Early Paleozoic Biochronology of the Great Basin, Western United States

Michael E. Taylor, *Scientific Editor*

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EARLY PALEOZOIC BIOCHRONOLOGY OF THE GREAT BASIN, WESTERN UNITED STATES

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The Ibexian, Lowermost Series in the North American Ordovician

By Reuben J. Ross Jr.,[1] Lehi F. Hintze,[2] Raymond L. Ethington,[3] James F. Miller,[4]
Michael E. Taylor,[5] *and* John E. Repetski[6]

With a section on ECHINODERM BIOSTRATIGRAPHY *by* James Sprinkle[7] *and* Thomas E. Guensburg[8]

ABSTRACT

The Ibexian Series, first proposed by Hintze (1982), is the accepted chronostratigraphic unit for the Lower Ordovician of North American usage. The lower boundary stratotype of the Ibexian Series is defined at a point in rock 39.1 meters (128.3 feet) above the base of the Lava Dam Member of the Notch Peak Formation in the Lava Dam Five section of the Steamboat Pass–Lava Dam composite section of Hintze and others (1988). The lower boundary of the Ibexian Series coincides with the lowest observed occurrence of *Cordylodus ?andresi* Viira and Sergeeva in Viira and others, 1987, which also defines the base of the *Hirsutodontus hirsutus* Subzone of the *Cordylodus proavus* Zone. This horizon is about 0.1 meter (4 inches) below the lowest trilobite sample assigned to the *Eurekia apopsis* Zone. The top of the Ibexian Series is defined as the base of the Whiterockian Series, which, at its stratotype, is drawn at the base of the *Tripodus laevis* Conodont Zone and coincidentally with the base of the *Paralenorthis-Orthidiella* Brachiopod Zone (=Zone L of Ross, 1951). In the type area of the Ibexian, the base of the *Tripodus laevis* Zone is 6.3 meters below the top of the Wah Wah Limestone.

The Ibexian Series is characterized by more than 150 conodont species and more than 150 trilobite and articulate brachiopod species from a composite stratotype of 11 measured sections in the type area, located in the southern House Range and southern Confusion Range in the USGS Notch Peak and The Barn 15-minute quadrangles, Millard County, Utah. The composite stratotype section involves the Lava Dam Member of the Notch Peak Formation, House Limestone, Fillmore Formation, and part of the Wah Wah Limestone. The composite section aggregates 801 meters (2,628 feet) of abundantly fossiliferous limestone and subordinate calcareous siliciclastic rocks that formed in a miogeoclinal, shallow-water carbonate-platform environment.

The Ibexian Series is here divided, in ascending order, into the Skullrockian, Stairsian, Tulean, and Blackhillsian Stages and into 11 conodont zones and 14 shelly fossil zones that augment and refine the original 10 Ross (1951) and Hintze (1953) shelly fossil zones, which have been widely used in correlation within the North American Faunal Province for 40 years. In addition nautiloid cephalopods, gastropods, sponges, echinoderms, ostracodes, and graptolites occur in the composite section.

Recent work shows that the base of the Ibexian Series can be recognized in low paleolatitude sites in both carbonate shelf and slope facies in the Western United States, Appalachian Mountains, eastern and western Canada, Mexico, Greenland, Kazakhstan, Australia, southeastern Asia, People’s Republic of China, and elsewhere. In deeper water carbonate facies the Ibexian Series is underlain in many places by rocks bearing the geographically widespread trilobite *Lotagnostus hedini* (Troedsson).

INTRODUCTION

Here we reiterate Hintze’s (1982) proposal that the Ibexian Series is superior to the fractionated and confusing Canadian Series, which to many stratigraphers has been the lowest Ordovician Series for the United States. We designate

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a stratotype for the lower boundary of the Series and tabulate its characteristic shelly fossil and conodont zones (figs. 8, 10; pl. 1, charts *A*–*C*). The fossils make remarkable biostratigraphic control available for the series in the type area. Four new stages (in ascending order Skullrockian, Stairsian, Tulean, and Blackhillsian) were tentatively proposed (Ross and others, 1993) to supplant current stratigraphically inexact, geographically confusing terms, and to construct a biochronologic reference section to be used for correlation throughout North America and other applicable areas. Our primary purpose here is to focus attention on the superb lithostratigraphic column in the Ibex area, to demonstrate the biostratigraphic excellence of the consolidated Ibexian stratigraphic succession, and to formally describe the new stages. In the opinion of the senior author, the continuity of the composite-stratotype section and its biostratigraphic documentation are currently unsurpassed by any other Lower Ordovician section in the world.

At the outset we note that the Pogonip Group (Hintze, 1951, p. 11–12; Nolan, Merriam, and Williams, 1956, p. 23–25; Merriam, 1963) includes the Lower Ordovician and lower Middle Ordovician formations of the Basin Ranges. Therefore the group includes but is not limited to the Ibexian units of this report.

After 30 years of fostering cooperative work on sections in the Ibex area, Hintze (1979) assembled an important summary of the biostratigraphic occurrences of trilobites, brachiopods, graptolites, conodonts, nautiloid cephalopods, and other fossils, by leading paleontological authorities and by graduate students. Detailed conodont studies were published by Miller (1969, 1988), Ethington and Clark (1971, 1981), Ethington and others (1987), and Miller in Hintze and others (1988).

The composite stratotype of the Ibexian Series has been and continues to be used increasingly as the reference section for the Lower Ordovician in North America with few exceptions (Ross and others, 1992). Perhaps the exceptions can be explained by poor distribution of its first publication (Hintze in Ross and others, 1982) in the United States or perhaps by the inertia of regional tolerance of habitual, if less exact, terminology. The Ibexian Series has been used outside the United States with increasing frequency.

Acceptance of the Ibexian Series stems from the ease with which its correlatives are recognized in the cratonic, carbonate-platform, and upper slope facies throughout the continent. The applicability of the Ibexian biostratigraphic zonation has been enhanced by the studies of Taylor and Halley (1974) in New York State, Stitt (1977, 1983) and Derby and others (1991) in Oklahoma, and Westrop (1986) and Loch and others (1993) in Alberta, Canada. Ji and Barnes (1996) have made a valuable contribution to Ibexian conodont biostratigraphy in Jasper National Park, Canada; their interpretation of the position of the Cambrian-Ordovician boundary differs slightly from ours.

Although no volcanic ash beds satisfactory for isotopic dating of the series have been found in North America to early 1997, based on correlation against controlled isotopic dating elsewhere, we estimate that the duration of the Ibexian Epoch probably exceeded 20 million years.

Field measurements were taken in feet and in many critical places the footages were painted on the rock. For purposes of publication feet have been converted to meters. So that geologists can identify stratigraphic levels, both meters and feet are given in this report to help them coordinate text with painted footages on the outcrops of specific units and horizons in the field.

IBEXIAN SERIES TYPE AREA AND SECTIONS

The Ibexian Series is superbly exposed in the southern House and Confusion Ranges of west-central Utah (figs. 1–7). Outcrops are readily accessible both north and south of combined U.S. Highway 6 and 50 in the southern Notch Peak 15-minute quadrangle (Hintze, 1974b) and from there southward for 19 km (12 mi) in the Black Hills on the east side of Tule Valley in The Barn quadrangle (Hintze, 1974a). The upper contact with beds assigned to the younger Whiterock Series is exposed 8–9.7 km (5–6 mi) to the west of Tule Valley at the south end of Blind Valley. The geologic map of The Barn quadrangle was partly modified by Hintze and others (1988, figs. 8, 9) to show formation and member boundaries in improved detail. New 1:24,000-scale topographic quadrangle maps became available in 1991 and are utilized in explanations of figures 1–7.

Following recommendations of the North American Stratigraphic Code (NACSN, 1983) and guidelines of the International Commission on Stratigraphy of the International Union of Geological Sciences (Cowie and others, 1986), the lower boundary stratotype of the Ibexian Series is defined as a point in rock in a measured section. The top of the Ibexian Series is defined as the base of the overlying Whiterockian Series.

Descriptions of the physical and many of the paleontological attributes of the Ibexian Series presented here graphically (pl. 1, chart *A* and part of chart *C*) are updated from data previously published by Hintze (1951, 1953, 1973, 1979) and Hintze and others (1988). Hintze and others (1972) called attention to this same series of sections at the 23rd International Geological Congress in Prague in 1968. Figure 1 indicates the locations of maps (figs. 2–7) showing measured traverses along which features of lithologic units are most easily observed and from which fossils were collected.

The type sections of the formations constituting the composite stratotype of the Ibexian Series lie in an area whose detailed geology was first mapped by Hintze (1974a, 1974b). The few fault displacements of Ibexian strata in the type area are small and easily taken into account in measuring and compiling a composite-stratotype section. Dips are low. Exposures are excellent and key beds can be traced over distances measured in kilometers. Fossils are abundant throughout the section.

Although the Ibexian Series was formally proposed by Hintze in Ross and others (1982), precise designation of a base was deferred pending recommendation of a Cambrian-Ordovician boundary level by the Cambrian-Ordovician Boundary Working Group of the International Commission on Stratigraphy, International Union of Geological Sciences (for example, Henningsmoen, 1973; Bassett and Dean, 1982; Norford, 1988; Chen, 1986). An expected international agreement failed to materialize in 1982. In 1985, Rolf Ludvigsen and S.R. Westrop, tired of waiting for a decision, designated the biostratigraphic level of the base of the Ibexian Series at the base of the *Eurekia apopsis* Zone in the published Lava Dam Five section of Miller and others (1982, text-fig. 8; also see Hintze and others, 1988, p. 23–24, pl. 1). The formal definition of the Ibexian Series as proposed here coincides with the observed base of the *Cordylodus proavus* Zone which for all practical purposes coincides with the base of the *Eurekia apopsis* Zone in the typical reference section (fig. 9). In the definition of the Ibexian lower-boundary stratotype, we place slight emphasis on conodonts rather than trilobites because conodonts are more easily extracted from the rock at closely spaced intervals, and many conodont taxa are geographically widespread.

The base of the Ibexian Series coincides with abrupt faunal change, sea-level change, and geochemical anomalies that are recognized over a broad geographic area (for example, Erdtmann and Miller, 1981; Miller, 1984, 1992; Miller and others, 1989; Wright and others, 1987; Nicoll and Shergold, 1991; Ripperdan and others, 1992; Shergold and Nicoll, 1992; and Ripperdan and others, 1993). The boundary is thought to coincide with an isochronous event that was global in scale (Miller and others, 1993).

ACKNOWLEDGMENTS

Dr. Peter Guth, Oceanography Department, U.S. Naval Academy, Annapolis, Md., provided us with a version of his STRATCOL computer program, specially modified to produce the biostratigraphic range charts shown on plate 1. Over a period of 4 years he has spent many hours working cheerfully with Ross to tailor STRATCOL for changes to computer programs and to a variety of printers. In fact it was the ease and accuracy of detail achieved by using STRATCOL that led to realization that the assembled Ibexian composite stratotype was unique in several ways. We thank James Reed of RockWare Earth Science Software, Wheat Ridge, Colo., and Cynthia Scheiner, Department of Geology, Colorado School of Mines, Golden, Colo., for advice on computer applications.

