scarce in the *Missisquoia typicalis* Subzone at CC 1539.

Family UNCERTAIN

Genus **Apoplanias** Lochman, 1964

Apoplanias rejectus Lochman

Pl. 4, figs. 8, 9

Apoplanias rejectus LOCHMAN, 1964a, p. 57-58, pl. 14, figs. 25-31, pl. 15, figs. 15-19; STITT, 1971b, p. 46-47, pl. 8, fig. 16.

Remarks.—The best preserved specimen of this species that could be illustrated from the Arbuckle Mountains (Stitt, 1971b, pl. 8, fig. 16) was broken and lacked the anterior border. A more complete cranidium and a librigena of this variable species are illustrated from the Wichita Mountains (pl. 4, figs. 8, 9).

Occurrence.—Common in the *Missisquoia typicalis* Subzone at CC 1524, 1526, 1539, 1570, 1578. Scarce in the base of the *Symphysurina brevispicata* Subzone at CC 1605.

Genus **Clelandia** Cossman, 1902

Clelandia texana Winston and Nicholls

Pl. 6, figs. 4, 5

Clelandia texana WINSTON and NICHOLLS, 1967, p. 89-90, pl. 12, figs. 11, 26; NORFORD, 1969, p. 1-15, pl. 1, figs. 4, 5, 8-10, 13, 14, 41, 42, pl. 2, fig. 33 (synonymy to date).

Remarks.—This species has been well described and illustrated by Winston and Nicholls (1967) and Norford (1969). *Clelandia texana* is characterized by the combination of (1) two pairs of glabellar furrows; (2) an occipital node; (3) wide, flaring posterior areas of the fixigenae; and (4) moderate convexity. Seven cranidia from two collections are assigned to this species; they are exfoliated and have the fine pits covering the dorsal surface mentioned by Norford (1969, p. 8). The glabellar furrows appear fainter on the Wichita Mountains specimens than on those illustrated by Winston and Nicholls and by Norford. Norford (p. 8) described the occipital ring as "more than a third as long (sag.) as glabella," but on the otherwise similar Wichita Mountains specimens the occipital ring varies from one-fourth to one-third of the glabellar length. One specimen has a tiny spine along the posterior edge of the occipital ring in addition to the usual occipital node.

Occurrence.—Scarce in the top of the *Symphysurina brevispicata* Subzone at CC 1859, 1861.

Genus **Drabia** Wilson, 1951

Drabia cf. **D. menusa** Wilson

Pl. 1, fig. 6

Drabia menusa Wilson, 1951, p. 641, pl. 94, figs. 6, 7, 26.

Remarks.—This genus and this particular species were well described and illustrated by Wilson. Four specimens from the Wichita Mountains have the narrow border, granular ornament, and steeply depressed brim that characterize this species. The specimens do not have the well-defined glabellar furrows described and illustrated by Wilson, and for this reason the Wichita Mountains specimens are only tentatively assigned to this taxon.

One fragmentary cranidium from the Arbuckle Mountains that was previously unidentified is assigned to this species.

The *Treatise* placed *Drabia* in the Family Ptychopariidae, Subfamily Ptychopariinae, along with nine other genera, all of which are Middle Cambrian and five of which are from outside North America. Palmer (1965b, p. 33) suggested that trilobite families might be more realistically composed if temporal and spatial data were given equal emphasis with morphological similarity. *Drabia* does not appear to have very much morphological similarity with the other members of the Subfamily Ptychopariinae, much less any sort of lineage from these Middle Cambrian forms. *Drabia* actually resembles *Bowmania* more than any other genus that I am familiar with, but again there is no apparent lineage through the middle and late Franconian. For these reasons, I prefer to place *Drabia* in Family Uncertain for the present.

Occurrence.—Scarce in the *Elvinia* Zone at CC 317. Scarce in the *Elvinia* Zone in the Arbuckle Mountains at RR 70 (float block approximately in place).

Genus **Ptychopleurites** Kobayashi, 1936

Ptychopleurites brevifrons (Kobayashi)

Pl. 4, figs. 6, 7; Pl. 5, fig. 10

Ptychopleura brevifrons Kobayashi, 1936a, p. 165-166, pl. 21, figs. 7, 8.

Ptychopleurites brevifrons (Kobayashi) Kobayashi, 1936b, p. 922.

Description.—Cranidium rectangular, only moderately convex. Glabella prominent, length two-thirds of cranidial length, slightly tapered, anteriorly rounded. Three pairs of faintly impressed glabellar furrows, posterior pair sharply recurved, anterior pair trend slightly forward. Axial furrow deeply impressed. Occipital furrow deeply impressed, curving anteriorly laterally to join axial furrow. Occipital ring typically poorly preserved, widest along axial line, with median node. Frontal area approximately one-sixth of glabellar length. Preglabellar furrow moderately impressed. Preglabellar field convex, one-fifth to one-third width of anterior border. Anterior border furrow straight, well impressed abaxially, becoming shallow and resembling a series of shallow pits at axial line. Anterior border convex, lip-like, tapers evenly abaxially. Fixigenae narrow, palpebral lobes elongate, centered at or slightly anterior of glabellar midlength. Palpebral furrows moderately impressed, slightly sigmoid in course. Eye ridges present but faint. Posterior areas triangular, elongate; posterior border furrow well impressed. Anterior course of facial sutures moderately divergent initially but then curves adaxially opposite and anterior of anterior end of glabella.

Entire surface of crandidum covered by closely spaced pits.

Pygidium and librigenae unknown.

Remarks.—This species is characterized by its prominent, faintly furrowed glabella and by the pits which cover the cranidium. Seven incompletely preserved cranidia from the Wichita and Arbuckle Mountains were compared with the holotype (GSC 8719; pl. 5, fig. 10) and paratype (GSC 8719a) of this species, and although some differences exist between specimens I believe that the holotype and the Oklahoma specimens are conspecific. The characteristic pitting is not as well preserved on the holotype as on some of the Oklahoma specimens (see pl. 4, fig. 6, for example), and the preglabellar field is somewhat sunken on the holotype. Characteristics that the holotype shares with the Oklahoma specimens include the deep axial and occipital furrows, the slightly tapering, similarly proportioned glabellae, the three pairs of faint glabellar furrows, and the somewhat elevated, convex, evenly tapering anterior border. The similarities outweigh the differences in my mind, and I have placed the Oklahoma specimens in *Ptychopleurites brevifrons*, which was originally described from Jones Ridge on the Alaska-Yukon boundary.

The paratype of this species (GSC 8719a) presents certain problems. The frontal area, most of the glabella, and the right anterior area of the librigena are missing, and the specimen as such does not look at all like its supposed illustration (Kobayashi, 1936a, pl. 21, fig. 8). Wilson and Frederickson (1950, p. 895) had earlier encountered the same problem. The paratype is perhaps congeneric, but in its present state of preservation this is about the most favorable comment that can be made.

Ptychopleurites brevifrons occurs with *Plethopeltis arbucklensis* and *Missisquoia depressa* in the *Missisquoia depressa* Subzone at the base of the *Missisquoia* Zone in both the Wichita and Arbuckle Mountains, and as such it will be a valuable index fossil for the base of the Ordovician. This is the first time that this taxon has been discovered in a well-defined biostratigraphic context. Kobayashi (1936a, p. 157) considered the Alaska-Yukon-boundary collection, including *Ptychopleurites brevifrons, Parabolinella? punctolineata,* and *Agnostus subobesus*, to be Late Cambrian, but Palmer (1968, p. B104) excluded this collection from his study of the Cambrian trilobites of Alaska. Palmer pointed out that *P. brevifrons* occurred "about 50 feet above the highest undoubted Cambrian collection and it lies above a collection that yielded only small brachiopods resembling *Nanorthis*, a characteristic Early Ordovician form." Thus the Alaska-Yukon-boundary occurrence of *P. brevifrons* can be interpreted as very low in the Lower Ordovician, but not in as certain a context as in Oklahoma.

The only other report of *Ptychopleurites* that I am aware of is by Taylor (1975, written communication), who reported *Ptychopleurites* in a collection with specimens of *Plethopeltis* and *Parabolinella* from the Hales Limestone in the Hot Creek Range of south-central Nevada. There the *Ptychopleurites-Plethopeltis* association occurs approximately 245 feet above a collection containing *Eurekia* (a diagnostic *Saukia* Zone taxon) and approximately 210 feet below a collection of *Symphysurina*, *Highgatella*, *Missisquoia*, *Leiobienvillia*, and *Parabolinella* (probably a *Symphysurina brevispicata* Subzone assemblage). This occurrence of *Ptychopleurites* is amenable to an earliest-Ordovician age assignment, which is what Taylor has given it, although it is hoped that some additional fossiliferous zones will be discovered in the Hales to pin down the biostratigraphic occurrence of *Ptychopleurites* more closely.

Occurrence.—In the Wichita Mountains, scarce in the *Missisquoia depressa* Subzone at CC 1497, 1499, 1501. In the Arbuckle Mountains, scarce in the *Missisquoia depressa* Subzone at JoR 1058, 1063.

Genus **Reaganaspis** Stitt, n. gen.

Pl. 1, figs. 8, 9

Material available.—28 cranidia, mostly well preserved.

Description.—Cranidium small, quadrate, low convexity. Glabella cylindrical, downsloping anteriorly, tapered, bluntly rounded. Three pairs of short glabellar furrows close to axial furrow. Axial furrow deeply impressed opposite glabellar furrows, lightly impressed elsewhere; preglabellar furrow faint. Occipital furrow moderately impressed at axis, more deeply impressed toward axial furrow. Occipital ring tapered laterally, broadest along axis; a few specimens have an occipital node. Frontal area one-third of cranidial length. Preglabellar field slightly depressed, nearly flat, slightly narrower (sag.) than convex anterior border. Anterior border broadest at axis, tapering laterally; appears in oblique light to be pitted. Anterior border furrow moderately impressed, posteriorly curved at lateral extremities. Fixigenae moderately broad, narrowest opposite palpebral lobes, slightly convex (exsag.), nearly flat (trans.). Prominent eye ridges extend to palpebral lobes, which are usually broken but when preserved are posteriorly located and upsloping. Palpebral furrow distinct. Posterior areas very narrow posterior of palpebral lobes; posterior border furrow well impressed. Anterior course of facial sutures moderately divergent.

Pygidium and librigenae unknown.

Type species.—Reaganaspis parva, n. sp.

Remarks.—This small trilobite is characterized by its cylindrical, bluntly rounded, anteriorly downsloping glabella, prominent eye ridges, small size, and pitted anterior border. The more cylindrical glabellae have less anterior taper than glabellae that are lower and wider at the occipital furrow. The anterior border furrow bends posteriorly at the saggital line on some specimens (pl. 1, fig. 9), but this trait is independent of the type of glabella.

This taxon differs from small specimens of *Cliffia lataegenae* in having less prominent glabellar furrows, in lacking the upsloping fixigenae of *C. lataegenae*, and in having a nearly flat rather than convex preglabellar field. Its affinities are unknown.

Etymology.—Reaganaspis refers to its occurrence in the Reagan Sandstone.

Reaganaspis parva Stitt, n. sp.

Pl. 1, figs. 8, 9

Remarks.—Because *Reaganaspis parva* is the only species assigned to *Reaganaspis*, the generic description also serves as the specific description.

Holotype.—OU 8206, plate 1, figure 8.

Paratype.—OU 8207, plate 1, figure 9.

Etymology.—Parvus, L., little, referring to the very small size of this trilobite.