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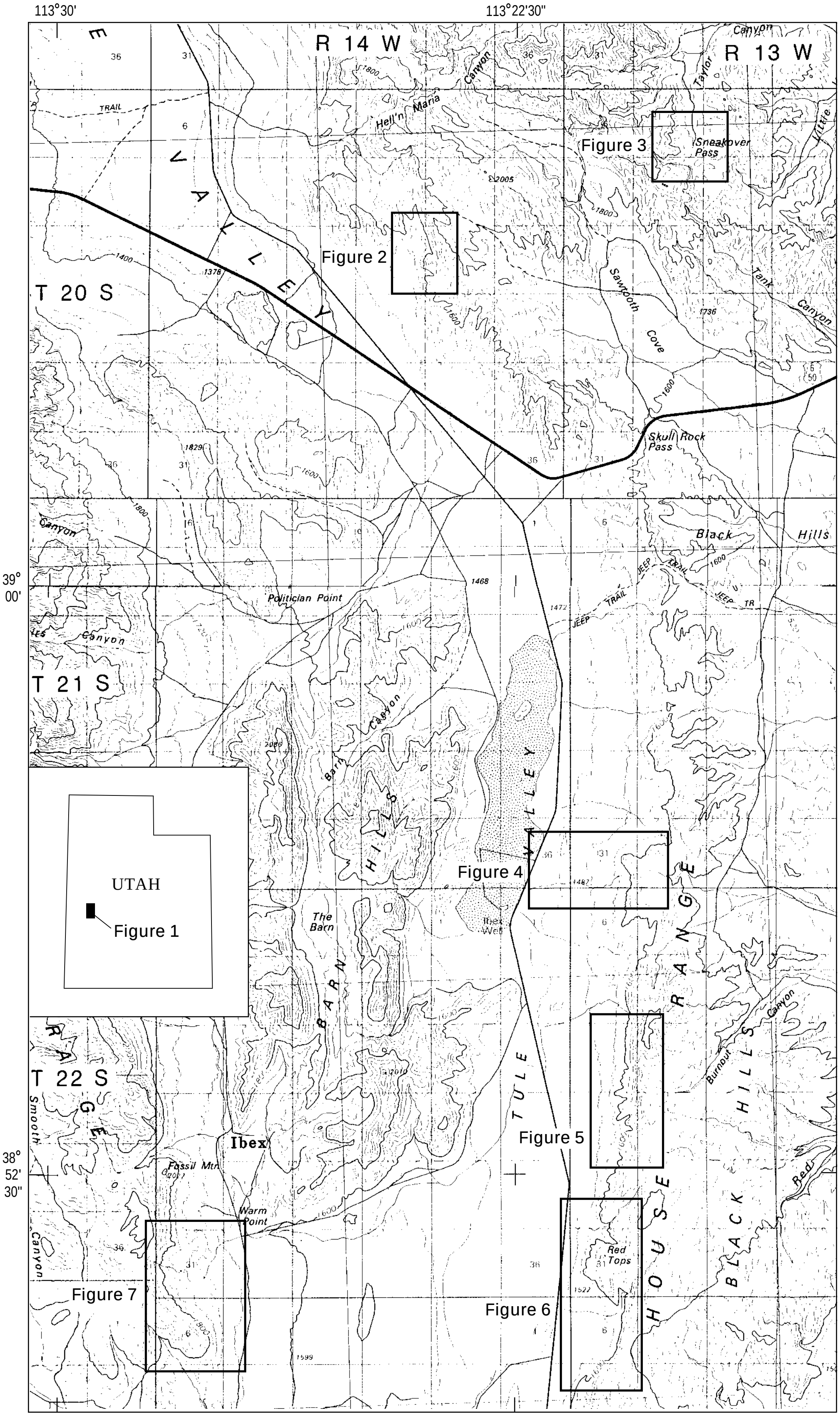
DEFINITION OF THE IBEXIAN SERIES

The lower-boundary stratotype of the Ibexian Series is here formally defined as a point in rock 39.1 m (128.3 ft) above the base of the Lava Dam Member of the Notch Peak Formation in the Lava Dam Five segment of the Steamboat Pass–Lava Dam section of Hintze and others (1988, p. 23–24, fig. 9; this report, figs. 8, 10). This measurement takes into account a 0.9 m (3 ft) offset by a minor normal fault in the lower part of the Lava Dam Member. The boundary stratotype point coincides with the lowest observed occurrence of *Cordylodus ?andresi* Viira and Sergeeva, in Viira and others, 1987, which locally defines the base of the *Hirsutodontus hirsutus* Subzone of the *Cordylodus proavus* Zone (fig. 8). This boundary stratotype point is approximately 0.1 m (4 in.) below the lowest observed occurrence of trilobites assigned to the *Eurekia apopsis* Zone (fig. 8). The highest observed occurrence of trilobites diagnostic of the underlying *Saukiella serotina* Subzone of the *Saukia* Zone is about 10 cm (4 in.) below the base of the *Cordylodus proavus* Zone. This near coincidence of boundaries of conodont and trilobite zones also occurs in Texas and Oklahoma (Miller and others, 1982).

The top of the Ibexian Series is recognized as the base of the Whiterockian Series, which was defined in the Monitor Range of central Nevada by Ross and Ethington (1991) as the base of the *Tripodus laevis* conodont Zone and the coincident base of the *Paralenorthis-Orthidiella* brachiopod Zone (=Zone L of Ross, 1951) (fig. 10). That level is 11 m (36 ft) below the top of the Wah Wah Limestone (see p. 11, 26–27).

Herein, we follow recommendations outlined in the North American Stratigraphic Code (NACSN, 1983) and the International Commission on Stratigraphy (Cowie and


113°30'
113°22'30"
R 14 W
R 13 W
T 20 S
T 21 S
T 22 S
39° 00'
38° 52' 30"
TRAIL
Hell'n Maria Canyon
Taylor Canyon
Sneakover Pass
Little
Figure 3
Figure 2
V A L L E Y
Sawtooth Cove
Tank Canyon
Skull Rock Pass
Black Hills
JEEP TRAIL
JEEP TR
Canyon
Politician Point
Canyon
Barn Canyon
B A R N H I L L S
The Barn
Ibex Well
T U L E V A L L E Y
Figure 4
H O U S E R A N G E
Burnout Canyon
B L A C K H I L L S
Red
Figure 5
Red Tops
Figure 6
Ibex
Fossil Mtn
Warm Point
Figure 7
Smooth Canyon
R A N G E
UTAH
Figure 1
2005
1800
1600
1400
1378
1736
1829
1468
1472
1487
2086
2010
1527
1599
36
31
1
6

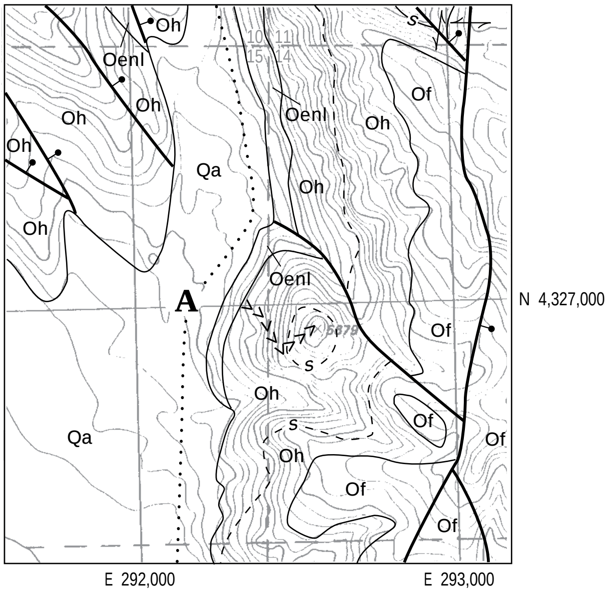


Figure 2. Geologic map showing location of the A Section of Hintze (1951, 1973). Oenl, Lava Dam Member of the Notch Peak Formation; Oh, House Limestone, the middle sandy zone of which is shown by a dashed line labeled s; Of, Fillmore Formation; Qa, surficial deposits. Heavy line, fault; bar and ball on downthrown side. Tielines indicate equivalent beds across faults. Line of section indicated by inverted “V’s.” Base from U.S. Geological Survey 1:24,000 Hell’n Moriah Canyon provisional quadrangle (1991). Geology from Hintze (1974b).

others, 1986) for definition of biostratigraphic and chronostratigraphic units. In addition, a distinction is made between definition of units by selection and description of a lower-boundary stratotype point in a measured section, and characterization which deals with the faunal content of units in the type area and the principal faunal data upon which correlations are interpreted (Murphy, 1977). Only the base of a unit is defined; tops are determined by the definition of the next overlying unit.

In order to help relocate the lower-boundary stratotype point of the Ibexian Series, J.F. Miller in the summer of 1992 drove a steel bolt marked with a brass plate (fig. 9*A*, *B*), into the upper part of the Lava Dam Member of the Notch Peak Formation at the Lava Dam Five section (fig. 6). The bolt is 39.1 m (128.3 ft) above the contact between the Red Tops Member and overlying Lava Dam Member of the Notch Peak Formation. The marker is approximately 59 m (194 ft) stratigraphically above the alluvial fill of the valley floor; the lower 20.1 m (66 ft) is the thickness of the exposed part of the Red Tops Member, and the upper 39 m (128.3 ft) is the thickness of part of the Lava Dam Member up to the boundary.

Definitions and faunal characterizations of the new Skullrockian, Stairsian, Tulean, and Blackhillsian Stages are given under appropriate headings herein.

We summarize, in ascending order, the lithostratigraphy, biostratigraphy, and chronostratigraphy of the Ibexian Series and adjacent rocks in the type area, which is located in the southern House Range–Ibex area of western Utah.

LITHOSTRATIGRAPHY

The stratotype section of the Ibexian Series is a composite section consisting of part of the Lava Dam Member of the Notch Peak Formation, all of the House Limestone and Fillmore Formation, and part of the Wah Wah Limestone. The House, Fillmore, and Wah Wah formations, which are the lower part of the Pogonip Group, were initially defined in this area by Hintze (1951) and redescribed by Hintze (1973). The locations of measured stratigraphic sections that include typical examples of these lithostratigraphic units are shown in figures 1–7, and geographic coordinates are tabulated in table 1.

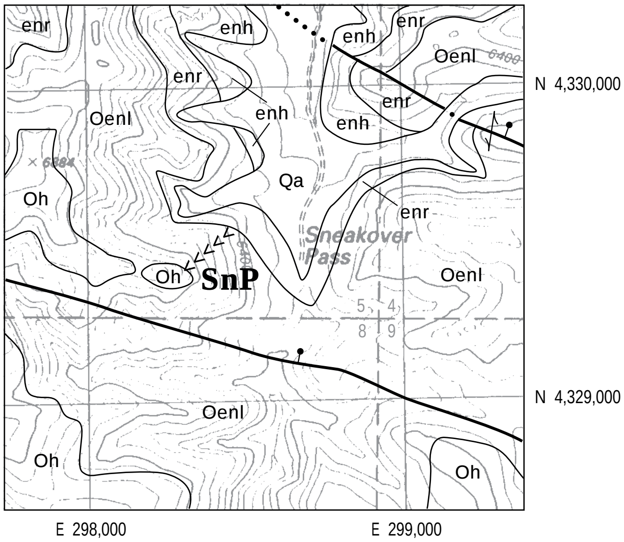


Figure 3. Geologic map showing location of the Sneakover Pass (SnP) measured section of Hintze and others (1988). enh, Hellnmaria Member of the Notch Peak Formation; enr, Red Tops Member of the Notch Peak Formation; Oenl, Lava Dam Member of the Notch Peak Formation; Oh, House Limestone; Qa, surficial deposits. Heavy line, fault; dotted where concealed; bar and ball on downthrown side. Tieline indicates equivalent beds across fault. Line of section indicated by inverted “V’s.” Base from U.S. Geological Survey 1:24,000 Skull Rock Pass provisional quadrangle (1978). Geology from Hintze (1974b).

Figure 1 (facing page). Index map of Ibex area, western Utah, showing locations of detailed maps in figures 2–7. Base from U.S. Geological Survey 100,000 Tule Valley (1981) and Wah Wah Mountains North (1980). The small squares on the map base are about 1 mi^2 in area.

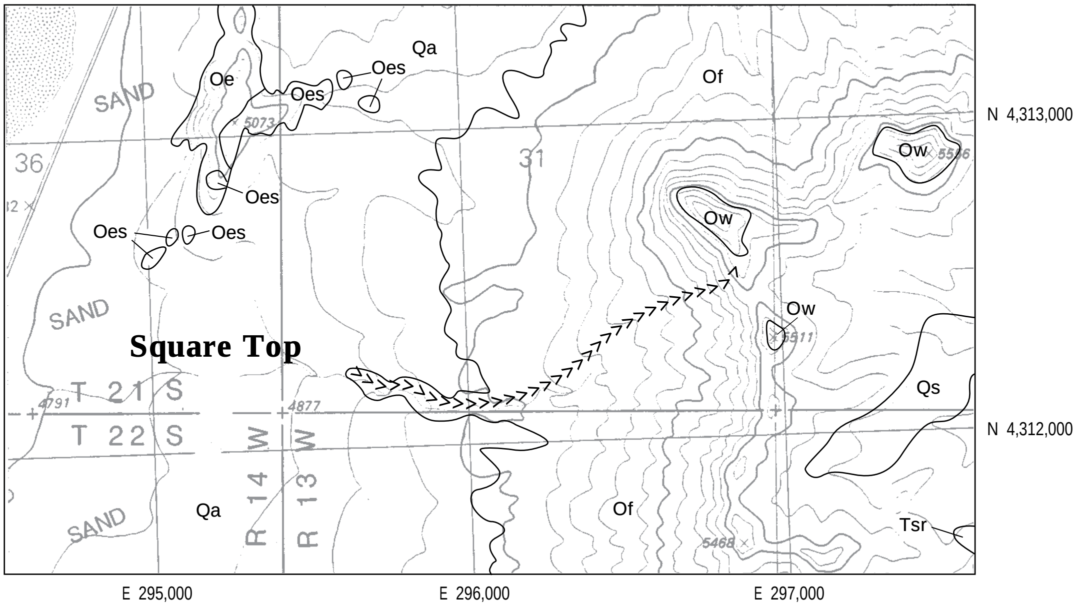


Figure 4. Geologic map showing location of the Square Top measured section of Hintze (1973). Of, Fillmore Formation; Ow, Wah Wah Limestone; Oe, Eureka Quartzite; Oes, Ely Springs Dolomite; Qa, surficial deposits; Qs, sand. Line of section indicated by inverted "V's." Base from U.S. Geological Survey 1:24,000 Burnout Canyon provisional quadrangle (1991). Geology from Hintze (1974a).

CONSTRUCTION OF THE COMPOSITE STRATOTYPE

The composite stratotype is based on lithostratigraphic units exposed in eight of the sections measured by Hintze (1951, 1953, and 1973) and by Hintze and others (1988) (figs. 2, 5, 6, and 7 herein). In order to establish a firm Cambrian foundation and to facilitate correlation with a section in the Southern Egan Range, being studied by W.C. Sweet, the Red Tops Member of the Notch Peak Formation at the Steamboat Pass–Lava Dam section is designated as the basal unit (fig. 6). It is 40 m (131 ft) thick. The Lava Dam Member (77.4 m (254 ft) thick) is the next higher unit and includes the base of the Ibexian Series 39.1 m (128.3 ft) above the base of the member, or 79 m (259.3 ft) above the base of the composite section (pl. 1). The lithostratigraphic description used to construct this lowest part of the composite stratotype is found on pages 23–25 of USGS Professional Paper 1393 (Hintze and others, 1988), including the exposed beds of the House Limestone through Unit 41. This inclusion provided a natural continuum for ranges of trilobites through the lower 26.2 m (86 ft) of the House strata.

The thickness of the House Limestone at Section A, its type section, was corrected from 475 ft to 515 ft by Hintze (1973, p. 8, table 1). However, J.F. Miller found during the 1994 field season that the thickness should be 558 ft (170 m), and we have adjusted the total thickness of the House Limestone accordingly. The House Limestone at the Lava Dam section is integrated with Section A by using only the upper 472 ft (143.8 m) (558 minus 86 ft) for the composite. Because of the change from the original 475 ft to 558 ft, the spacing of the trilobite collections reported by Hintze (1951, p. 30–33; 1953, p. 24–25) was revised proportionally. The spacing of conodonts is that reported by Ethington and Clark for Section A (1981, table 1).

The top of the House Limestone at the Lava Dam North section is marked by a resistant thoroughly burrowed limestone bed, 3 m (10 ft) thick, that is traced northward to the B Section (Hintze, 1951, p. 33–37; 1953, p. 25–26), as verified by Ethington and Ross in June 1994. This permits integration of the ranges of trilobites in the top 104.6 m (343 ft) of the B Section with those in the A Section.

The Fillmore Formation was separated into six members by Hintze (1973, p. 9–11, table 2) (numbered 1 to 6 on p. 8–11 herein). In assembling the composite we have used the two lowest members from the C Section, respectively 485 ft and 320 ft thick. The third and fourth members, 180 ft and 324 ft thick, were taken from the Mesa Section. However, in order to assemble the greatest available thickness, the fourth member in the H Section is integrated by aligning "Marker ledge 1" in unit 6 (Hintze, 1973, p. 27) with the same "Marker ledge 1" in unit 2 in the Mesa Section (Hintze, 1973, p. 20). The resulting aggregate thickness of the Fillmore Formation at the top of the fourth member is 1,322 ft. By aligning the "Marker ledge 1" in unit 4 in the G Section (Hintze, 1973, p. 24), the ranges of trilobites in the three sections have been integrated. Both the fifth and sixth members of the Fillmore are taken from

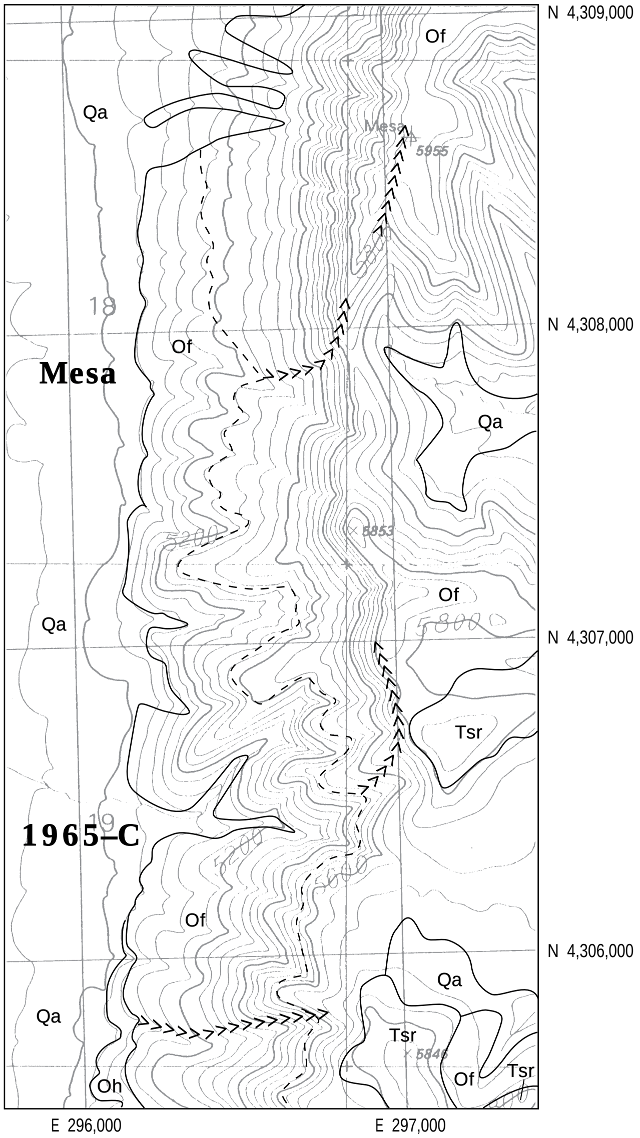


Figure 5. Geologic map showing location of the Mesa and 1965-C measured sections of Hintze (1973). In the 1965-C Section, the lower boundary stratotype of the Tulean Stage is marked by the lowest observed occurrence of *Menoparia genalunata* located at 11.6 m (38 ft) above the base of unit 2 of the informal slope-forming shaly siltstone member of the Fillmore Formation. Oh, House Limestone; Of, Fillmore Formation (dashed line indicates a key bed); Tsr, Skull Rock Pass Conglomerate (Hintze and Davis, 1992); Qa, surficial deposits. Lines of sections indicated by inverted "V's." Base from U.S. Geological Survey 1:24,000 Burnout Canyon provisional quadrangle (1991). Geology from Hintze (1974a).

the H Section. The total thickness of the Fillmore aggregates 558 m (1,803 ft). The thickness of the composite section at the top of the Fillmore is 836 m (2,744 ft).

The Wah Wah Limestone, Juab Limestone, and Kanosh Shale and their trilobite and brachiopod faunas are taken from the J Section (Hintze, 1973, p. 28–30; 1951, p. 57–63; 1953, p. 36–40).

Conodonts of the Fillmore Formation are taken from the same pertinent sections as published by Ethington and Clark (1981), but collections made by Ethington in 1994 supplement earlier collections in the J Section.

NOTCH PEAK FORMATION

The Notch Peak Formation of Walcott (1908a, b) was redescribed and divided in ascending order into the Hellnmaria, Red Tops, and Lava Dam Members by Hintze and others (1988). The lithostratigraphy and biostratigraphy of the Notch Peak Formation in the Steamboat Pass–Lava Dam area were described by Hintze and others (1988, p. 23-26). Emendations to biostratigraphic ranges of conodonts and trilobites were given by Miller and others (1982) and Miller and Taylor (1989).

HELLNMARIA AND RED TOPS MEMBERS

The Hellnmaria and Red Tops Members are mentioned here only for completeness, because neither member is involved in the Ibexian Series. The Red Tops is the lowest unit exposed in the lower part of the Lava Dam Five segment of the Steamboat Pass–Lava Dam section (Hintze and others, 1988, p. 23–26).

The Lava Dam Five segment of the Steamboat Pass–Lava Dam section begins in a minor gully near the south end of the "Lava Dam," a channel eroded into the Notch Peak Formation and filled with Oligocene volcanic rocks, and Tule Valley fill (Hintze, 1988, figs. 8, 9; this report, figs. 1, 6). The base of the section is within the Red Tops Member, 20.1 m (66 ft) below the contact between the Red Tops and Lava Dam Members of the Notch Peak Formation. The stratigraphically lowest point in the measured section is marked by "0" with yellow paint. The exposed part of the Red Tops Member consists of current-rippled oolitic, skeletal, and intraclastic lime grainstone and lime packstone that contains trilobites representative of the *Saukiella junia* Subzone of the *Saukia* Zone (Taylor, 1971; Taylor in Hintze and others, 1988, pl. 1). In constructing the composite stratigraphic section shown on plate 1 the full thickness of the Red Tops Member, 39.9 m (=131 ft) has been used (Hintze and others, 1988, p. 25).

LAVA DAM MEMBER

The type locality of the Lava Dam Member is at Sneakover Pass (fig. 3) in the central House Range (Hintze and others, 1988, p. 21, fig. 5, table 1) where it is 110.9 m (364 ft) thick. As a result of facies changes, the Lava Dam Member is 76.0 m (249.5 ft) thick in the Steamboat Pass–Lava Dam composite section (Hintze and others, 1988, p. 25).

Table 1. Universal Transverse Mercator 1,000 m grid coordinates, Zone 12, for bottoms and tops of constituent segments of the Ibexian Series composite stratotype section.

[Map locations are shown in figures 1–7. Segments are listed in the order they should be visited to demonstrate the continuity of the section]

SEGMENT	BOTTOM	TOP
Lava Dam Five	E 295,950 m; N 4,300,980 m	E 295,910 m; N 4,300,770 m
Lava Dam North	E 296,230 m; N 4,302,000 m	E 296,560 m; N 4,302,120 m
A (1951)	E 292,320 m; N 4,326,980 m	E 292,570 m; N 4,326,910 m
B (1951)	E 296,060 m; N 4,304,150 m	E 296,330 m; N 4,304,400 m
Sneakover Pass	E 298,440 m; N 4,329,580 m	E 298,250 m; N 4,329,450 m
Square Top	E 295,600 m; N 4,312,230 m	E 295,870 m; N 4,312,540 m
Mesa (lower)	E 296,600 m; N 4,307,850 m	E 296,860 m; N 4,308,100 m
Mesa (upper)	E 297,100 m; N 4,308,320 m	E 297,040 m; N 4,308,600 m
1965-C (lower)	E 296,160 m; N 4,305,800 m	E 296,760 m; N 4,305,800 m
1965-C (upper)	E 296,880 m; N 4,306,500 m	E 296,950 m; N 4,307,000 m
G	E 287,400 m; N 4,300,720 m	E 287,680 m; N 4,301,080 m
H (lower)	E 287,200 m; N 4,301,800 m	E 286,900 m; N 4,301,830 m
H (middle)	E 286,960 m; N 4,302,220 m	E 286,600 m; N 4,302,130 m
H (upper)	E 286,590 m; N 4,302,130 m	E 286,400 m; N 4,302,150 m
J	E 286,640 m; N 4,303,670 m	E 285,700 m; N 4,304,060 m

The Lava Dam Member consists of skeletal, oolitic, and intraclastic lime grainstone and of cherty lime mud-supported limestone. Massive stromatolitic limestone forms the upper half of the Lava Dam Member in sections farther north, but stromatolites are restricted to a thin interval in the middle part of the member at the Lava Dam. In most of its exposures the member forms conspicuous cliffs and ledges below the low ledges and rounded slopes of the conformably overlying House Limestone.

HOUSE LIMESTONE

The type locality of the House Limestone is the A Section of Hintze (1973, p. 8–9; 1951, p. 30–33), where the formation was considered to be 156.9 m (515 ft) thick. Subsequent inspection in 1993 led J.F. Miller to conclude that a unit 13.1 m (43 ft) thick had been left out of this measurement. The thickness of the House Limestone used in the composite section is therefore 170.1 m (558 ft) on plate 1. Supplementary sections are the Lava Dam North (LDN) section of Hintze (1973, p. 15–16) and Lava Dam Five (LD5) section. Figures 2 and 6 show locations of sections.