Occurrence.—Abundant in the *Elvinia* Zone at CC 317.

Gen. and sp. undet. no. 1

Pl. 3, fig. 4

Remarks.—One small, incomplete cranidium is unique enough to merit description. This cranidium is distinguished by its smooth, tall, narrow, furrowless, *Apachia*-like glabella flanked by flat to slightly convex, broadly triangular fixigenae that are covered by medium granules. The axial furrow is less sharply impressed than the occipital and posterior border furrows. The frontal area and anterior fixigenae are either not preserved or else were inadvertently destroyed during cleaning. Transverse furrows cross the fixigenae and connect with the axial furrow near the anterior end of the glabella. The affinities of this distinctive cranidium are unknown to me, but it is so easily recognizable that I illustrate it in the hope that it might have some future biostratigraphic value if even a few specimens were recovered from another area.

Occurrence.—Scarce in *Drumaspis* Subzone at CC 481.

Gen. and sp. undet. no. 2

Pl. 3, fig. 5

Description.—Cranidium rectangular, strongly convex (long.), moderately convex (trans.). Glabella large, approximately four-fifths of cranidial length, moderately convex overall, strongly convex anteriorly (long.). Glabella very slightly tapered, anteriorly rounded, glabellar furrows either absent or extremely faint. Axial, preglabellar, anterior-border, occipital, and posterior-border furrows all moderately impressed. Occipital furrow curves posteriorly away from axial line, then becomes faint and curves anteriorly and is only very faintly connected to axial furrow. Occipital ring widest at axial line; on most specimens there is an occipital node. Frontal area short, approximately one-tenth of cranidial length; anterior border three to four times as wide a preglabellar field at axial line. Anterior-border furrow crescentic, nearly merging with preglabellar furrow at axial line. Anterior fixigenae narrow, straplike. Palpebral area furrowless, located posterior of glabellar midlength. Posterior areas narrowly triangular. Anterior course of facial sutures slightly divergent.

Exoskeleton and internal mold of cranidium appear to be very finely pitted.

Librigenae and pygidium unknown.

Remarks.—This species is characterized by its large, furrowless glabella that is sharply convex anteriorly and its crescentic anterior-border furrow that nearly merges with the preglabellar furrow, greatly reducing and almost eliminating the preglabellar field. These features serve to distinguish it from *Drumaspis*, which is perhaps the most similar genus. Genus and species undet. no. 2 is distinguished from *Yukonaspis* (Palmer, 1968, p. 100-101, pl. 15, figs. 15, 19) by its more convex glabella and lower, smaller palpebral lobes.

Seven cranidia, mostly fragmentary, are assigned to this taxon; the best one is illustrated.

Occurrence.—Scarce in the *Drumaspis* Subzone at CC 512, 517, 521.

Gen. and sp. undet. no. 3

Pl. 6, figs. 9, 10

Gen. and sp. undet. Winston and Nicholls, 1967, p. 90-91, pl. 13, figs. 16, 19.

Remarks.—Winston and Nicholls adequately described this unusual trilobite with the bullet-shaped glabella and an anterior ridge running across the preglabellar field from the anterior end of the glabella to the anterior border. The only addition to their description that I can make from the six specimens I have is that on the specimens where the occipital ring is not broken there is a moderately long occipital spine emanating from the posterior margin of the ring (pl. 6, fig. 10).

In both Texas and Oklahoma, this taxon occurs in the upper part of the range of *Missisquoia* and as such may be useful biostratigraphically.

Occurrence.—Scarce in the *Symphysurina brevispicata* Subzone at CC 1652.

Unassigned pygidium no. 1

Pl. 6, fig. 8

Remarks.—Seven pygidia from four collections cannot be assigned with certainty to any genus or species. The pygidia are triangular (length three-fifths of width) with only a faintly defined axial furrow. However, the first and, in some specimens, second axial rings are clearly set off by furrows on the exoskeleton, and the corresponding pleural furrow is absent on most of the nearly flat pleural field but is moderately impressed on the convex downslope of the pleural field near the margin. The exoskeleton is pitted on the illustrated pygidium, suggesting a relationship to *Symphysurina bulbosa* with which it occurs. However, the internal mold appears to be smooth, whereas the mold of *S. bulbosa* is distinctly pitted. Also, the overall topography of the pleural field of *S. bulbosa* becomes increasingly convex toward the margin, whereas on the pygidia in question the pleural-field margins are S-shaped in cross section, being initially convexly downsloping but becoming slightly concave at the margin. In this latter aspect they suggest a relationship to something with a border like *Parabellefontia.*

Although these specimens are small, I do not believe that they are normal *Symphysurina* meraspids just a few molts short of the holaspid condition. Other pygidia of similar size that are assignable to various species of *Symphysurina* appear to be holaspids and do not retain a "segment" appearance along their anterior end. I believe the delineation of the first and second pleurae in these pygidia is a holaspid characteristic for this taxon.

One of these pygidia (from CC 1891), like the others in other respects, bears a pygidial spine and may represent a different species.

Occurrence.—Scarce in the *Symphysurina bulbosa* Subzone at CC 1866, 1873, 1891, 1916.

Unassigned pygidium no. 2

Pl. 6, fig. 7

Remarks.—Six fragmentary pygidia from two collections cannot be assigned with certainty to any genus or species. The pygidia are trapezoidal in outline (length slightly less than one-half of width) with faint axial furrows that gradually die out posteriorly. The pleural fields are flat near the axis and then bend sharply downward abaxially to what is at most a very narrow, wirelike border. Along the posterior end of the pygidium, the pleural field becomes concave toward the margin, forming a shelflike area that is restricted to the posterior edge of the pygidium. The surface of the pygidium appears to be covered with fine pits.

These pygidia are somewhat similar to one illustrated by Winston and Nicholls (1967, p. 91-92, pl. 13, fig. 17). However, their specimen is relatively wider than mine, and the marginal shelflike area along the posterior of the pygidium extends much farther toward the anterior edge of the pygidium on their specimen than on mine.

The Wichita Mountains pygidia differ from pygidia of *Parabellefontia* (Hintze, 1952, p. 193-195, pl. 3, figs. 7, 8) in that the latter have a different outline, a continuous border set off by a definite border furrow, and a post-axial ridge.

Occurrence.—Scarce in the *Symphysurina bulbosa* Subzone at CC 1874, 1916.

Unassigned pygidium L

Pl. 2, fig. 1

Unassigned pygidium L Wilson, 1951, p. 650, pl. 95, fig. 14.

Remarks.—Wilson described this wide pygidium with the distinctive rows of pustules that occur along the posterior margin of the pleural segments and across the axis, as well as the pustules on the pleural-field posterior of the axis. Wilson had two specimens from his locality 47-5w.8a in Pennsylvania, and I have one from CC 319. Species common to both of these beds are *Dellea suada*, *Dokimocephalus intermedius*, and *Elvinia roemeri*, all of which have different pygidia than pygidium L. The generic and specific assignment of this pygidium must await further discoveries.

Occurrence.—Scarce in the *Elvinia* Zone at CC 319.

MEASURED SECTION

Chandler Creek Section (CC)

This painted section is approximately 14 miles north of Lawton, Oklahoma, in a northwest-trending outcrop belt of Upper Cambrian and Lower Ordovician rocks. The lower part of the Reagan Sandstone crops out on land leased by Mr. E. DeMarcus (home located in the southeast corner of sec. 13, T. 4 N., R. 13 W.). The rest of the measured section is on land owned by Mr. E. H. Mannschreek, of Anadarko, Oklahoma. Permission to visit the section should be secured from both of these cooperative gentlemen before proceeding to the outcrop.

A road log is given below to make location of the section easier, and a geologic map of the area directly surrounding the section is shown in figure 12. Township and range coordinates for this section are E½SW¼ and SE¼ sec. 17, T. 4 N., R. 12 W., and NW¼SW¼ sec. 16, T. 4 N., R. 12 W., Richards Spur, Oklahoma, 7½-minute quadrangle map, 1956 edition.

The section was measured with a Brunton compass and a 5-foot Jacob's staff, and the rocks were painted every 5 feet with a stripe of yellow paint. Stripes were numbered every 25 feet above the base of the section. The stripes originally painted on the Reagan Sandstone in 1969 had weathered off by 1973, but the stripes on the limestone beds are still usable.

Fresh, wetted surfaces of the limestones were examined in the field and in the laboratory, and the descriptions utilize Folk's (1959, 1962) limestone classification. Colors were estimated from the fresh, wet surfaces. Weathering descriptions were recorded in the field. Thin beds are 6 inches or less thick, medium beds are 6 inches to 1 foot thick, and thick beds are more than 1 foot thick. Algal limestones in which bedding is indistinct are sometimes referred to as "massive." Offset directions assume an upsection traverse. A total of 249 beds yielding identifiable fossils were collected, and the footage numbers and the identified taxa in each collection are listed after the lithologic description of the interval involved. Species are listed alphabetically in each collection, and the number of cranidia, pygidia, and librigenae assignable to each taxon is given in parentheses after the name. For example, "CC-794 *Rasettia capax* (2-1-1)" means that at 794 feet above the base of the Chandler Creek measured section 2 cranidia, 1 pygidium, and 1 librigena assignable to *Rasettia capax* were collected. Refer to plate 7 (in pocket) for a diagram of trilobite occurrences and ranges for this section.

Mileage	
0.0	Junction of U.S. 281 and 277 with U.S. 62 (Cache Road). Proceed north on 281, 277, and 62.
2.6	Fort Sill Key Gate.
6.3	Junction of U.S. 281, 277, and 62 with State 49. Turn left (west) on State 49.
10.1	Junction of State 49 and 58. Turn right (north) on State 58.
12.6	Mount Scott and Lake Lawtonka on left.
13.7	Turn right onto paved section-line road and continue north.
14.7	Stop sign. Continue north.
15.2	Paved road changes to gravel road.
15.7	Intersectionwith east-west, section-line gravel road. Continue north.
16.7	Turn right through wire gate if prior permission obtained from Mr. DeMarcus and Mr. Mannschreek. DeMarcus house is 1 mile west of here on north side of gravel road.
16.9	Continue across dry creek bed, curve left through wooden and tin sheds, bear right through fence, and proceed over crest of hill and then downhill toward farm pond.
17.0	Park vehicle at tank. Proceed northeast along west side of tree-lined intermittent stream to contact between Carlton Rhyolite and Reagan Sandstone. Section proceeds up steep Reagan scarp face directly ahead, then is offset southeast at Reagan—Honey Creek Limestone contact to third hill, then continues upsection.