Only the lower 27.6 m (90.5 ft) of the House Limestone is present at the Lava Dam Five section. The composite section is offset and continues on the north side of the Lava Dam where outcrops are continuous from the upper part of the Lava Dam Member of the Notch Peak Formation through the House Limestone and into the Fillmore Formation.

The House Limestone consists of thinly to thickly bedded, dark-gray limestone containing abundant brown to black chert, grading from irregular masses to well-bedded continuous layers. The base is marked by arenaceous limestone in the Lava Dam Five section. Detailed descriptions of the Lava Dam Five section and other sections of the Notch Peak Formation and the lower part of the House Limestone are given by Hintze and others (1988), and by Hintze (1951, 1973).

FILLMORE FORMATION

Although Hintze (1951, p. 14) designated his sections D, G, and H as the composite type section of the Fillmore Limestone, his subsequent (1973, p. 16–19) redescription of the Fillmore Formation and its five informal lithostratigraphic members has effectively supplanted that definition. These members aggregate 549.5 m (1,803 ft) in thickness. The informal members and their best representative sections are discussed here in ascending order. Because of a change in his original C Section, it is essential that reference be made to the modifications in location of the measured section that is designated 1965-C Section by Hintze (1973, p. 16; and fig. 5 herein).

BASAL LEDGE-FORMING LIMESTONE MEMBER (1)

The typical reference section of the informal ledge-forming limestone member (1) is in the 1965-C Section of Hintze (1973, p. 18–19) where the informal member is 147.8 m (485 ft) thick. The lowermost 22.5 m (71.5 ft) form the ledgy part of the member, which rests directly on the uppermost massive ledge of the House Limestone at this locality. A supplementary section is in the G Section of Hintze (1973, p. 25). See figures 5 and 7 for locations.

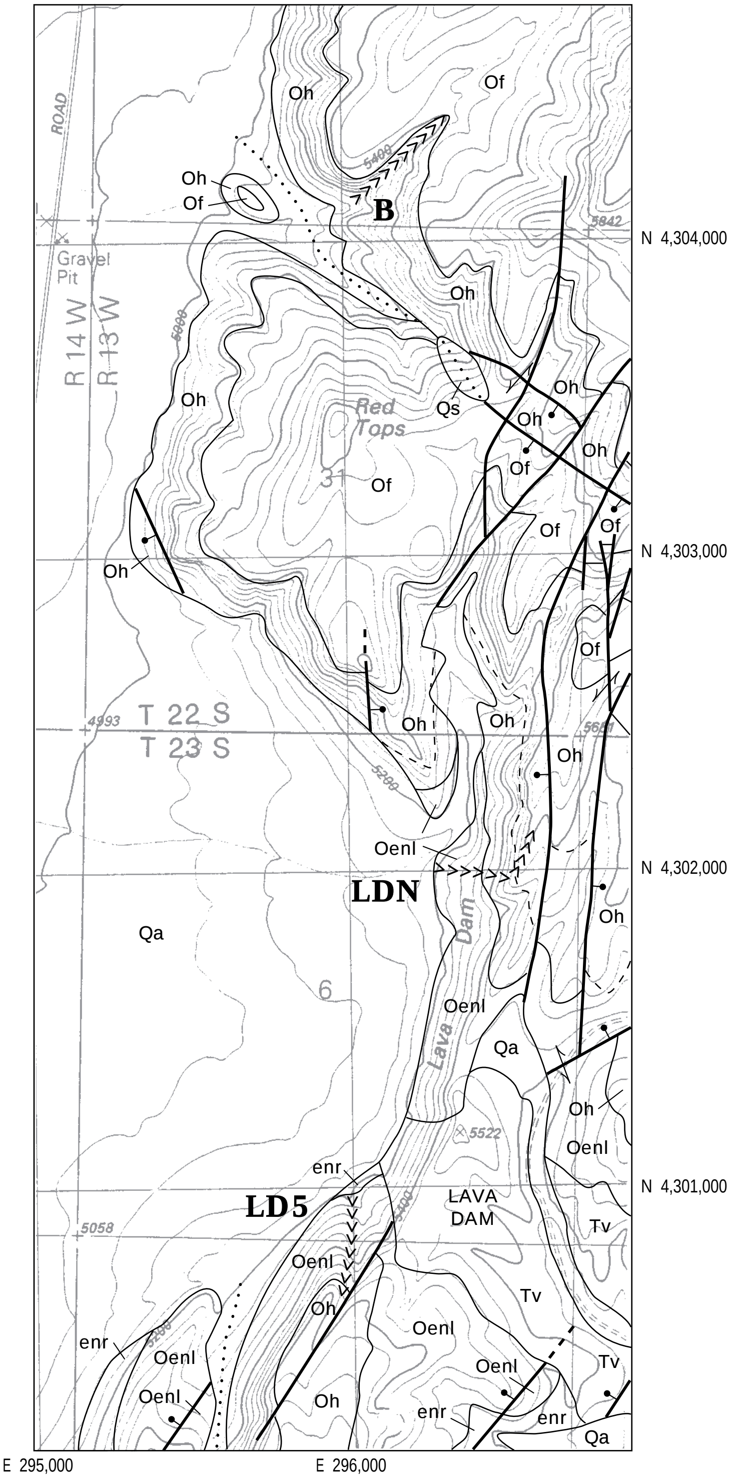


Figure 6. Geologic map showing location of the B Section of Hintze (1951) and the Lava Dam North (LDN) and Lava Dam Five (LD5) measured sections of Hintze (1973) and Hintze and others (1988). enr, Red Tops Member of the Notch Peak Formation; Oenl, Lava Dam Member of the Notch Peak Formation; Oh, House Limestone (dashed line indicates a key bed); Of, Fillmore Formation; Tv, Tertiary volcanic rocks; Qa, surficial deposits; Qs, sand. Heavy line, fault; dashed where inferred; dotted where concealed; bar and ball on downthrown side. Tielines indicate equivalent beds across faults. Lines of sections are indicated by inverted "V's." Lower boundary stratotypes of the Ibexian Series and Skullrockian Stage are coincident and located in the LD5 Section (see text). Base from U.S. Geological Survey 1:24,000 Red Tops provisional quadrangle (1991). Geology from Hintze (1974a) and Hintze and others (1988).

SLOPE-FORMING SHALY SILTSTONE MEMBER (2)

The typical reference section of the informal slope-forming shaly siltstone member (2) is in the 1965-C Section of Hintze (1973, p. 17–18), where the informal member is 97.5 m (320 ft) thick. It should be noted that only the uppermost 9.4 m (30 ft) are exposed above the underlying informal basal ledge-forming limestone member and that the section is offset approximately 0.8 km (0.5 mi) to the north (see fig. 5). In the Mesa supplementary section, the member is 98 m (312 ft) thick; its base is traced northward from the 1965-C Section. A second supplementary section is the G Section of Hintze (1973, p. 21–22 and 25). See figures 5 and 7 for locations.

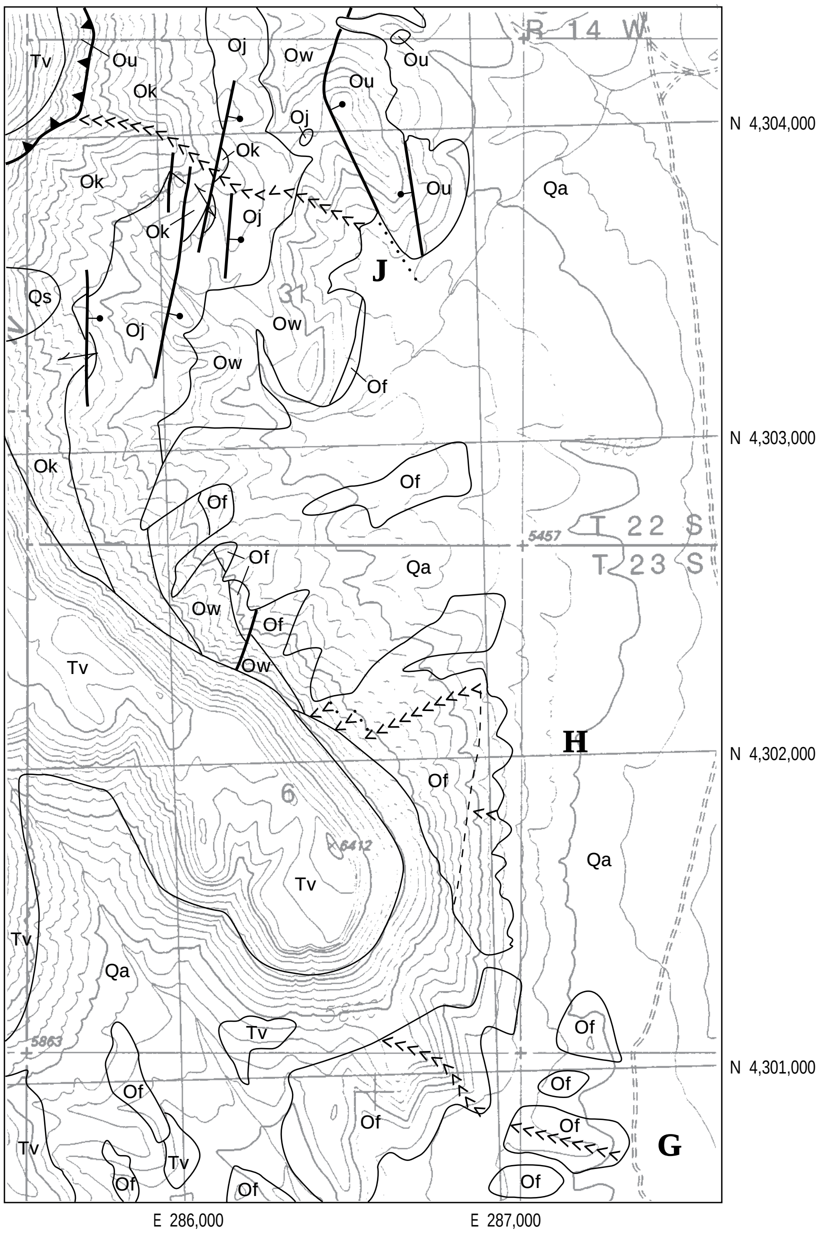


Figure 7. Geologic map showing location of the G, H, and J measured sections of Hintze (1951, 1973). The lower boundary of the Tulean Stage is located 1.8 m (6 ft) above the base of unit 2 of the informal slope-forming shaly siltstone member of Hintze (1973, p. 25) in the G Section. The lower boundary stratotype of the Blackhillsian Stage is 5.8 m (19 ft) above the base of unit 2 of the informal calcarenite member of Hintze (1973, p. 26) in the H Section. Of, Fillmore Formation (dashed lines indicate key beds); Ow, Wah Wah Limestone; Oj, Juab Limestone; Ok, Kanosh Shale; Ou, undivided Middle and Upper Ordovician rocks, considerably faulted; Tv, Tertiary volcanic rocks; Qa, surficial deposits; Qs, sand. Heavy line, fault, dotted where covered; bar and ball on downthrown side; sawteeth on upthrown block. Tie lines indicate equivalent beds across faults. Lines of section are indicated by inverted "V's." Base from U.S. Geological Survey 1:24,000 Warm Point provisional quadrangle (1991). Geology from Hintze (1974a).

LIGHT-GRAY LEDGE-FORMING MEMBER (3)

The typical reference section of the informal light-gray ledge-forming member (3) is in the Mesa Section of Hintze (1973, p. 20–21) where the informal member is 54.9 m (180.0 ft) thick. The position of the base of the member is established by tracing the base of the underlying informal member (2) northward from the 1965-C Section. Only 48.8 m (160 ft) of this member (3) is present in the supplementary 1965-C Section and 59.1 m (194 ft) in the G Section of Hintze (1973, p. 17 and 24). See figures 5 and 7 for locations.

BROWN SLOPE AND LEDGE MEMBER (4)

The typical reference section of the informal brown slope and ledge member (4) is in the Mesa Section of Hintze (1973, p. 20) where the informal member is 98.8 m (324 ft) thick. A conspicuous 1.5-m-thick (5 ft) ledge located 51.8–53.3 m (170–175 ft) above the base of the informal member is used as a marker to offset 0.3 km (0.2 mi) to the northwest and to correlate with the highest of four marker ledges in the G supplementary section of Hintze (1973, p. 23–24) and in the H Section (Hintze, 1973, p. 27). See figures 5 and 7 for locations.

CALCARENITE MEMBER (5)

The typical reference section of the informal calcarenite member (4) is in the H Section of Hintze (1973, p. 26–27) where the member is 94.5 m (310 ft) thick. A supplementary section is in the Square Top section of Hintze (1973, p. 22). See figures 4 and 7 for locations.

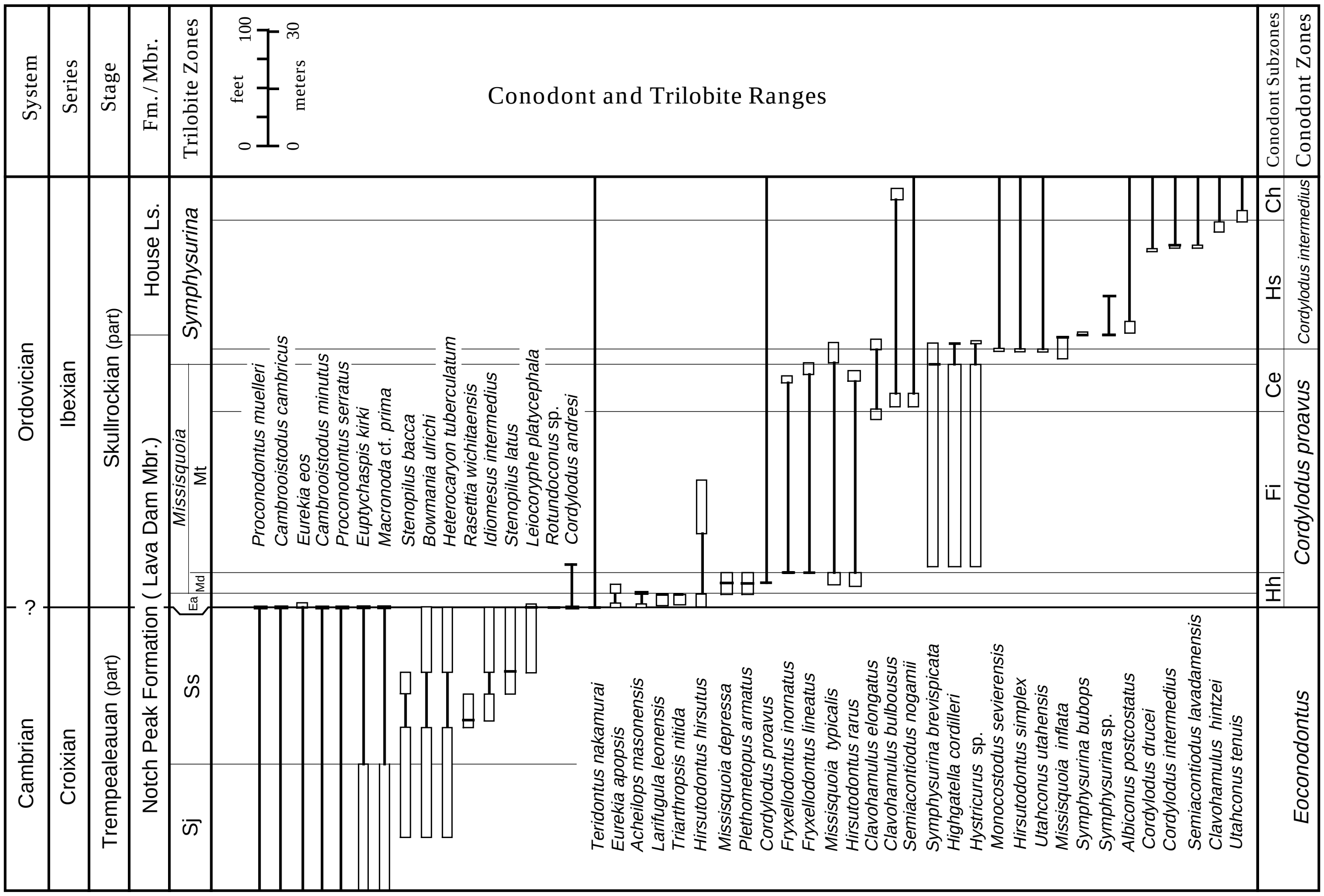


Figure 8. Detailed range chart for selected trilobites and conodonts at the lower boundary-stratotype of the Ibexian Series in the Lava Dam Five segment of the Steamboat Pass–Lava Dam section of Hintze and others (1988). Lowest observed occurrence of *Cordylodus andresi* coincides with the stratigraphic level of a steel bolt marking the base of the Ibexian Series at 39.1 m (128.3 ft) above the base of the Lava Dam Member of the Notch Peak Formation. Open rectangles are error bars that provide a semiquantitative (nonprobabilistic) estimate of how well established are lowest and highest occurrences of a species as suggested by occurrence/absence in subjacent and superjacent fossil-bearing samples. Sj, *Saukiella junia* Subzone and Ss, *Saukiella serotina* Subzone of *Saukia* Zone; Ea, *Eurekia apopsis* Zone; Md, *Missisquoia depressa* Subzone and Mt, *Missisquoia typicalis* Subzone of *Missisquoia* Zone; Hh, *Hirsutodontus hirsutus* Subzone, Fi, *Fryxellodontus inornatus* Subzone, and Ce, *Clavohamulus hintzei* Subzone of the *Cordylodus proavus* Zone; Hs, *Hirsutodontus simplex* Subzone and Ch, *Clavohamulus hintzei* Subzone of *Cordylodus intermedius* Zone.

CALATHIUM CALCISILTITE MEMBER (6)

The typical reference section of the informal *Calathium* calcisiltite member (5) is in the H Section of Hintze (1973, p. 26), where the informal member is 51.8 m (170 ft) thick. A supplementary section is in the Square Top section of Hintze (1973, p. 22). See figures 4 and 7 for locations.

WAH WAH LIMESTONE

The type section of the Wah Wah Limestone is in the J Section of Hintze (1951, p. 16–17). The formation is well exposed in the mountain front between sections H and J of Hintze (1951; 1973, p. 29–30). The Wah Wah is 78.6 m (258 ft) thick, but only the lower 67.6 m (222 ft) is Ibexian in age. The upper 11 m (36 ft) of the formation is correlated with the lowermost beds of the type Whiterockian Series (Ross and Ethington, 1991). See figure 7 for location.

IBEXIAN BIOSTRATIGRAPHY

INTRODUCTORY STATEMENT

As applied to lower Paleozoic rocks of the Western United States and elsewhere, trilobite zones and subzones traditionally have been contiguous assemblage zones and subzones (Taylor, 1987, p. 55, fig. 7.3). They are defined and characterized by associations of taxa that occur in a consistent homotaxial arrangement. (Compare NACSN, 1983, p. 862–863, fig. 4.) Correlation of trilobite assemblage zones

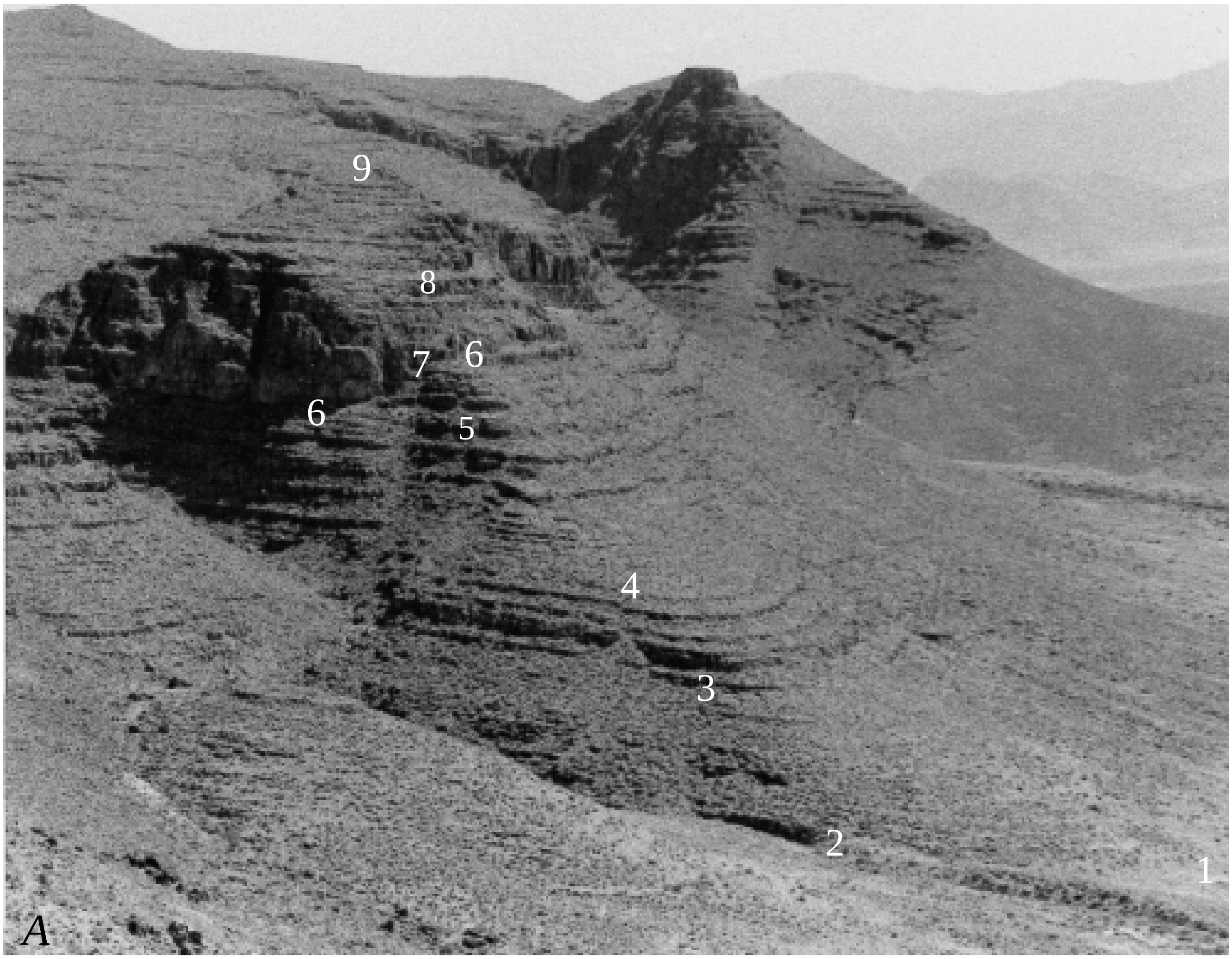


Figure 9 (above and facing page). Lava Dam Five section (LD5), southern House Range, Utah. *A*, Areal view, looking south. Numbers on photograph identify the following: 1, east end of dirt track connecting to Tule Valley Road; 2, base of Lava Dam Five traverse within the Red Tops Member of the Notch Peak Formation; 3, base of Lava Dam Member, from which all vertical measurements on plate 1 are taken; 4, normal fault that repeats 3 ft (0.9 m) of strata in lower part of Lava Dam Member (left side is uplifted); 5, boundary stratotype point at base of the Ibexian Series; 6, base of massive cliff-forming limestone unit in upper part of Lava Dam Member; 7, vertical fault with 12.2 m (40 ft) displacement (strata to right uplifted); 8, base of House Limestone; 9, top of LD5 part of measured section. See figure 6 for location of traverse. *B*, Closeup of lower boundary stratotype point of Ibexian Series, viewed from the east. Metal plaque near tip of arrow, attached to outcrop by an iron bolt, is engraved, “Base of Ibexian Series J.F. Miller 1992.” Paint numbers 130 and 135 indicate footage above base of Lava Dam Member without correction for 3-ft-displacement fault shown in view *A* (position 4). Photographs by J.F. Miller.

emphasizes comparison of faunal content of the zone, rather than zonal boundaries. In contrast, conodont zones and subzones are customarily interval zones in the nomenclature of the North American Stratigraphic Code (NACSN, 1983, p. 862, fig. 5; also compare Taylor, 1987, p. 55, fig. 7.3) and normally are defined by the lowest observed occurrence of a specified taxon in a typical reference section. Correlation by conodont interval zones may be accomplished by recognizing the lowest occurrence of the defining taxon in rocks away from the typical reference section and by assuming that the two points are isochronous. In this practice, emphasis is placed on boundaries rather than content of conodont interval zones. Used alone the interval-zone method of correlation risks error because of ecological (facies) differences in sections away from the boundary stratotype.

In this report, we have integrated conodont, brachiopod, and trilobite biostratigraphic data (fig. 10). The result is a biostratigraphic classification scheme that includes zones that are (1) defined by the lowest observed occurrence of a particular taxon; and (2) characterized by faunal assemblages with species that lived under different ecologic requirements and whose remains exhibit widely divergent patterns of paleobiogeographic distribution. Thus, the Ibexian high-resolution zonal scheme enhances the probability of overcoming local facies differences and improving precision in long-range biochronologic correlations.