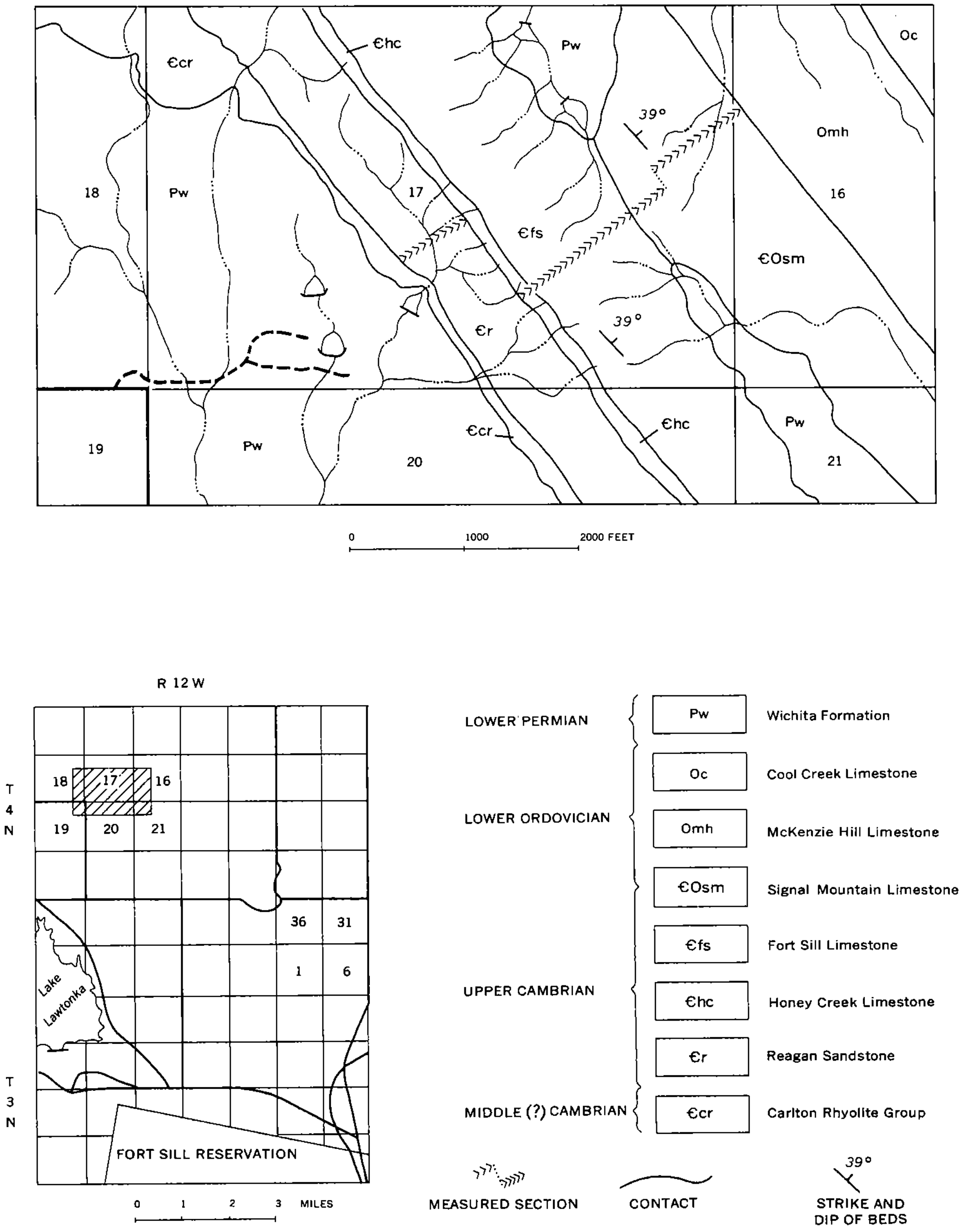

Figure 12. Geologic map of area surrounding Chandler Creek section. Index map at lower left shows area mapped (diagonal lines).

Formations cropping out in the line of section have the following thicknesses:

Signal Mountain Limestone	871 feet
Fort Sill Limestone	592 feet
Honey Creek Limestone	52 feet
Reagan Sandstone	411 feet

Signal Mountain Limestone: 871 feet thick

DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
24. Limestone: intraclastic trilobite biomicrite and trilobite biomicrite. Medium to dark grayish brown, thin to medium beds; weathers light to medium gray. Interval mostly covered.	63	1,863-1,926

Symphysurina Zone
Symphysurina bulbosa Subzone

CC 1916	*Symphysurina brevispicata* (2-0-1)
	Symphysurina bulbosa (2-1-0)
	Unassigned pygidium no. 1 (0-2-0)
	Unassigned pygidium no. 2 (0-2-0)
CC 1901	*Symphysurina bulbosa* (1-0-0)
CC 1899	*Hystricurus* sp. undet. (1-0-0)
	Symphysurina brevispicata (5-1-0)
	Symphysurina bulbosa (0-1-0)
CC 1891	*Hystricurus* sp. undet. (1-0-0)
	Symphysurina brevispicata (6-0-0)
	Symphysurina bulbosa (0-1-0)
	Unassigned pygidium no. 1 (0-1-0)
CC 1888	*Symphysurina brevispicata* (1-0-0)
CC 1887	*Symphysurina brevispicata* (2-0-0)
CC 1876	*Symphysurina bulbosa* (1-1-0)
CC 1874	*Symphysurina brevispicata* (2-0-0)
	Symphysurina bulbosa (0-0-3)
	Unassigned pygidium no. 2 (0-4-0)
CC 1873	*Symphysurina bulbosa* (3-6-0)
	Unassigned pygidium no. 1 (0-3-0)
CC 1870	*Symphysurina brevispicata* (0-1-0)
CC 1869	*Symphysurina* sp. undet. (1-0-0)
CC 1866	*Symphysurina brevispicata* (8-1-2)
	Symphysurina bulbosa (0-4-0)
	Unassigned pygidium no. 1 (0-1-0)

Symphysurina brevispicata Subzone

CC 1864	*Symphysurina* sp. undet. (1-0-0)

DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
23. Limestone: mostly trilobite biomicrite and pelsparite; scattered trilobite biosparite and intrasparite. Medium grayish brown, thin to medium beds; weathers light to medium gray. Interval mostly covered.	72	1,791-1,863

Symphysurina brevispicata Subzone

CC 1863	*Symphysurina brevispicata* (5-3-0)
CC 1861	*Clelandia texana* (1-0-0)
	Symphysurina brevispicata (6-5-1)
CC 1860	*Symphysurina brevispicata* (3-3-1)
CC 1859	*Clelandia texana* (6-0-0)
CC 1856	*Symphysurina brevispicata* (6-2-2)
CC 1849	*Hystricurus* sp. undet. (1-0-0)
	Symphysurina brevispicata (1-1-2)
CC 1827.5	*Symphysurina brevispicata* (3-2-2)
CC 1823.5	*Symphysurina* sp. undet. (2-0-0)
CC 1823	*Hystricurus millardensis* (0-1-0)
	Symphysurina brevispicata (0-5-2)
CC 1820	*Symphysurina brevispicata* (0-0-1)
	Symphysurina sp. A Ross (1-0-1)
CC 1814	*Homagnostus reductus* (1-0-0)
	Hystricurus millardensis (2-0-0)
	Symphysurina brevispicata (3-2-1)
	Symphysurina sp. A Ross (3-3-1)
CC 1813	*Homagnostus reductus* (0-1-0)
	Hystricurus millardensis (1-0-0)
	Symphysurina brevispicata (7-3-2)
	Symphysurina sp. A Ross (0-0-1)
CC 1811	*Symphysurina brevispicata* (6-3-1)
CC 1802	*Hystricurus millardensis* (2-0-0)
	Symphysurina sp. undet. (7-0-0)
CC 1798	*Symphysurina* sp. A Ross (3-0-1)
CC 1796	*Hystricurus millardensis* (1-1-0)
CC 1794	*Hystricurus millardensis* (1-0-1)
	Symphysurina brevispicata (12-1-2)
	Symphysurina pygidium no. 1 (0-1-0)
CC 1793	*Hystricurus millardensis* (4-1-1)
CC 1792	*Hystricurus millardensis* (1-0-0)
	Symphysurina pygidium no. 1 (0-2-0)
	Symphysurina sp. A Ross (1-2-2)

DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
22. Limestone: sparse trilobite biomicrite. Scattered glauconite, hematite, and very fine quartz sand. Medium to dark grayish brown, thin to medium beds. Upper part of interval mostly covered. Section crosses small normal fault (northwest side downthrown) with 11-foot offset at 1,715 feet. Footages in this report have been corrected, but outcrop paint stripes and painted numbers have *not* been corrected.	87	1,704-1,791

Symphysurina brevispicata Subzone

CC 1791	*Hystricurus millardensis* (4-2-3)
CC 1789	*Hystricurus millardensis* (12-3-1)
CC 1781	*Hystricurus millardensis* (1-0-0)
	Symphysurina brevispicata (5-1-1)
CC 1773	*Symphysurina brevispicata* (1-0-0)
CC 1751	*Missisquoia typicalis* (1-0-0)
CC 1749	*Symphysurina bubops* (2-2-0)
CC 1733	*Highgatella cordilleri* (1-0-0)
CC 1718	*Symphysurina* sp. A Ross (0-0-2)

DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
21. Limestone: sparse trilobite biomicrite, trilobite pelsparite, and pelsparite. Dark grayish brown, mostly medium but some thin and thick beds; weathers light to medium gray, with brown mottles on some beds. Interval mostly covered.	100	1,604-1,704

Symphysurina brevispicata Subzone

CC 1692	*Hystricurus millardensis* (1-0-0)
CC 1682	*Hystricurus millardensis* (2-0-0)
	Symphysurina brevispicata (0-1-0)

	DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
CC 1671.5	*Missisquoia typicalis* (4-6-0)		
CC 1665	*Missisquoia typicalis* (12-5-0)		
CC 1654	*Missisquoia typicalis* (2-0-0)		
CC 1652	Genus and species undet. no. 3 (6-0-0) *Hystricurus millardensis* (4-0-0) *Missisquoia typicalis* (7-4-0)		
CC 1645	*Hystricurus millardensis* (1-0-0) *Missisquoia typicalis* (1-1-0)		
CC 1625	*Missisquoia typicalis* (54-30-27)		
CC 1620	*Missisquoia typicalis* (1-2-3)		
CC 1612	*Highgatella cordilleri* (1-0-1) *Missisquoia typicalis* (4-2-0)		
CC 1605	*Apoplanias rejectus* (3-0-0) *Highgatella cordilleri* (1-0-0) *Missisquoia typicalis* (8-3-0) *Symphysurina* sp. A Ross (1-2-1)		
	20. Limestone: mostly trilobite pelsparite and biomicrite. Scattered intraclasts, very fine quartz sand, and glauconite. Silicified valves of *Apheoorthis* on bedding surfaces. Medium to dark grayish brown, medium to thin beds; weathers light to medium gray, with some brown mottling in the pelsparite beds.	67	1,537-1,604
	Symphysurina brevispicata Subzone		
CC 1604	*Missisquoia typicalis* (2-0-1) *Symphysurina brevispicata* (1-0-1)		
	Missisquoia Zone *Missisquoia typicalis* Subzone		
CC 1597	*Missisquoia typicalis* (1-0-0)		
CC 1593	*Missisquoia typicalis* (68-39-24)		
CC 1590	*Missisquoia typicalis* (1-1-1)		
CC 1588	*Missisquoia typicalis* (23-18-9)		
CC 1585	*Missisquoia typicalis* (12-4-2)		
CC 1578	*Apoplanias rejectus* (1-0-1) *Symphysurina* cf. *S. cleora* (1-0-1)		
CC 1570	*Apoplanias rejectus* (2-0-0) *Missisquoia typicalis* (7-0-3)		
CC 1557	*Missisquoia typicalis* (1-0-0)		
CC 1547	*Missisquoia typicalis* (22-16-7)		
CC 1539	*Apoplanias rejectus* (9-0-6) *Highgatella* sp. undet. (1-0-0)		
	19. Limestone: trilobite biomicrite with lesser amounts of intrasparite and pelsparite. Scattered very fine quartz sand, glauconite, and ferroan dolomite. Silicified valves of *Apheoorthis* present on bedding surfaces above 1,524 feet. Medium to dark grayish brown, medium to thin beds; weathers light to medium gray, with some brown mottled beds. Interval mostly covered. Section crosses small normal fault (northwest side downthrown) with 5-foot offset at 1,533 feet. Footages in this report have been corrected, but outcrop stripes and painted numbers have *not* been corrected.	81	1,456-1,537
	Missisquoia typicalis Subzone		
CC 1526	*Apoplanias rejectus* (5-2-0)		
CC 1524	*Apoplanias rejectus* (1-0-1) *Missisquoia typicalis* (0-1-0)		
	Missisquoia depressa Subzone		
CC 1507.5	*Plethopeltis arbucklensis* (2-1-0)		
CC 1501	*Plethopeltis arbucklensis* (9-8-4) *Ptychopleurites brevifrons* (3-0-0)		
CC 1499	*Homagnostus reductus* (0-1-0) *Missisquoia depressa* (0-1-0) *Plethopeltis arbucklensis* (2-7-8) *Ptychopleurites brevifrons* (2-0-0)		
CC 1497	*Missisquoia depressa* (2-3-0) *Plethopeltis arbucklensis* (3-7-2) *Ptychopleurites brevifrons* (1-0-0)		
	Saukia Zone *Corbinia apopsis* Subzone		
CC 1491	*Apatokephaloides clivosus* (2-0-0) *Corbinia apopsis* (21-5-0) *Idiomesus levisensis* (3-0-0) *Leiobienvillia leonensis* (1-0-0) *Plethometopus obtusus* (1-0-0) *Triarthropsis limbata* (1-0-0)		
CC 1482.5	*Apatokephaloides clivosus* (1-0-0) *Corbinia apopsis* (1-0-0)		
CC 1479	*Acheilops masonensis* (1-0-0) *Apatokephaloides clivosus* (1-1-0)		
	Saukiella serotina Subzone		
CC 1469	*Bowmania sagitta* (1-0-0) *Stenopilus latus* (5-0-0)		
	18. Limestone: mostly trilobite biomicrite with scattered pelmicrite. Scattered hematitic intraclasts; very fine quartz sand at 1,441 feet. Light to medium gray, thin to medium beds; weathers medium gray. Interval mostly covered.	79	1,377-1,456
	Saukiella serotina Subzone		
CC 1456	*Euptychaspis kirki* (1-0-0) *Rasettia wichitaensis* (1-0-0)		
CC 1453	*Euptychaspis jugalis* (1-0-0) *Euptychaspis kirki* (1-0-0) *Rasettia wichitaensis* (0-1-0)		
CC 1447	*Euptychaspis kirki* (1-0-0) *Eurekia eos* (1-0-0)		
CC 1441	*Euptychaspis kirki* (1-0-1) *Eurekia eos* (0-1-0)		
CC 1439	*Euptychaspis kirki* (1-0-0)		
CC 1427	*Euptychaspis kirki* (2-0-0) *Idiomesus levisensis* (1-0-0)		
CC 1425	*Bayfieldia simata* (1-0-0)		
CC 1423	*Plethometopus convergens* (1-0-0)		
CC 1414	*Bayfieldia simata* (0-4-0) *Bowmania sagitta* (1-0-0) *Euptychaspis kirki* (2-1-0) *Idiomesus levisensis* (1-0-0) *Leiocoryphe platycephala* (2-0-0) *Stenopilus latus* (3-0-0)		
CC 1405	*Euptychaspis kirki* (2-0-0) *Idiomesus levisensis* (1-0-0) *Stenopilus latus* (3-0-0)		

	DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
CC 1391	*Euptychaspis jugalis* (1-0-0)		
	Eurekia eos (3-0-0)		
	Plethometopus convergens (1-0-0)		
	Rasettia wichitaensis (1-0-0)		
	Saukiella serotina (0-1-0)		
17. Limestone: glauconitic-packed trilobite biomicrite. Scattered intraclasts, fine quartz sand, and ferroan dolomite. Medium to dark grayish brown, mostly thin to medium, slabby beds; weathers medium gray.		54	1,323-1,377
	Saukiella serotina Subzone		
CC 1377	*Bayfieldia simata* (1-0-0)		
CC 1375	*Calvinella tenuisculpta* (1-0-0)		
CC 1374	*Bynumina vescula* (2-1-0)		
	Eurekia eos (0-0-1)		
	Stenopilus latus (1-0-0)		
CC 1364	*Bynumina vescula* (1-0-0)		
	Calvinella tenuisculpta (2-0-0)		
	Idiomesus levisensis (1-0-0)		
CC 1358	*Calvinella tenuisculpta* (2-0-0)		
	Eurekia eos (1-2-2)		
	Stenopilus latus (1-0-0)		
CC 1350	*Eurekia eos* (1-0-0)		
	Idiomesus levisensis (1-0-0)		
CC 1348	*Eurekia eos* (0-1-0)		
CC 1347	*Bayfieldia simata* (1-1-0)		
	Bynumina vescula (1-1-0)		
	Euptychaspis jugalis (2-2-0)		
	Euptychaspis kirki (1-0-0)		
	Euptychaspis typicalis (1-0-0)		
	Eurekia eos (2-0-0)		
	Saukiella serotina (2-1-1)		
CC 1343	*Eurekia eos* (1-0-1)		
	Saukiella serotina (0-1-0)		
CC 1327	*Euptychaspis typicalis* (1-0-0)		
16. Limestone: intraclastic trilobite oosparite and intraclastic trilobite biomicrite and biosparite. Scattered ferroan dolomite. Medium grayish brown, thin to medium slabby beds; weathers light to medium gray.		68	1,255-1,323
	Saukiella serotina Subzone		
CC 1323	*Bayfieldia simata* (2-0-0)		
	Bynumina vescula (0-2-0)		
	Euptychaspis kirki (1-0-0)		
	Eurekia eos (4-0-5)		
	Idiomesus levisensis (2-0-0)		
	Triarthropsis limbata (1-0-0)		
	Saukiella junia Subzone		
CC 1322	*Bayfieldia simata* (1-0-0)		
	Euptychaspis jugalis (3-0-0)		
	Euptychaspis typicalis (4-0-0)		
	Eurekia eos (0-2-1)		
	Idiomesus levisensis (5-0-0)		
	Saukiella junia var. A (2-2-0)		
	Stenopilus latus (2-0-0)		
CC 1312	*Eurekia eos* (1-0-0)		
CC 1300	*Stenopilus latus* (3-0-0)		
CC 1298	*Bayfieldia simata* (0-2-0)		
	Euptychaspis jugalis (32-3-0)		
	Idiomesus levisensis (6-4-0)		
	Rasettia wichitaensis (0-1-0)		
	Stenopilus latus (49-9-0)		
CC 1297	*Euptychaspis jugalis* (3-0-0)		
	Stenopilus latus (1-1-0)		
CC 1295	*Euptychaspis jugalis* (1-0-0)		
	Stenopilus latus (2-0-0)		
CC 1289	*Eurekia eos* (1-0-0)		
	Stenopilus latus (1-0-0)		
CC 1287	*Bayfieldia simata* (0-1-0)		
	Bynumina vescula (1-0-0)		
	Euptychaspis jugalis (1-0-0)		
	Stenopilus latus (0-1-0)		
CC 1281	*Eurekia eos* (2-1-0)		
	Idiomesus levisensis (2-0-0)		
	Stenopilus latus (5-1-0)		
	Triarthropsis sp. undet. (1-0-0)		
CC 1279	*Stenopilus latus* (1-0-0)		
CC 1272	*Bayfieldia simata* (1-0-0)		
CC 1270	*Saukiella junia* var. B (0-1-0)		
CC 1265	*Bayfieldia simata* (1-0-0)		
CC 1263	*Plethometopus convergens* (1-0-0)		
	Stenopilus latus (1-0-0)		
CC 1257	*Bayfieldia simata* (1-0-0)		
15. Limestone: sandy trilobite biomicrite; scattered fine pelsparite. Fine quartz sand content decreases upsection to zero above 1,235 feet. Scattered intraclasts in lower 40 feet of unit; scattered oosparite beds from 1,216 to 1,225 feet. Scattered scarce glauconite and ferroan dolomite. Medium grayish brown, mostly thin to medium slabby beds with some thick beds in upper 80 feet of unit. Weathers light to medium gray to grayish brown.		117	1,138-1,255
	Saukiella junia Subzone		
CC 1255	*Bayfieldia simata* (0-1-0)		
	Euptychaspis typicalis (2-0-0)		
	Idiomesus levisensis (5-0-0)		
	Saukia tumida (1-0-0)		
	Stenopilus latus (4-0-0)		
CC 1253	*Bayfieldia simata* (2-1-0)		
	Leiocoryphe platycephala (0-1-0)		
CC 1249	*Bayfieldia simata* (1-0-0)		
	Stenopilus latus (6-0-0)		
CC 1248	*Bayfieldia simata* (1-0-0)		
	Idiomesus levisensis (1-0-0)		
	Plethometopus convergens (2-0-0)		
	Saukia tumida (3-0-0)		
	Stenopilus latus (0-0-1)		
CC 1246	*Bayfieldia simata* (1-4-0)		
CC 1242	*Bayfieldia binodosa* (2-1-0)		
	Bayfieldia simata (1-1-0)		
	Bynumina vescula (1-0-0)		
	Euptychaspis typicalis (2-0-0)		
	Stenopilus latus (1-0-0)		
CC 1236	*Bayfieldia binodosa* (0-0-1)		
	Stenopilus latus (2-0-0)		
CC 1235	*Bayfieldia binodosa* (1-0-0)		

	DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
	Saukiella junia var. B (0-2-0)		
	Stenopilus latus (3-0-0)		
CC 1233	*Stenopilus latus* (1-0-0)		
CC 1231.5	*Euptychaspis typicalis* (1-0-0)		
	Magnacephalus smilus (0-0-1)		
	Rasettia wichitaensis (1-1-0)		
CC 1229	*Rasettia wichitaensis* (0-1-0)		
CC 1225	*Bayfieldia binodosa* (4-2-2)		
	Bynumina vescula (1-0-0)		
	Stenopilus latus (2-0-0)		
CC 1216	*Bayfieldia binodosa* (1-0-0)		
	Euptychaspis typicalis (3-0-0)		
	Magnacephalus smilus (1-0-1)		
	Saukiella junia var. B (0-1-0)		
CC 1215	*Bayfieldia binodosa* (3-0-3)		
	Saukiella junia var. B (1-0-2)		
CC 1204	*Acheilops* cf. *A. dilatus* (1-0-0)		
	Bayfieldia binodosa (2-0-0)		
	Idiomesus levisensis (1-0-0)		
	Rasettia wichitaensis (0-1-0)		
CC 1200	*Bayfieldia binodosa* (1-0-0)		
	Bowmania pennsylvanica (1-0-0)		
	Saukia tumida (1-0-0)		
	Saukiella junia var. B (1-2-0)		
	Triarthropsis sp. undet. (1-0-2)		
CC 1188	*Bayfieldia binodosa* (4-2-3)		
	Euptychaspis typicalis (10-0-0)		
	Idiomesus levisensis (2-0-0)		
	Plethometopus convergens (10-0-0)		
	Saukia tumida (2-0-0)		
	Triarthropsis marginata (1-0-0)		
CC 1176	*Bayfieldia binodosa* (1-1-0)		
CC 1172	*Bayfieldia binodosa* (5-3-0)		
	Saukiella pepinensis (3-2-3)		
CC 1171	*Bayfieldia binodosa* (3-2-3)		
	Euptychaspis typicalis (1-0-0)		
	Saukia tumida (0-0-1)		
	Saukiella pepinensis (1-0-0)		
	Stenopilus latus (3-1-0)		
	Rasettia magna Subzone		
CC 1167	*Bayfieldia binodosa* (2-0-0)		
CC 1162	*Bayfieldia binodosa* (0-2-5)		
	Heterocaryon tuberculatum (1-0-0)		
CC 1160	*Bayfieldia binodosa* (2-1-2)		
CC 1154	*Bayfieldia binodosa* (5-0-6)		
CC 1148	*Bayfieldia binodosa* (2-0-0)		
	Euptychaspis frontalis (1-0-0)		
	Plethometopus convergens (1-0-0)		
CC 1146	*Bayfieldia binodosa* (1-0-0)		
CC 1142	*Bayfieldia binodosa* (1-0-2)		
	Rasettia magna (0-1-0)		
	14. Limestone: oolitic trilobite intrasparite, trilobite biomicrite, and intraclastic trilobite pelsparite. Intraclasts usually trilobite biomicrite or fine pelsparite. Scattered ferroan dolomite, glauconite, and fine quartz sand. Medium grayish brown, thin to medium beds; weathers light gray to brownish gray. Very rough-topped beds toward top of unit. Silicified cephalopods(?) at 1,112 feet.	38	1,100-1,138
	Rasettia magna Subzone		
CC 1133	*Bayfieldia binodosa* (7-3-2)		
	Plethometopus sp. undet. (1-0-0)		
CC 1130	*Bayfieldia binodosa* (3-3-0)		
	Plethometopus convergens (1-0-0)		
CC 1114	*Bayfieldia binodosa* (1-0-0)		
CC 1109	*Bayfieldia binodosa* (3-0-9)		
	Bynumina vescula (1-0-0)		
CC 1105	*Bynumina vescula* (1-0-0)		
	13. Limestone: trilobite algal biomicrite. Scattered oolites, pelsparite, fine intrasparite, and oncolites (usually with trilobite fragments for nuclei). Very light gray, thick to massive beds; weathers light to medium gray.	45	1,055-1,100
	Rasettia magna Subzone		
CC 1100	*Stenopilus* sp. undet. (1-0-0)		
CC 1067	*Plethometopus granulosus* (1-1-0)		
	Rasettia magna (0-0-1)		
	Stenopilus pronus (1-0-0)		
CC 1065	*Plethometopus granulosus* (1-0-0)		
	Stenopilus pronus (3-0-1)		
CC 1064	*Stenopilus* sp. undet. (1-0-0)		
	Theodenisia microps (1-0-0)		
CC 1058	*Plethometopus granulosus* (1-0-0)		
	Rasettia magna (0-1-0)		
	Stenopilus pronus (2-0-0)		
CC 1057	*Plethometopus granulosus* (8-1-0)		
	Rasettia magna (1-4-0)		
	Stenopilus pronus (4-0-0)		

Fort Sill Limestone: 592 feet thick

	12. Limestone: mostly domal stromatolite biomicrite. Sparse trilobite biomicrite, pelsparite, and oolitic intrasparite occur between and around the algal domes. Scattered ferroan dolomite. Light to medium grayish brown, thick to massive beds; weathers to light- to medium-gray, rounded masses. Stromatolitic algal heads common on weathered surfaces throughout this interval.	116	939-1,055
	Rasettia magna Subzone		
CC 1054	*Plethometopus granulosus* (6-1-0)		
	Stenopilus pronus (2-0-0)		
CC 1050	*Plethometopus granulosus* (2-0-0)		
	Rasettia magna (0-2-0)		
	Stenopilus pronus (1-0-0)		
CC 1034	*Rasettia magna* (2-1-0)		
CC 1032	*Rasettia magna* (3-2-2)		
	Theodenisia microps (1-0-0)		
CC 1030	*Bowmania pennsylvanica* (1-0-0)		
	Leiocoryphe occipitalis (1-0-0)		
	Plethometopus granulosus (1-0-1)		
	Triarthropsis sp. undet. (1-0-0)		
CC 1028	*Plethometopus granulosus* (5-0-0)		
CC 1017	*Bowmania pennsylvanica* (1-0-0)		

	DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
	Leiocoryphe occipitalis (1-0-0)		
	Plethometopus granulosus (2-0-0)		
CC 1013	*Rasettia magna* (0-1-1)		
CC 1012	*Plethometopus granulosus* (4-0-0)		
	Rasettia magna (1-0-0)		
	Theodenisia microps (1-0-0)		
CC 1010	*Plethometopus granulosus* (1-0-0)		
	Rasettia magna (2-2-1)		
	Stenopilus pronus (3-0-0)		
	Theodenisia microps (1-0-0)		
	Triarthropsis sp. undet. (1-0-0)		
CC 1007	*Theodenisia microps* (1-0-0)		
CC 998	*Leiocoryphe occipitalis* (1-0-0)		
	Theodenisia microps (1-0-0)		
CC 996	*Plethometopus granulosus* (1-0-0)		
	Rasettia magna (1-0-0)		
CC 993	*Rasettia magna* (1-1-1)		
CC 992	*Plethometopus granulosus* (1-0-0)		
	Rasettia magna (0-1-0)		
CC 986	*Plethometopus granulosus* (1-0-0)		
	Stenopilus pronus (3-0-0)		
CC 985	*Stenopilus pronus* (2-1-0)		
CC 967	*Plethometopus granulosus* (2-0-0)		
	Stenopilus pronus (1-0-0)		
CC 952	*Monocheilus truncatus* (1-0-0)		
	Rasettia magna (4-2-0)		
11. Limestone: packed trilobite biosparite and intrasparite. Scattered lenses of sparse trilobite biomicrite. Scattered ferroan dolomite rhombs. Light to dark grayish brown, mostly thin beds becoming thick to massive above 910 feet; weathers light to medium gray. Silicified molluscs at 933 feet.		64	875-939
	Rasettia magna Subzone		
CC 939	*Theodenisia microps* (1-0-0)		
CC 935	*Keithiella scrupulosa* (2-0-0)		
	Leiocoryphe occipitalis (4-1-0)		
	Monocheilus truncatus (2-0-0)		
	Rasettia magna (2-4-0)		
CC 914	*Idiomesus levisensis* (1-0-0)		
	Plethometopus sp. undet. (1-0-0)		
	Rasettia magna (1-0-0)		
	Triarthropsis marginata (4-0-0)		
CC 910	*Keithiella scrupulosa* (1-0-0)		
	Rasettia capax (1-0-0)		
	Triarthropsis marginata (25-2-0)		
CC 903	*Plethometopus* sp. undet. (3-0-0)		
CC 901	*Keithiella scrupulosa* (2-0-0)		
	Leiocoryphe occipitalis (0-1-0)		
	Monocheilus truncatus (1-0-0)		
	Plethometopus granulosus (0-1-0)		
	Rasettia capax (1-0-0)		
	Rasettia magna (5-1-0)		
	Triarthropsis sp. undet. (5-0-0)		
CC 898	*Keithiella scrupulosa* (1-0-0)		
	Monocheilus truncatus (1-0-0)		
	Rasettia capax (0-1-0)		
CC 897	*Keithiella scrupulosa* (1-0-0)		
	Rasettia magna (1-0-0)		
CC 893	*Geragnostus intermedius* (0-2-0)		
	Rasettia capax (2-2-0)		
	Rasettia magna (2-2-0)		
CC 884	*Keithiella scrupulosa* (1-0-0)		
	Rasettia capax (0-1-0)		
CC 881	*Bowmania pennsylvanica* (1-0-0)		
	Rasettia magna (2-2-0)		
10. Limestone: trilobite biomicrite. Scattered ferroan dolomite. Medium grayish brown, thin to medium beds; weathers light to medium gray. Silicified cephalopods at 859 feet.		47	828-875
	Rasettia magna Subzone		
CC 875	*Eurekia granulosa* (1-0-0)		
	Idiomesus levisensis (1-0-0)		
	Keithiella scrupulosa (1-0-0)		
	Rasettia capax (2-1-0)		
	Rasettia magna (3-1-0)		
	Theodenisia microps (1-0-1)		
CC 872	*Rasettia* sp. undet. (1-0-1)		
CC 868	*Geragnostus intermedius* (1-0-0)		
	Keithiella scrupulosa (1-0-0)		
	Monocheilus truncatus (1-0-0)		
	Rasettia capax (11-4-0)		
	Rasettia magna (1-1-1)		
CC 865	*Eurekia granulosa* (0-2-0)		
	Idiomesus levisensis (2-0-0)		
	Leiocoryphe occipitalis (1-0-0)		
	Monocheilus truncatus (2-0-0)		
	Rasettia capax (1-0-0)		
	Rasettia magna (1-3-0)		
	Theodenisia microps (1-0-0)		
	Saratogia Zone		
CC 860	*Rasettia capax* (2-0-1)		
9. Limestone: trilobite biomicrite; intraclastic biosparite bed at 820 feet. Scarce very fine quartz sand, ferroan dolomite, and linguloid brachiopods; scattered pelsparite. Medium grayish brown, mostly medium to thick beds; weathers light to medium gray. Brown dolomite stringers on some weathered surfaces.		63	765-828
	Saratogia Zone		
CC 820	*Leiocoryphe occipitalis* (1-1-0)		
CC 813	*Rasettia capax* (0-0-1)		
CC 809	*Stigmacephaloides verticalis* (3-0-0)		
CC 807	*Saratogia fria* (1-0-0)		
	Stigmacephaloides verticalis (2-0-0)		
CC 805	*Rasettia capax* (1-0-0)		
	Saratogia fria (1-0-0)		
CC 803	*Rasettia capax* (0-2-1)		
	Saratogia fria (1-0-1)		
CC 800	*Stigmacephaloides verticalis* (1-0-0)		
CC 798	*Rasettia capax* (0-0-1)		
CC 797	*Rasettia capax* (0-1-0)		
	Stigmacephaloides verticalis (11-0-0)		
CC 795	*Leiocoryphe occipitalis* (1-0-0)		
CC 794	*Rasettia capax* (2-1-1)		
	Stigmacephaloides verticalis (9-0-0)		

CC 791	*Rasettia capax* (0-0-1)
	Saratogia fria (1-0-0)
	Stigmacephaloides verticalis (2-0-0)
CC 790	*Stigmacephaloides verticalis* (1-0-0)
CC 789	*Rasettia capax* (1-0-0)
CC 784	*Stigmacephaloides verticalis* (2-0-0)
CC 782	*Stigmacephaloides verticalis* (4-0-0)
CC 777	*Rasettia capax* (1-1-0)
	Stigmacephaloides verticalis (5-0-0)
CC 772	*Stigmacephaloides verticalis* (2-0-0)
CC 768	*Rasettia capax* (0-2-1)
	Saratogia fria (0-0-1)
	Stigmacephaloides verticalis (2-0-0)

DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
8. Limestone: mostly trilobite biomicrite and pelsparite; scattered biosparite. Very fine quartz sand common but decreasing toward top of unit; intraclasts scarce. Medium to light grayish brown, mostly medium to thick beds that weather light to medium gray. Thin-bedded, predominantly brown-weathering pelsparite from 720 to 750 feet. Silicified *Billingsella* at 695, 720, 730, 733, and 751 feet. Brown dolomitic stringers common on weathered surfaces.	85	680-765