PRE-IBEXIAN FAUNAL ZONES

The lithostratigraphy and biostratigraphy of rocks underlying the lower boundary of the Ibexian Series are briefly summarized here to provide a context for definition of the lower-boundary stratotype in the Lava Dam Five segment of the Steamboat Pass–Lava Dam section of Hintze and others (1988, fig. 8; this report, figs. 6, 8).

Although the Notch Peak Formation of the Ibex area has yielded trilobites that are as old as the Upper Cambrian *Taenicephalus* Zone (Taylor, 1971; M.E. Taylor in Miller and others, 1982), for practical reasons discussion here begins in the Lava Dam Member of the Notch Peak Formation with trilobites of the Upper Cambrian *Saukiella serotina* Subzone of the *Saukia* Zone.

The *Saukiella serotina* Subzone of the *Saukia* Zone was named by Longacre (1970, p. 12) as a replacement name for the *Saukiella norwalkensis* Subzone of Winston and Nicholls (1967, p. 69), which was based on an association of trilobites underlying the *Corbinia apopsis* Subzone of the *Saukia* Zone (=*Eurekia apopsis* Zone of this report) in the Wilberns Formation of central Texas.

The *Saukiella serotina* Subzone is recognized in the Lava Dam Five section by the occurrence of *Euptychaspis kirki* Kobayashi, *Macronoda* sp., *Heterocaryon tuberculatum* Rasetti, and *Leiocoryphe platycephala* Kobayashi. Based on present knowledge, no indicator of the *Saukiella serotina* Subzone occurs above the lower-boundary stratotype point at the base of the Ibexian Series.

Pre-Ibexian conodonts in the Lava Dam Member of the Notch Peak Formation in the Lava Dam Five section are assigned to the *Cambrooistodus minutus* Subzone of the *Eoconodontus* Zone (Miller, 1988) (figs. 8, 10). Conodont species present include *Cambrooistodus cambricus*, *Cambrooistodus minutus*, *Eoconodontus notchpeakensis*, *Phakelodus elongatus*, *Proconodontus muelleri*, *Proconodontus serratus*, and *Prosagittodontus eureka*, all but one of whose ranges terminate abruptly in the Ibex area at the lower boundary of the Ibexian Series. Other conodonts that range across the lower boundary of the Ibexian include *Eoconodontus notchpeakensis*, *Furnishina* sp., *Problematoconites perforatus*, *Prooneotodus gallatini*, and *Prooneotodus rotundatus*. Rare specimens assigned to *Rotundoconus* sp. occur at the top of the *Cambrooistodus minutus* Subzone.

IBEXIAN FAUNAL ZONES AND CHRONOSTRATIGRAPHY

Silicified trilobites of the type Ibexian were first described in a classic monograph by Hintze (1953). Jensen (1967) documented the stratigraphic occurrences of brachiopods, although most of the species he described were from younger Whiterockian strata. Demeter (1973), Terrell (1973), and Young (1973) augmented taxonomic knowledge of Ibexian trilobites as well as information on their stratigraphic ranges. Conodont occurrences for these sections were documented by Miller (1969), Ethington and Clark (1971, 1981), Ethington and others (1987), Miller and others (1982, p. 168–169), Miller in Hintze and others (1988, pl. 1), and Miller (1988). Hook and Flower (1977) described numerous nautiloid cephalopods from the Ibexian part of the Wah Wah Limestone. Braithwaite (1976) described graptolites from the Ibexian sections, but their ranges have not been precisely determined. The ranges of genera and species of echinoderms are discussed in Appendix 4 by James Sprinkle and T.E. Guensburg, and are shown on plate 1, chart *C*.

IBEXIAN STAGES AND TRILOBITE ZONES

Ross (1951) and Hintze (1953) subdivided the Lower Ordovician into a succession of trilobite and brachiopod assemblage zones, which have been widely applied in biostratigraphic correlation of North American rocks here assigned to the Ibexian Series. Ethington and Clark (1981), Miller and others (1982), and Ethington and others (1987) provided detailed conodont zonal ranges in the Ibexian type area, but the conodont zone boundaries do not precisely coincide with the trilobite zone boundaries. As a matter of convenience and for general communication, we divide the Ibexian Series into four new stages with stage boundaries primarily defined on trilobite ranges in the composite stratotype section of the series. The stages take their names from geographic features in the general vicinity of the Ibexian composite stratotype in the southern House and Confusion Ranges. However, rocks exposed at those geographic features are not representative of the chronostratigraphic units. The new stage names and their component shelly fossil and conodont zones are listed in figure 10. The inadequacies of former Lower Ordovician stages are discussed in a section entitled “Historical Perspective.”

The utility of the trilobite zones of the type Ibexian is exceptionally well illustrated by Dean’s (1989) monograph on the trilobites of the Survey Peak, Outram, and Skoki Formations at Wilcox Pass, Jasper National Park, Alberta.

SKULLROCKIAN STAGE (NEW)

The lower-boundary stratotype of the Skullrockian Stage coincides with the lower-boundary stratotype of the Ibexian Series, 39.1 m (128.3 ft) above the base of the Lava Dam Five section of the Steamboat Pass–Lava Dam composite section. This point coincides with the base of the *Hirsutodontus hirsutus* Subzone of the *Cordylodus proavus* Zone. The name “Skullrockian Stage” is taken from Skull Rock Pass (UTM Coord., Zone 12: E 297,380 m; N 4,322,800 m), although the rocks exposed in the pass are actually younger than the Skullrockian Stage.

The Skullrockian Stage is characterized by the *Eurekia apopsis* Zone, *Missisquoia*, *Symphysurina*, *Bellefontia-Xenostegium*, and *Paraplethopeltis* trilobite Zones, and the *Cordylodus proavus*, *Cordylodus intermedius*, *Cordylodus lindstromi*, *Iapetognathus*, *Cordylodus angulatus*, and all except the uppermost part of the *Rossodus manitouensis* conodont Zones. The upper limit of the stage is the base of the Stairsian Stage, which is drawn at the base of the *Leiostegium-Kainella* Zone.

EUREKIA APOPSIS ZONE

Nomenclatural history of divisions of the *Saukia* Zone has been recently summarized by Loch and others (1993). Herein we follow Ludvigsen and Westrop (1985, p. 139–140, fig. 1) by including the *Eurekia apopsis* Subzone of the *Saukia* Zone in the overlying Ibexian Series, rather than in the underlying Croixian Series as recommended by Loch and others (1993, fig. 3). The *Eurekia apopsis* Subzone can be recognized widely in North American platform sites; therefore, we recognize the subzone as an independent zone in this report.

The *Eurekia apopsis* Zone is recognized in the Lava Dam Member in the Lava Dam Five section by the occurrence of *Eurekia apopsis* (Winston and Nicholls), *Acheilops masonensis* Winston and Nicholls, *Larifugula leonensis* (Winston and Nicholls), and *Triarthropsis nitida* Ulrich (pl. 1; fig. 8). Lowest trilobite collections assigned to the *Eurekia apopsis* Zone were collected 39.2 m (128.6 ft) above the base of the Lava Dam Member, whereas the highest collections are from 40.9 m (134.1 ft) above the base of the member. In the composite column (pl. 1) the zone ranges from 80.46 m (264 ft) to 83.2 m (273 ft) above the base.

MISSISQUOIA ZONE

The *Missisquoia* Zone was named by Winston and Nicholls (1967) for a characteristic trilobite assemblage in the upper part of the Wilberns Formation in central Texas. Derby and others (1972) redefined the *Missisquoia* Zone to include those faunas above the “*Saukia* Zone” (that is, above

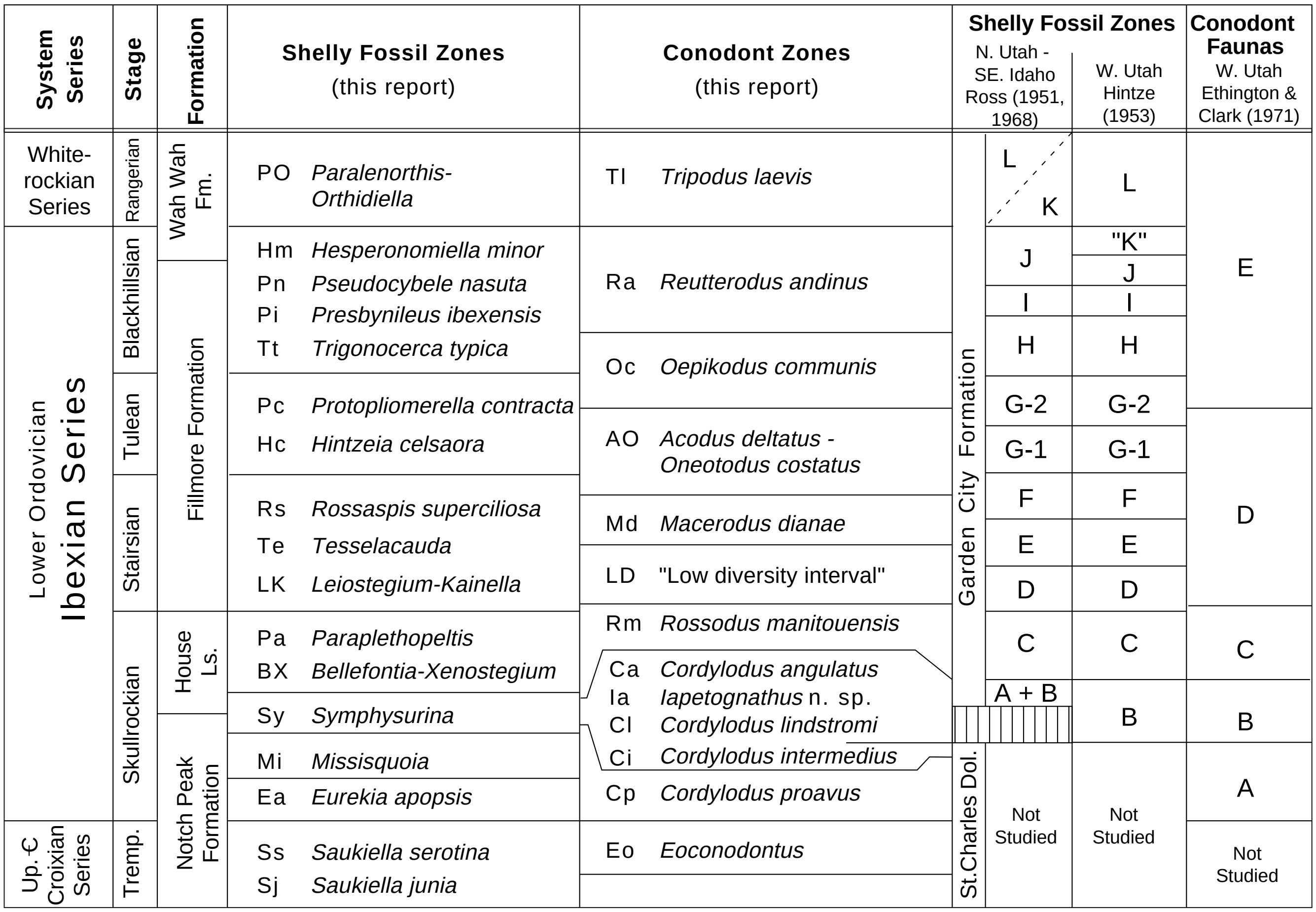


Figure 10. New stages of the Ibexian Series showing the shelly fossil and conodont zones by which they are characterized with recommended abbreviations for zones. Also shown are correlations with previous lettered shelly fossil zones of Ross (1951) for northern Utah and southeastern Idaho, Hintze (1953) for the Ibex area of western Utah, and lettered conodont faunas of Ethington and Clark (1971). Line pattern, rocks missing at unconformity.

the *Eurekia apopsis* Zone of this report) and below the lowest occurrence of *Symphysurina* in the Survey Peak Formation, southern Alberta, Canada. This restricted the lower part of the zone in order to exclude the lower range of *Symphysurina*, which had been included in the original zone by Winston and Nicholls (1967). Taylor and Halley (1974) recognized the *Missisquoia* Zone in eastern New York State.

Stitt (1977, pl. 12) refined and divided the *Missisquoia* Zone into a lower *Missisquoia depressa* Subzone and an upper *Missisquoia typicalis* Subzone in the Signal Mountain Limestone in Oklahoma. Both subzones can be recognized in the Lava Dam Member of the Notch Peak Formation in the Lava Dam Five section. The *Missisquoia depressa* Subzone is indicated by trilobites collected from 41.5 m (136.1 ft) above the base of the Lava Dam Member in the Lava Dam Five section. The assemblage contains *Missisquoia depressa* Stitt, *Plethometopus armatus* (Billings), and a single olenid? free cheek.