Saratogia Zone

CC 760	*Rasettia capax* (0-1-0)
CC 758	*Rasettia capax* (1-0-0)
CC 755	*Rasettia capax* (0-1-0)
	Saratogia fria (0-1-0)
CC 745	*Rasettia capax* (0-0-1)
CC 743	*Saratogia fria* (11-1-3)
	Stigmacephaloides verticalis (2-0-0)
CC 742	*Saratogia fria* (5-0-2)
	Stigmacephaloides verticalis (1-0-0)
CC 738	*Rasettia capax* (0-1-0)
	Saratogia fria (2-0-2)
CC 735	*Saratogia fria* (10-0-3)
CC 734	*Saratogia fria* (1-0-1)
	Stigmacephaloides verticalis (2-0-0)
CC 730	*Stigmacephaloides verticalis* (1-0-0)
CC 728	*Leiocoryphe occipitalis* (1-0-0)
	Rasettia capax (1-5-0)
	Saratogia fria (1-0-1)
	Stigmacephaloides verticalis (3-0-0)
CC 720	*Stigmacephaloides verticalis* (1-0-0)
CC 714	*Rasettia capax* (0-0-1)
	Stigmacephaloides verticalis (10-0-0)
CC 709	*Stigmacephaloides verticalis* (1-0-0)
CC 708	*Rasettia capax* (0-0-1)
	Stigmacephaloides verticalis (3-0-0)
CC 705	*Leiocoryphe occipitalis* (1-0-0)
	Rasettia capax (0-1-0)
CC 702	*Leiocoryphe occipitalis* (5-0-0)
	Rasettia capax (0-3-1)
CC 700	*Rasettia capax* (0-1-0)
CC 687	*Dartonaspis wichitaensis* (3-1-0)
	Stigmacephaloides curvabilis (2-0-0)
CC 683	*Dartonaspis wichitaensis* (0-1-0)
CC 681	*Dartonaspis wichitaensis* (1-1-0)

DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
7. Limestone: Pelsparite and sparse trilobite biomicrite; scattered beds of laminated (algal?) pelsparite, especially in lower 50 feet and upper 30 feet of unit. Very fine quartz sand common; intraclasts and sponge spicules scarce. Medium- to dark-grayish-brown, thin platy beds; weathers medium brown to brownish gray; knotty-surfaced beds. Silicified *Billingsella* at 657, 661, and 674 feet. Unusual soft-sediment deformation just west of line of section from 620 to 628 feet.	93	587-680

Saratogia Zone

CC 680	*Dartonaspis wichitaensis* (0-0-1)
CC 674	*Dartonaspis wichitaensis* (6-8-0)
CC 661	*Saratogia fria* (1-0-0)
	Stigmacephaloides curvabilis (1-0-0)
CC 660	*Pseudagnostus communis* (1-0-0)
CC 657.5	*Dartonaspis wichitaensis* (6-2-0)
	Ptychaspis sp. undet. (1-0-1)
	Stigmacephaloides curvabilis (1-0-0)
CC 648	*Dartonaspis wichitaensis* (37-2-0)
	Pseudagnostus communis (1-0-0)
	Ptychaspis sp. undet. (1-0-0)
CC 627	*Dartonaspis wichitaensis* (2-0-0)
	Pseudagnostus communis (1-0-0)
CC 621	*Dartonaspis wichitaensis* (6-1-0)
	Pseudagnostus communis (0-2-0)
	Saratogia fria (2-0-0)
	Stigmacephaloides curvabilis (2-0-0)
CC 613	*Dartonaspis wichitaensis* (12-2-0)
	Leiocoryphe occipitalis (2-0-0)
	Pseudagnostus communis (3-2-0)
	Ptychaspis sp. undet. (2-0-0)
	Saratogia fria (1-0-0)
	Stigmacephaloides curvabilis (4-0-0)
CC 612	*Dartonaspis wichitaensis* (12-3-2)
	Pseudagnostus communis (0-1-0)
	Wilbernia expansa (1-1-0)
CC 611	*Stigmacephaloides curvabilis* (6-1-0)

DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
6. Limestone: sparse trilobite biomicrite and biosparite; scattered beds of pelsparite or intrasparite. Common very fine quartz sand; scattered phosphatic brachiopods, glauconite feldspar, and dolomite. Light gray to light reddish purple, mostly medium to thick beds; weathers light to medium gray usually, but if very sandy, weathers to medium brown.	124	463-587

Saratogia Zone

CC 587	*Dartonaspis wichitaensis* (1-0-0)

Drumaspis Subzone

CC 563	*Drumaspis idahoensis* (1-0-0)
	Leiocoryphe occipitalis (4-0-0)
	Pseudagnostus communis (0-1-0)
	Saratogia fria (3-0-0)
	Stigmacephaloides curvabilis (6-1-0)

CC 560 *Drumaspis idahoensis* (2-0-0)
Stigmacephaloides curvabilis (1-0-0)
CC 555 *Stigmacephaloides curvabilis* (11-1-0)
CC 534 *Drumaspis idahoensis* (1-0-0)
CC 521 *Drumaspis idahoensis* (1-0-0)
Genus and species undet. no. 2 (1-0-0)
Ptychaspis sp. undet. (1-0-0)
CC 517 *Drumaspis idahoensis* (2-0-0)
Genus and species undet. no. 2 (2-0-0)
Pseudagnostus communis (0-1-0)
Ptychaspis sp. undet. (1-0-0)
CC 512 *Drumaspis idahoensis* (3-0-0)
Genus and species undet. no. 2 (4-0-0)
CC 507 *Drumaspis idahoensis* (4-0-0)
Drumaspis texana (1-0-0)
Ellipsocephaloides silvestris (1-0-0)
CC 503 *Saratogia fria* (1-0-0)
CC 501 *Saratogia modesta* (1-0-0)
CC 491 *Drumaspis idahoensis* (5-0-0)
Drumaspis texana (2-0-0)
Ellipsocephaloides silvestris (2-1-0)
Pseudagnostus communis (0-2-0)
Saratogia fria (1-0-0)
Saratogia modesta (3-0-0)
CC 484 *Drumaspis idahoensis* (4-0-0)
Pseudagnostus communis (0-2-0)
Wilbernia cf. *W. pero* (1-0-0)
CC 481 *Conaspis* cf. *C. tumida* (1-0-0)
Drumaspis texana (1-0-0)
Ellipsocephaloides silvestris (2-1-0)
Genus and species undet. no. 1 (1-0-0)
Geragnostus intermedius (1-1-0)
Pseudagnostus communis (0-1-0)
CC 477 *Drumaspis idahoensis* (1-0-0)
Ellipsocephaloides silvestris (3-0-0)
Geragnostus intermedius (5-3-0)
Pseudagnostus communis (7-5-0)
Saratogia fria (9-0-0)
Wilbernia expansa (3-0-0)
CC 475 *Conaspis* cf. *C. tumida* (1-0-0)
Drumaspis idahoensis (1-0-0)
Drumaspis texana (1-0-0)
Ellipsocephaloides silvestris (1-0-0)
Pseudagnostus communis (1-0-0)
Saratogia fria (2-0-0)
Saratogia modesta (1-0-0)
CC 470 *Saratogia modesta* (1-0-0)
CC 468 *Pseudagnostus communis* (3-0-0)

Honey Creek Limestone: 52 feet thick

DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
5. Limestone: glauconitic trilobite biosparite and biomicrite. Trilobites and acrotretid and linguloid brachiopods common to abundant; articulate brachiopods and pelmatozoan fragments scarce to common. Quartz and feldspar sand and silt-sized grains common; glauconite abundant near base, decreasing upward. Scattered ferroan dolomite throughout units. Light to medium gray, sometimes reddish purple, thin to medium beds; weathers medium gray.	52	411-463

Section offset to third small hill to southeast (about 850 feet) at top of Reagan Sandstone.

Drumaspis Subzone

CC 461 *Idahoia lirae* (1-0-0)
CC 457.5 *Conaspis* cf. *C. tumida* (1-0-0)
Drumaspis texana (2-0-0)
Idahoia lirae (1-0-0)
Pseudagnostus communis (16-9-0)
Saratogia americana (2-0-0)
Wilbernia diademata (2-0-0)

Idahoia lirae Subzone

CC 450 *Saratogia modesta* (1-0-0)
CC 447 *Ptychaspis bullasa* (1-0-0)
CC 435 *Saratogia americana* (3-0-0)
CC 433 *Idahoia lirae* (4-0-0)
Pseudagnostus communis (0-1-0)
CC 431 *Idahoia lirae* (1-0-0)
Pseudagnostus communis (0-1-0)
CC 429 *Idahoia lirae* (1-0-0)
Idahoia lirae var. A (14-0-0)
Pseudagnostus communis (1-2-0)
Wilbernia expansa (1-0-0)
CC 426 *Idahoia lirae* (1-0-0)
Wilbernia expansa (1-0-0)
CC 422 *Idahoia lirae* (12-0-0)
Pseudagnostus communis (10-3-0)
Wilbernia diademata (1-0-0)
Wilbernia expansa (3-0-0)

Taenicephalus Zone

CC 418 *Conaspis* cf. *C. tumida* (16-0-0)
Pseudagnostus communis (69-44-0)
Taenicephalus shumardi (29-2-0)
Wilbernia expansa (7-0-0)
CC 415 *Pseudagnostus communis* (2-3-0)
Taenicephalus shumardi (1-0-0)
CC 413 *Conaspis* cf. *C. tumida* (1-0-0)
Pseudagnostus communis (56-40-0)
Taenicephalus shumardi (16-4-0)

Reagan Sandstone: 411 feet thick

DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
4. Sandstone with minor limestone lenses and beds. Most abundant lithology is fine-grained hematitic, glauconitic arkose containing scattered squashed phosphatic brachiopods. Arkose is light brown to reddish brown, thin to thick bedded; weathers various shades of brown. Some beds contain numerous small, lens-shaped vugs that may be places where limestone has weathered out. Beds and lenses of gray, sandy, glauconitic trilobite biosparite occur at 235 and 258 feet and are common between 317 and 374 feet. Pelmatozoan fragments and phosphatic and calcite brachiopods are scarce to common. Inclined laminae or thin beds of arkose commonly cut across biosparite beds, which are brownish gray, thin to medium bedded, recessive, and weather medium gray.	191	220-411

	DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
	Taenicephalus Zone		
	Parabolinoides Subzone		
CC 374	*Parabolinoides contractus* (26-10-0)		
CC 365	*Parabolinoides contractus* (15-0-0)		
	Parabolinoides granulosus (1-0-0)		
CC 364	*Irvingella major* (0-1-0)		
	Parabolinoides contractus (30-1-0)		
	Elvinia Zone		
CC 362	*Irvingella major* (1-0-0)		
CC 355	(float) *Comanchia amplooculata* (13-3-0)		
	Irvingella major (3-0-0)		
CC 351	*Buttsia drabensis* (1-0-0)		
	Camaraspis convexa (20-1-0)		
	Cliffia lataegenae (7-4-0)		
	Dellea suada (36-0-0)		
	Dokimocephalus curtus (1-0-0)		
	Dokimocephalus sp. undet. (2-0-6)		
	Elvinia roemeri (5-0-0)		
	Homagnostus tumidosus (2-0-0)		
	Irvingella major (1-0-0)		
	Morosa? bothra (8-0-0)		
	Pterocephalia sanctisabae (5-8-0)		
CC 350	*Camaraspis convexa* (7-0-0)		
	Dellea suada (10-0-0)		
	Dokimocephalus sp. undet. (0-0-2)		
	Elvinia roemeri (1-0-0)		
	Morosa? bothra (1-0-0)		
	Pterocephalia sanctisabae (1-2-0)		
CC 348	*Camaraspis convexa* (4-1-0)		
	Cliffia lataegenae (2-1-0)		
	Dellea suada (4-0-0)		
	Elvinia roemeri (1-0-0)		
	Morosa? bothra (9-0-0)		
	Morosa simplexa (1-0-0)		
	Pterocephalia sanctisabae (2-1-0)		
CC 341	*Camaraspis convexa* (19-0-0)		
	Cliffia lataegenae (1-1-0)		
	Dellea suada (13-0-0)		
	Dokimocephalus curtus (2-0-0)		
	Doklimocephalus sp. undet. (0-0-2)		
	Elvinia roemeri (6-0-0)		
	Morosa? bothra (2-0-0)		
	Morosa simplexa (2-0-0)		
	Pseudagnostus communis (0-1-0)		
	Pseudosaratogia lata (20-0-2)		
	Pterocephalia sanctisabae (8-7-0)		
CC 337	*Camaraspis convexa* (9-0-0)		
	Cliffia lataegenae (2-0-0)		
	Elvinia roemeri (0-1-0)		
	Pseudosaratogia lata (9-0-1)		
	Pterocephalia sanctisabae (0-2-0)		
CC 332	*Camaraspis convexa* (6-0-0)		
	Cliffia lataegenae (4-0-0)		
	Dellea suada (17-0-0)		
	Dokimocephalus sp. undet. (0-0-2)		
	Elvinia roemeri (2-0-0)		
	Morosa simplexa (1-0-0)		
	Pseudagnostus communis (2-2-0)		
	Pseudosaratogia lata (5-0-0)		
	Pterocephalia sanctisabae (4-1-0)		
CC 329	*Camaraspis convexa* (25-2-0)		
	Cliffia lataegenae (2-2-0)		
	Dellea suada (14-0-0)		
	Dokimocephalus intermedius (2-0-0)		
	Elvinia roemeri (2-0-0)		
	Morosa? bothra (2-0-0)		
	Morosa simplexa (4-0-0)		
	Pseudagnostus communis (2-1-0)		
	Pseudosaratogia lata (7-0-1)		
	Pterocephalia sanctisabae (7-5-0)		
CC 328	*Camaraspis convexa* (8-0-0)		
	Dellea suada (3-0-0)		
CC 322	*Camaraspis convexa* (2-0-0)		
	Dellea suada (3-0-0)		
	Dokimocephalus sp. undet. (0-0-1)		
	Elvinia roemeri (3-0-0)		
	Pseudosaratogia lata (6-0-0)		
	Pterocephalia sanctisabae (1-2-0)		
CC 319	*Burnetiella ectypa* (3-0-0)		
	Camaraspis convexa (6-0-0)		
	Dellea suada (18-0-0)		
	Dokimocephalus sp. undet. (1-0-4)		
	Elvinia roemeri (38-12-0)		
	Pseudagnostus communis (2-0-0)		
	Pseudosaratogia lata (14-0-0)		
	Pterocephalia sanctisabae (10-4-0)		
	Unassigned pygidium L (0-1-0)		
CC 317	*Apachia trigonis* (9-0-0)		
	Camaraspis convexa (1-0-0)		
	Camaraspis parabola (7-0-0)		
	Cheilocephalus wichitaensis (1-4-0)		
	Cliffia lataegenae (19-20-0)		
	Deckera completa (1-0-0)		
	Dellea suada (16-0-0)		
	Drabia cf. *D. menusa* (4-0-0)		
	Elvinia roemeri (27-15-0)		
	Irvingella major (12-0-0)		
	Kindbladia wichitaensis (21-0-0)		
	Plataspella anatina (2-0-0)		
	Pseudagnostus communis (12-12-0)		
	Pseudosaratogia lata (8-0-0)		
	Pterocephalia sanctisabae (0-2-0)		
	Reaganaspis parva (28-0-0)		
	Xenocheilos minutum (4-0-0)		
CC 258	*Camaraspis convexa* (3-1-0)		
	Cliffia lataegenae (5-5-0)		
	Dellea suada (7-0-0)		
	Homagnostus tumidosus (1-0-0)		
	Irvingella major (4-1-0)		
	Kindbladia wichitaensis (13-1-0)		
	Plastaspella anatina (1-0-0)		
	Pseudagnostus communis (3-0-0)		
	Sulcocephalus cereus (1-0-0)		
	Sulcocephalus latus (3-0-0)		
CC 235	*Irvingella major* (5-2-0)		
	Kindbladia wichitaensis (6-0-1)		
CC 225	*Kindbladia wichitaensis* (1-0-0)		
	3. Covered	140	80-220
	2. Sandstone: fine- to coarse-grained, hematitic, glauconitic arkose. Squashed phosphatic brachiopods scarce; abundant hematite occurs as pellets and cement. Thicker beds highly cross-bedded, both large-scale planar cross-beds and small-scale, climbing-ripple(?) cross-beds. Light brown to dark red-	73	7-80

DESCRIPTION	THICKNESS IN FEET	FEET ABOVE BASE
dish brown, mostly medium (but some thin and thick) beds; weathers whitish red to various shades of reddish brown.		
1. Covered	7	0-7

Carlton Rhyolite Group: not measured or described

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PLATES

Plate 1

TRILOBITES OF THE *Elvinia* ZONE

Figure		*Page*
1-3	*Pseudosaratogia lata* Wilson. *1*, unexfoliated large cranidium, ×4 (OU 8199), from CC 341; *2*, mostly unexfoliated medium cranidium, ×7 (OU 8200), from CC 337; *3*, unexfoliated large librigena, ×3 (OU 8201), from CC 341.	40
4, 5	*Cheilocephalus wichitaensis* Resser. *4*, mostly exfoliated large cranidium, ×3 (OU 8202), from CC 317; *5*, slightly exfoliated medium pygidium, ×6 (OU 8203), from CC 317.	39
6	*Drabia* cf. *D. menusa* Wilson. Internal mold of medium cranidium, ×6 (OU 8204), from CC 317.	46
7	*Buttsia drabensis* Wilson. Internal mold of medium cranidium, ×7 (OU 8205), from CC 351.	39
8, 9	*Reaganaspis parva* Stitt, n. gen., n. sp. *8*, unexfoliated large cranidium, ×15 (OU 8206, holotype), from CC 317; *9*, unexfoliated medium cranidium, ×22 (OU 8207, paratype), from CC 317.	48
10	*Camaraspis parabola* Frederickson. Internal mold of medium cranidium, ×4 (OU 8208), from CC 317.	43

Plate 1

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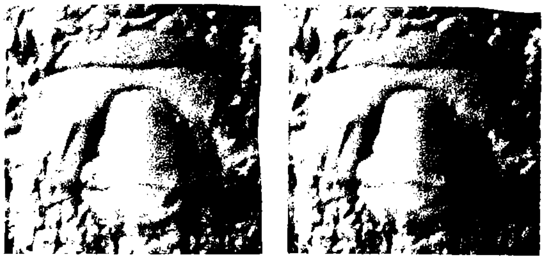

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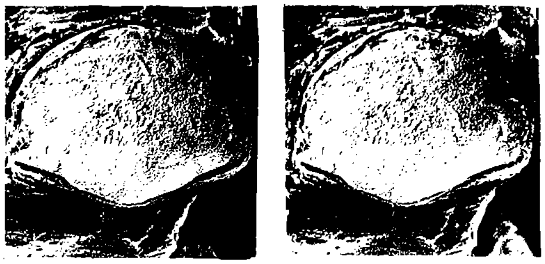

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Plate 2

TRILOBITES OF THE *Elvinia* AND *Saratogia* ZONES

Figure		*Page*
	***Elvinia* Zone**	
1	Unassigned pygidium L Wilson. Mostly unexfoliated large pygidium, ×5 (OU 8209), from CC 319.	50
	***Saratogia* Zone**	
2	*Saratogia americana* Lochman and Hu. Internal mold of medium cranidium, ×4 (OU 8210), from CC 435.	41
3	*Idahoia*? sp. undet. Mostly exfoliated large cranidium, ×2 (OU 8211), from CC 621.	41
4	*Ptychaspis bullasa* Lochman and Hu. Internal mold of small cranidium, ×10 (OU 8212), from CC 447.	43
5	*Ptychaspis* sp. undet. Internal mold of medium cranidium, ×2 (OU 8213), from CC 613.	44
6	*Stigmacephaloides curvabilis* Ellinwood. Internal mold of medium cranidium, ×4 (OU 8214), from CC 661.	41
7-9	*Stigmacephaloides verticalis* Stitt, n. sp. *7*, internal mold of medium cranidium, ×5 (OU 8215, paratype), from CC 714; *8*, internal mold of large cranidium with upturned border preserved, ×4 (OU 8216, paratype), from CC 794; *9*, unexfoliated medium librigena, ×9 (OU 8217, paratype), from CC 797.	41
10	*Wilbernia* cf. *W. pero* (Walcott). Mostly unexfoliated small cranidium, ×5 (OU 8218), from CC 484.	42

Plate 2


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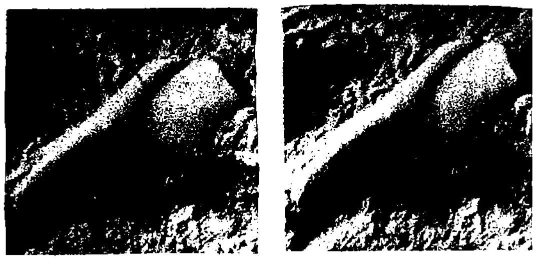
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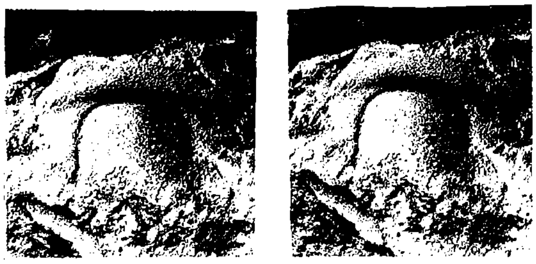
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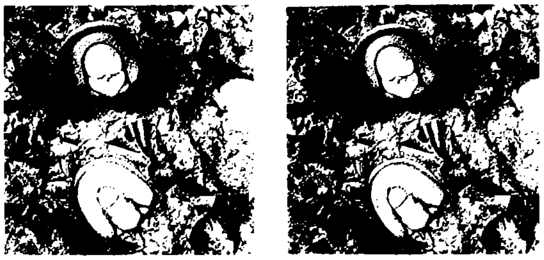
Plate 3

Trilobites of the *Saratogia* and *Saukia* Zones

Figure		*Page*
	Saratogia Zone	
1	*Geragnostus intermedius* Palmer. Unexfoliated medium cranidium and pygidium, ×6 (OU 8219), from CC 477.	36
2	*Briscoia* sp. undet. Internal mold of medium cranidium, ×2½ (OU 8220), from CC 742.	39
3	*Leiocoryphe occipitalis* Rasetti. Unexfoliated small cranidium, ×13 (OU 8221), from CC 563.	42
4	Genus and species undetermined no. 1. Unexfoliated small cranidium, ×14 (OU 8222), from CC 481.	48
5	Genus and species undetermined no. 2. Internal mold of large cranidium, ×4 (OU 8223), from CC 517.	48
	Saukia Zone	
6	*Euptychaspis frontalis* Longacre. Internal mold of small cranidium, ×10 (OU 8224), from CC 1148.	43
7	*Keithiella scrupulosa* Ellinwood. Internal mold of large cranidium, ×5 (OU 8225), from CC 935.	43
8, 9	*Triarthropsis* sp. undet. *8*, internal mold of medium cranidium, ×12 (OU 8226), from CC 901; *9*, internal mold of large cranidium showing anterior fixigenae on right side curving around to join frontal area, ×11 (OU 8227), from CC 901.	39
10	*Acheilops* cf. *A. dilatus* Ulrich. Internal mold of medium cranidium, ×11 (OU 8228), from CC 1204.	38