The *Missisquoia typicalis* Subzone is recognized in the Lava Dam Five section by the occurrence of *Missisquoia typicalis* Shaw. The subzone extends from 43.0 to 72.6 m (141.0 to 238.1 ft) above the base of the Lava Dam Member. This translates to an interval 83.2 m (273 ft) to 114.3 m (375 ft) above the base of the composite section (pl. 1, charts *A*–*C*).

The top of the *Missisquoia* Zone coincides with the lower boundary of the *Symphysurina* Zone which is recognized locally by the lowest occurrence of *Symphysurina brevispicata.*

SYMPHYSURINA ZONE (=ZONES A AND B, REVISED)

Lower and Middle Ordovician rocks in the Western United States were initially divided by Ross (1949, 1951, 1953, 1968) into a scheme of trilobite and brachiopod assemblage zones lettered from A to M in the Garden City and Swan Peak formations of southeastern Idaho and northeastern Utah. Hintze (1951, 1953, 1954) applied Ross's zonal scheme, with some emendations, to the Pogonip Group in the House Range–Ibex area of western Utah, the area of the present report. Hintze (1953, p. 5) did not recognize Zone A of Ross; instead he assigned his lowest Ordovician trilobite assemblage to Zone B, which he called the *Symphysurina* Zone. Hintze's (1953, p. 7) *Symphysurina* Zone consists of a lower part characterized by *Hystricurus millardensis* Hintze and *Symphysurina brevispicata* Hintze, and an upper part that contains different species of *Hystricurus* and *Symphysurina* in association with species of *Clelandia, Xenostegium,* and *Bellefontia*.

Stitt (1977) studied detailed trilobite ranges in the Signal Mountain Limestone of the Wichita Mountains, Oklahoma, and divided the *Symphysurina* Zone into a lower *Symphysurina brevispicata* Subzone, a middle *Symphysurina bulbosa* Subzone, and an upper *Symphysurina woosteri* Subzone. Stitt (1977, p. 32–36, pl. 7) defined the base of the *Symphysurina brevispicata* Subzone as the lowest observed occurrence of *Symphysurina brevispicata* Hintze and *Highgatella cordilleri* (Lochman). The overlying *Symphysurina bulbosa* Subzone is defined by the lowest observed occurrence of *Symphysurina bulbosa* Lochman. As so defined, the *Symphysurina brevispicata* Subzone can be recognized in the Steamboat Pass–Lava Dam composite section beginning 73.5 m (241 ft) above the base of the Lava Dam Member (equals 1.6 m (5.4 ft) below the top of Notch Peak Formation). In the composite section (pl. 1, charts *A–C*) the *Symphysurina* Zone ranges from 114.3 m (375 ft) to 216 m (708.6 ft) above the base.

Taylor and Landing (1982) studied new trilobite and conodont collections from the lowermost part of the Garden City Formation in northeastern Utah and southeastern Idaho and showed that an unconformity exists between the Garden City and the underlying St. Charles Formation. They concluded that the hiatus corresponds to most of the *Symphysurina brevispicata* Subzone, whereas trilobite Zones A and B of Ross (1949, 1951) are equivalent to the upper part of the *Symphysurina* Zone B of Hintze (1951, 1953) (see further, Stitt, 1977, p. 35–36; and Taylor and Landing, 1982, p. 184–185).

Stitt's (1977) three-fold division of the *Symphysurina* Zone currently cannot be recognized in the type area of the Ibexian Series. The possible reason for this is the presence of a massive cliff-forming layer, composed of lime mudstone from which few fossils can be broken out, within the stratigraphic interval of the *Symphysurina* Zone.

The top of the *Symphysurina* Zone in the type area of the Ibexian Series is here recognized at the lower boundary of the overlying *Bellefontia-Xenostegium* Zone (pl. 1, chart *A*), which corresponds to assemblages assigned to the upper part of the *Symphysurina* Zone B by Hintze (1953, p. 6–8).

The following trilobite species characterize the *Symphysurina* Zone, as revised herein, in the typical reference section of the Skullrockian Stage:

Trilobites:
Hystricurus millardensis Hintze
Pseudokainella? sp.
Symphysurina brevispicata Hintze
Highgatella cordilleri (Lochman)
Missisquoia inflata Winston and Nicholls
Symphysurina bubops Winston and Nicholls

BELLEFONTIA-XENOSTEGIUM ZONE (=ZONE B IN PART)

The *Bellefontia-Xenostegium* Zone was named by Aitken and Norford (1967, p. 180) in Alberta. Stitt (1983, p. 13–15) restricted the *Bellefontia-Xenostegium* Zone to trilobite assemblages that occur above the *Symphysurina* Zone and below the *Paraplethopeltis* Zone in the McKenzie Hill Formation of Oklahoma. The zone is correlated with the upper part of *Symphysurina* Zone B of Hintze (1953) and is here recognized as a separate zone in western Utah. The *Bellefontia-Xenostegium* Zone occurs in a stratigraphic interval 71 m (233 ft) to 5.5 m (18 ft) below the top of the House Limestone in the B Section of Hintze (1951). That is equivalent to 216 m (708.6 ft) to 281 m (923 ft) in the composite section.

The following trilobite and brachiopod species characterize the *Bellefontia-Xenostegium* Zone in the typical reference section of the Skullrockian Stage:

Trilobites:
Bellefontia chamberlaini Clark
Bellefontia ibexensis Hintze
Clelandia utahensis Ross
Hystricurus genalatus Ross
Hystricurus politus Ross
Parabellefontia concinna Hintze
Symphysurina globocapitella Hintze
Symphysurina cf. *S. cleora* (Walcott)
Symphysurina cf. *S. spicata* Walcott
Symphysurina uncaspicata Hintze
Symphysurina cf. *S. woosteri* Walcott
Xenostegium franklinense Ross
Xenostegium cf. *X. acuminiferentis* (Ross)
Brachiopods:
Apheoorthis cf. *A. melita* (Hall and Whitfield)
Lingulella cf. *L. pogonipensis* Walcott

PARAPLETHOPELTIS ZONE (=ZONE C)

In northeastern Utah, Ross (1951, p. 16, 19, 29) found an interval 30 ft thick in the Garden City Formation that was poorly fossiliferous and lacked markedly distinctive trilobites or brachiopods. Hintze (1953, p. 8) discovered forms by which this thin interval might be correlated. However, his assemblage included *Hystricurus genalatus* Ross, a species thought to be characteristic of the underlying *Xenostegium-Bellefontia* association of Ross's (1951) Zone B. The distinguishing taxa are two species assigned to *Paraplethopeltis*.

The zone occurs in a bed approximately 2.5 m (8 ft) thick located 3.05 to 6.4 m (10 to 18 ft) below the top of the House Limestone in the B Section of Hintze (1951, p. 34). This horizon is approximately 281.5 m (923.6 ft) above the base of the composite section (pl. 1).

Trilobite and brachiopod species recorded from the *Paraplethopeltis* Zone in the Ibex area include:

Trilobites:
Hystricurus genalatus Ross
Paraplethopeltis genacurvus Hintze
Paraplethopeltis genarectus Hintze
Brachiopod:
Syntrophina cf. *S. campbelli* (Walcott)

STAIRSIAN STAGE (NEW)

The lower boundary stratotype for the Stairsian Stage is in a thick-bedded, fine-grained ledge-forming limestone, 2.9–3.0 m (9.5–10.0 ft) thick that forms the prominent uppermost part of the House Limestone in the B Section of Hintze (1951, p. 33–34). This limestone marker bed is traced northward in outcrop to the base of the 1965-C Section of Hintze (1973, p. 16–25). The base of the stage coincides with the lowest observed occurrence of *Leiostegium* and *Kainella*, which coincides with the base of the *Leiostegium-Kainella* Zone (=Zone D of Hintze, 1953, p. 9). In addition to the *Leiostegium-Kainella* Zone, the Stairsian Stage is characterized by the *Tesselacauda, Rossaspis superciliosa*, uppermost part of *Rossodus manitouensis*, Low Diversity Interval, *Macerodus dianae*, and lower part of the *Acodus deltatus–Oneotodus costatus* Zones.

The Stairsian Stage takes its name from “The Stairs,” a narrow valley along U.S. Highway 6 and 50 that descends from Skull Rock Pass westward into Tule Valley (UTM Coord., Zone 12: E 297,000 m; N 4,322,200 m). Alternating layers of resistant limestone and nonresistant shale of the Fillmore Formation inspired the name.

The top of the Stairsian Stage is the base of the Tulean Stage, which is defined by the lowest observed occurrence of faunas assigned to the *Hintzeia celsaora* Zone.

LEIOSTEGIUM-KAINELLA ZONE (=ZONE D)

As noted, the base of the *Leiostegium-Kainella* Zone is in a thick limestone unit, 2.9–3.0 m (9.5–10.0 ft) thick, which forms the uppermost part of the House Limestone in the B Section of Hintze (1951, p. 34). The base of the zone lies at least 0.76 m (2.5 ft) below the top of the House Limestone. Therefore, the boundary is no higher than 286 m (938 ft) above the base of the composite section (pl. 1, charts *A–C*). Ethington and Ross revisited Hintze’s (1951) B Section on June 17, 1994, to verify the observations of K.M. Engel (1984) concerning the positioning of this boundary.

The base of the *Leiostegium-Kainella* Zone is defined under “Stairsian Stage.” On plate 1, the *Leiostegium-Kainella* Zone is indicated by the letters LK. In the typical reference section of the Stairsian Stage, the zone is characterized by the following shelly fossils:

Trilobites:
Apatokephalus finalis (Walcott)
Hystricurus sp.
Kainella sp.
Leiostegium manitouensis Walcott
Pseudoclelandia sp.
Rossaspis pliomeris Demeter
Brachiopods:
Apheoorthis cf. *A. meeki* Ulrich and Cooper
Nanorthis cf. *N. hamburgensis* (Walcott)
Syntrophina sp.

As noted by Hintze (1953, p. 9), the *Leiostegium-Kainella* Zone has proven to be one of the most useful assemblages for correlation throughout North America, as well as in Colombia and Argentina. It occurs in a variety of depositional facies, from the shallow-shelf deposits of the Manitou Formation of Colorado, to the Roberts Creek Mountains and Antelope Range of central Nevada, and in volcaniclastic breccias (Ross, 1958) of the Valmy Formation in western Nevada. Both *Kainella* and *Leiostegium* are present in the Survey Peak Formation in Alberta (Dean, 1978). Pratt (1988) reported *Leiostegium* and *Kainella eleutherolfi* Pratt from the Rabbitkettle Formation in the MacKenzie Mountains, N.W.T. *Kainella* and *Leiostegium* are illustrated by Pribyl and Vanek (1980, pl. 12) from Bolivia. Although *Kainella* seems to be the cosmopolitan form, often associated with the olenid *Hypermecaspis*, *Leiostegium* is reported as far away as the Digger Island Fauna from Warata Bay, Victoria (Jell, 1985). Also, Qian in Chen and Gong (1986, p. 257–260) reported species of *Leiostegium* in the Dayangcha section, northeastern China. Demeter (1973) described *Rossaspis pliomeris* as a stem species for pliomerids found in younger assemblages.

TESSELACAUDA ZONE (=ZONE E)

The base of the *Tesselacauda* Zone occurs in unit 23 of the informal ledge-forming limestone member (member 1) of the Fillmore Formation in the 1965-C Section of Hintze (1973, p. 18). This level is approximately 112 m (368 ft) above the base of the Fillmore Formation. Although that level appears to be approximately 399 m (1,309.6 ft) above the base of the composite section, Demeter (1973, p. 42; text-fig. 2) and Terrell (1973, p. 71) showed that the lowest indicator of the zone is from 349 m (1,145 ft) of the composite section (pl. 1).

This assemblage zone has been recognized in the subsurface of the Williston Basin by Lochman (1966) despite the lack of silicified preservation. It is also present in the upper part of the middle member and upper member of the Survey Peak Formation in Alberta (Dean, 1978), where it is indicated by *Leiostegium (Evansaspis), Tesselacauda*, and *Paenebeltella*. Terrell (1973) made additional collections from the Ibex area and noted four species characteristic of Zone F that occurred in the upper part of the range of a Zone E assemblage. Demeter (1973) confirmed the presence of *Tesselacauda depressa* and added *Pilekia*? *loella* to the assemblage. He also indicated that *Pilekia*? *trio* Hintze ranges into Zone F.