Plate 3



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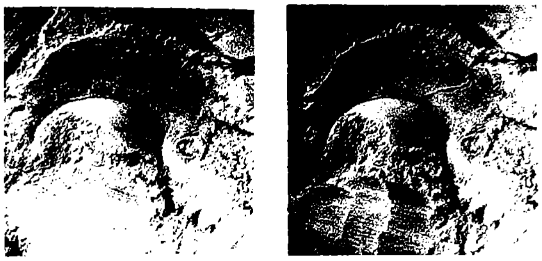

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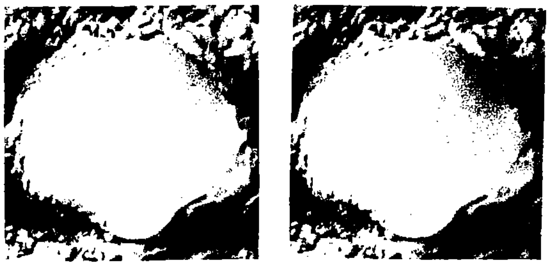

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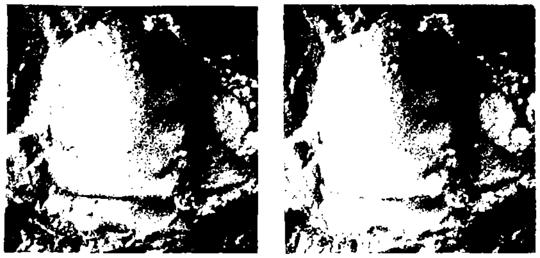

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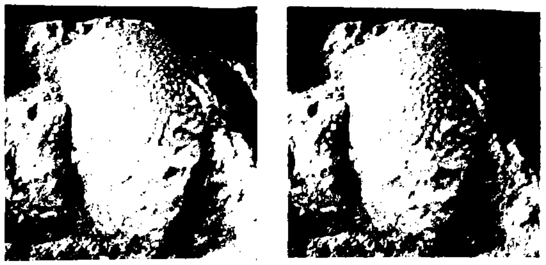

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Plate 4

TRILOBITES OF THE *Saukia*, *Missisquoia*, AND *Symphysurina* ZONES

Figure		*Page*
	Saukia Zone	
1	*Bowmania sagitta* Winston and Nicholls. Internal mold of large cranidium, ×4 (OU 8229), from CC 1414.	40
2	*Saukiella pepinensis* (Owen). Internal mold of medium cranidium, ×3 (OU 8230), from CC 1172.	44
3, 4	*Saukiella junia* (Walcott), var. B, Winston and Nicholls. *3*, mostly unexfoliated small cranidium, ×11 (OU 8231), from CC 1200; *4*, mostly exfoliated medium pygidium, ×2½ (OU 8232), from CC 1200.	44
5	*Saukiella junia* (Walcott), var. A, Winston and Nicholls. Internal mold of large cranidium, ×1 (OU 8233), from CC 1322.	44
	Missisquoia Zone	
6, 7	*Ptychopleurites brevifrons* (Kobayashi). *6*, internal mold of large cranidium showing distinctive punctation, ×7 (OU 8234), from CC 1499; *7*, mostly unexfoliated medium cranidium showing punctation on exoskeleton, ×8 (OU 8235), from JoR 1058.	46
8, 9	*Apoplanias rejectus* Lochman. *8*, internal mold of medium cranidium, ×5 (OU 8236), from CC 1526; *9*, unexfoliated medium librigena, ×3 (OU 8237), from CC 1534.	45
	Symphysurina Zone	
10	*Symphysurina brevispicata* Hintze. Internal mold of medium librigena showing characteristic genal spine, ×4 (OU 8238), from CC 1781.	37


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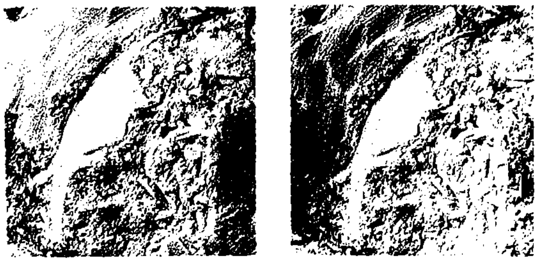
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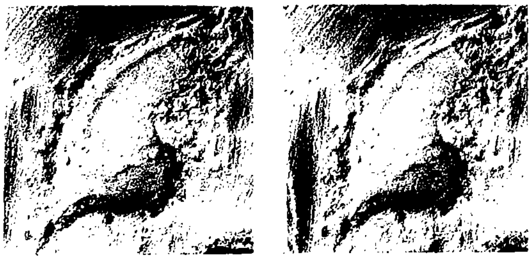
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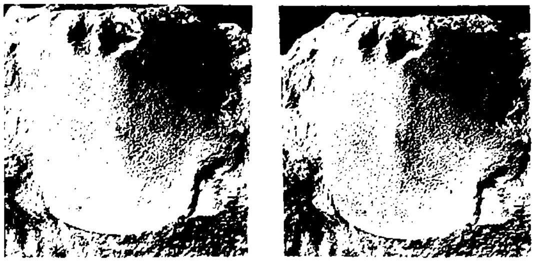
Plate 5

Trilobites of the *Symphysurina* Zone

Figure		*Page*
1-6	*Symphysurina bulbosa* Lochman. *1*, internal mold of medium cranidium showing characteristic punctation, ×4 (OU 8239), from CC 1873; *2*, mostly unexfoliated small cranidium showing faint punctation on exoskeleton, ×6 (OU 8240), from CC 1873; *3*, internal mold of librigena showing characteristic punctation and genal spine, ×4 (OU 8241), from CC 1874; *4*, internal mold of librigena showing (in anterior view) axial projection of nearly vertical border, ×3 (OU 8242), from CC 1899; *5*, mostly exfoliated medium pygidium, ×3 (OU 8243), from CC 1876; *6*, internal mold of large fragmentary pygidium showing slightly inflated area at end of axis, ×4 (OU 8244), from CC 1866.	37
7	*Symphysurina bubops* Winston and Nicholls. Mostly unexfoliated medium cranidium, ×4 (OU 8245), from CC 1749.	37
8	*Symphysurina* cf. *S. cleora* (Walcott). Internal mold of large librigena, ×4 (OU 8246), from CC 1578.	37
9	*Symphysurina* sp. A Ross. Mostly unexfoliated medium librigena, ×4 (OU 8247), from CC 1718.	38
10	*Ptychopleurites brevifrons* (Kobayashi). Mostly exfoliated medium cranidium, ×7 (GSC 8719, holotype), from Jones Ridge, Alaska-Yukon boundary.	46



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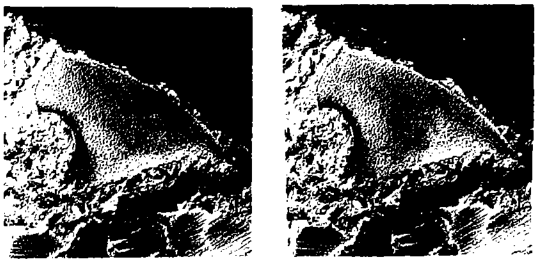

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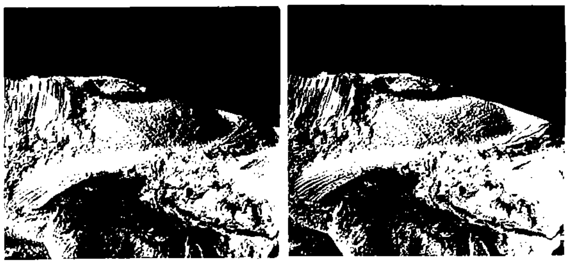

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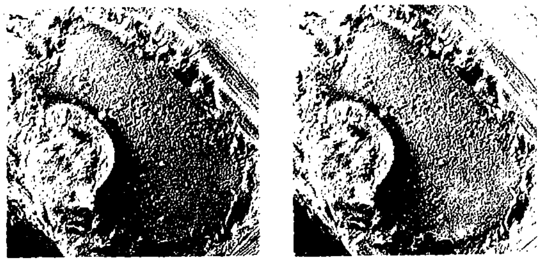

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Plate 6

TRILOBITES OF THE *Symphysurina* ZONE

Figure		*Page*
1, 2	*Highgatella cordilleri* (Lochman). *1*, partly exfoliated medium cranidium, ×5 (OU 8248), from CC 1605; *2*, mostly exfoliated, fragmented large cranidium showing characteristic inflated preglabellar field, ×5 (OU 8249), from CC 1733.	45
3	*Highgatella*? sp. undet. Internal mold of medium cranidium, ×5 (OU 8250), from CC 1539 (*Missisquoia* Zone only).	45
4, 5	*Clelandia texana* Winston and Nicholls. *4*, internal mold of medium cranidium, ×11 (OU 8251), from CC 1861; *5*, unexfoliated medium cranidium, ×11 (OU 8252), from CC 1859.	45
6	*Symphysurina* pygidium no. 1. Internal mold of medium pygidium, ×3 (OU 8253), from CC 1794.	38
7	Unassigned pygidium no. 2. Slightly exfoliated medium pygidium, ×4 (OU 8254), from CC 1916.	49
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Plate 6

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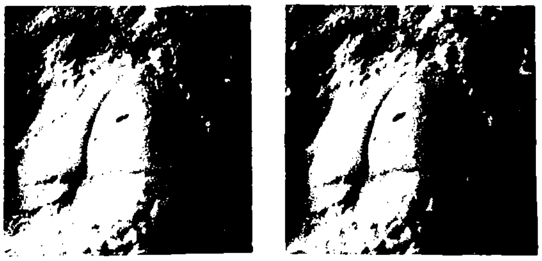

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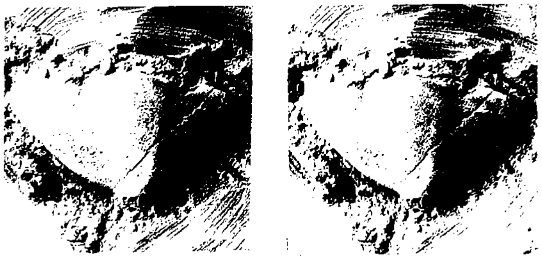

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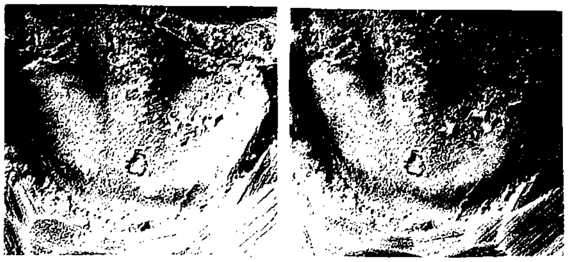

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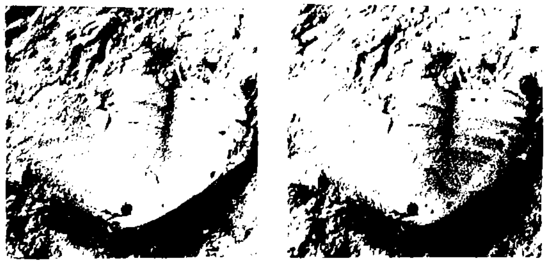

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