Trilobites:
Amblycranium variabile Ross
Amechilus palaora Ross
Hillyardina sp.
Hystricurus robustus Ross
Hystricurus sp. C of Ross (1951)
Leiostegium (Evansaspis) formosa Hintze (=*L. (E.) ceratopygoides* Raymond)
Paenebeltella vultulata Ross
Parahystricurus carinatus Ross
Pseudoclelandia lenisora Ross
Pseudoclelandia aff. *P. fluxafissura* Ross
Tesselacauda aff. *T. depressa* Ross
Tesselacauda depressa Ross
Pilekia? *trio* Hintze
Pilekia? *loella* Demeter
Brachiopod:
Syntrophina? sp.

ROSSASPIS SUPERCILIOSA ZONE (=ZONE F)

Hintze (1953, p. 11) applied the name *Protopliomerops superciliosa* Zone to a trilobite assemblage in the Fillmore Formation with a high percentage of taxa in common with Zone F of Ross (1951) in northeastern Utah. Harrington (1957, p. 812) placed *Protopliomerops* in junior synonymy with *Rossaspis*.

From the Tarutao Formation of Southern Thailand, Stait and others (1984) reported *Rossaspis bunopasi*, a species almost indistinguishable from *Rossaspis superciliosa*. It and associated trilobites suggest correlation with this part of the Ibexian Series. There is an increasing variety of pliomerid trilobites, possibly derived from *Rossaspis*, in younger assemblages in the Tarutao Formation. *Hystricurus* and *Hystricurus*-like forms seem to reach a maximum diversity in this zone.

The base of the *Rossaspis superciliosa* Zone is in unit 4 of the informal basal ledge-forming limestone member (member 1) of the Fillmore Formation in G Section of Hintze (1973, p. 25). This level is 53 m (174 ft) above the lowest exposure of the Fillmore Formation in that section. The level is 124 m (406 ft) above the base of the Fillmore Formation in the 1965-C Section of Hintze (1973) and approximately 408 m (1,340 ft) above the base of the composite section (pl. 1).

Trilobites:
Amblycranium cornutum Ross
Goniophrys prima Ross
Hillyardina semicylindrica Ross
Hyperbolochilus marginauctum Ross
Hystricurus contractus Ross
Hystricurus flectimembrus Ross
Hystricurus oculilunatus Ross
Parahystricurus fraudator Ross
Parahystricurus bispicatus Hintze
Pseudoclelandia cornupsittaca Ross
Pseudoclelandia fluxafissura Ross
Pseudohystricurus obesus Ross
Rossaspis superciliosa (Ross)

TULEAN STAGE (NEW)

The Tulean Stage takes its name from Tule Valley, which bounds the west side of the House Range. Lower Paleozoic strata, including those of the Ibexian Series, are extensively exposed along both sides of the valley.

The base of the Tulean Stage coincides with the base of the *Hintzeia celsaora* Zone. In some sections that level may be indicated by the lowest occurrence of *Menoparia genalunata* and *Psalikilus spinosum*. In other sections the earliest appearance of *Hintzeia celsaora*, name bearer of zone G-1 of Hintze (1953, p. 12) may be the better indicator. Although *Aulacoparina quadrata* is present in either case, the difference stratigraphically may be as much as 11.6 m (38 ft). Currently the lowest occurrence of *Menoparia genalunata* is the pragmatic choice because of its recognition outside the Ibex area.

The stratotype for the base of the Tulean Stage is located in unit 2 of the informal slope-forming shaly siltstone member (member 2) of the Fillmore Formation. In the 1965-C Section of Hintze (1973, p. 17), unit 2 is 28 m (92 ft) thick, and underlain by 3.4 m (11 ft) of the informal slope-forming shaly siltstone member. The lowest reported occurrence of *Menoparia genalunata* is 11.6 m (38 ft) above the base of unit 2. In the G Section of Hintze (1973, p. 25), unit 2 is 9.1 m (30 ft) thick, but underlain by a 24.7 m (81 ft) covered interval from which no distinctive fossils have been reported. Here the lowest reported occurrence of *Menoparia genalunata* is 1.8 m (6 ft) above the base of unit 2, where it is joined by *Hintzeia celsaora*. That occurrence is approximately 448 m (1,472 ft) above the base of the composite section.

We expect that additional attempts to collect fossils from the poorly exposed shaly beds below unit 2 of member 2 will require that the base of the stage be redefined downward.

HINTZEIA CELSAORA ZONE (=ZONE G-1)

The lowest part of the Outram Formation (Dean, 1978) in Alberta contains species characteristic of this zone, particularly *Menoparia genalunata*. Lochman (1966, p. 524–526) recognized the zone in the subsurface of the Williston Basin, but preferred to combine it with the next higher zone (=Zones G-1 and G-2). *Benthamaspis obreptus* (Lochman) was reported by Lochman (1966, p. 541–542) from the Deadwood Formation in the Williston Basin, Montana. A similar species was reported by Ross (1958) from a volcaniclastic flow breccia in central Nevada.

Trilobites:
Aulacoparina quadrata (Hintze)
Hintzeia celsaora (Ross)
Hintzeia firmimarginis (Hintze)
Menoparia genalunata Ross
Peltabellia sp. B of Hintze (1953)
Psalikilus spinosum Hintze
Graptolite:
Rhabdinopora sp.

PROTOPLIOMERELLA CONTRACTA ZONE (=ZONE G-2)

The lower contact of the *Protopliomerella contracta* Zone is located at the bottom of unit 2 of the informal light-gray ledge-forming member (member 3) of the Fillmore Formation in the G Section of Hintze (1973, p. 25). In the G and H Sections the zone ranges upward for 183 m (600 ft) through most of the overlying informal brown slope and ledge member (member 4). The base of the zone is approximately 518 m (1,700 ft) above the base of the composite section (pl. 1).

The *Protopliomerella contracta* Zone of Hintze (1953, p. 13) is equivalent to Zone G-2 of Ross (1951). In addition to the lists of Ross (1951, p. 28) and Hintze (1953, p. 14), note should be made of the study of pliomerids by Demeter (1973). Fortey and Peel (1990) found both *Peltabellia* and *Licnocephala* in the Poulsen Cliff Formation in northern Greenland and gave an excellent account of the wide geographic occurrence of *Peltabellia*.

Trilobites:
Aulacoparia venta (Hintze)
Aulacoparina impressa Lochman
Hintzeia celsaora (Ross)
Licnocephala bicornuta Ross
Licnocephala? *cavigladius* Hintze
Macropyge gladiator Ross
Menoparia genalunata Ross
Peltabellia peltabella (Ross)
Peltabellia sp. A of Hintze (1953)
Protopliomerella contracta (Ross)
Protopliomerella pauca Demeter
Protopliomerops quattuor Hintze
Psalikilus paraspinosum Hintze
Psalikilus typicum Ross
Protopresbynileus willdeni (Hintze)
Ptyocephalus fillmorensis (Hintze)
Scinocephalus solitecti Ross

Brachiopods, cephalopods, and graptolites:
Nanorthis sp.
Syntrophina? sp.
Endoceras sp.
Rhabdinopora sp.
Didymograptus? sp.

BLACKHILLSIAN STAGE (NEW)

The Blackhillsian Stage takes its name from the low hills at the south end of the House Range that extend southward from Skull Rock Pass for more than 32 km (20 mi). The dark color of the lower Paleozoic carbonate rocks exposed there lends itself to the name. Many of the exposures of the Ibexian Series are arrayed along the west flank of these Black Hills. The base of the stage and of its lowest faunal zone, the *Trigonocerca typica* Zone, is marked by the lowest observed occurrence of *Trigonocerca typica*. The lower boundary stratotype is located in the H Section of Hintze (1973, p. 26), 5.8 m (19 ft) above the base of unit 2 of the informal calcarenite member (member 5) of the Fillmore Formation. This level is 708 m (2,327 ft) above the bottom of the composite section (pl. 1).

TRIGONOCERCA TYPICA ZONE (=ZONE H)

As just mentioned, the base of the *Trigonocerca typica* Zone of Hintze occurs 5.8 m (19 ft) above the base of unit 2 of the informal calcarenite member (member 5) of the Fillmore Formation in the H Section of Hintze (1973, p. 26). It is equivalent to Zone H of Ross (1951, p. 28). To the lists of taxa published by Ross (1951, p. 28) and by Hintze (1953, p. 16) the faunal list of Young (1973) must be added. The earliest appearance of cosmopolitan *Carolinites*, *Ischyrotoma*, and *Pseudocybele*, and the arrival of bathyurinids, such as *Goniotelina*, set the stage for the closing of the Ibexian Epoch. *Trigonocerca typica* can be recovered in many outcrops from bioclastic limestones with relative ease. Fortey (1979) in a well-illustrated paper interpreted the Catoche Formation of western Newfoundland to be correlative with this zone.

Ischyrotoma blanda Hintze normally is considered a member of this assemblage, but in the H Section it occurs 8.8 m (29 ft) lower in the section.

Trilobites:
Amblycranium? *linearus* Young
Carolinites genacinaca nevadensis Hintze
Carolinites killaryensis utahensis Hintze
Diacanthaspis? *trispineus* Young
Goniotelina? *plicolabeonus* Young
Goniotelina? *unicornis* Young
Ischyrotoma blanda (Hintze)
Ischyrotoma ovata (Hintze)
Kanoshia? *depressa* Young

Peltabellia? sp.
Presbynileus elongatus (Hintze)
Protopliomerops? *quattuor brevis* Young
Psalikilopsis alticapitalis Young
Pseudocybele lemurei Hintze
Pseudocybele altinasuta Hintze
Ptyocephalus accliva Hintze
Opipeuter angularis (Young)
Shumardia exopthalmus Ross
Trigonocerca typica Ross
Trigonocerca typica piochensis Hintze

Graptolites:
Didymograptus cf. *D. nitidus*
Rhabdinopora? 2 spp.

Brachiopods:
Diparelasma sp.
Trematorthis? sp.

Molluscs:
Euomphalus? sp.
Catoraphiceras sp.
Endoceras sp.

***PRESBYNILEUS IBEXENSIS* ZONE (=ZONE I)**

The *Presbynileus ibexensis* Zone as recognized by Hintze (1953, p. 15) is equivalent to Zone I of Ross (1951). The base of the zone is 3.3 m (10 ft) above the bottom of unit 7, which forms the uppermost 35 ft of the informal calcarenite member (member 5) of the Fillmore Formation in the H Section of Hintze (1973, p. 25). The level is approximately 777 m (2,549 ft) above the base of the composite section (pl. 1).

Trilobites:
Carolinites genacinaca Ross
Isoteloides flexus Hintze
Ptyocephalus yersini (Hintze)
Ptyocephalus accliva (Hintze)
Presbynileus ibexensis (Hintze)
Pseudocybele altinasuta (Hintze)
Pseudocybele lemurei Hintze
Goniotelus? sp.

Brachiopods:
Hesperonomia sp.
Diparelasma sp.

Graptolites:
Phyllograptus sp.
Retiograptus sp.

***PSEUDOCYBELE NASUTA* ZONE (=ZONE J)**

The *Pseudocybele nasuta* Zone was recognized by Hintze (1953, p. 15–18) in the uppermost Fillmore Formation and lower Wah Wah Limestone. It is equivalent to Zone J of Ross (1951). The base of the zone is 8.8 m (29 ft) above the base of unit 9 of the informal *Calathium* siltstone member (member 6) of the Fillmore Formation in the H Section of Hintze (1973, p. 26). The lower boundary of the zone is defined by the lowest observed occurrence of *Pseudocybele nasuta*, which is approximately 830 m (2,723 ft) above the bottom of the composite section.

The *Pseudocybele nasuta* Zone has yielded one of the most diverse and abundant faunas in the Ibexian Series. The following list is supplemented by *Diparelasma rowelli* Ross and *Tritoechia loganensis* Ross from the Garden City Formation (Ross, 1951, p. 27–28; 1968, p. H2–H4). Because of the great diversity of trilobites and burst of orthid brachiopods, this zone has been recognized widely. Dean (1988) noted the zone's occurrence in the upper McKay Group in British Columbia and (1978) in the top of the Outram Formation in Alberta. The zone is also represented in the Dounans Limestone in the Highland Border Complex, Scotland (Ingham and others, 1985).

Trilobites:
Benthamaspis diminutiva Hintze
Carolinites genacinaca Ross
Cybelopsis cf. *C. speciosa* Poulsen
Goniotelina williamsi (Ross)
Goniotelina brighti (Hintze)
Goniotelina brevus (Hintze)
Goniotelina wahwahensis (Hintze)
Ischyrotoma caudanodosa (Ross)
Isoteloides polaris Poulsen
Kanoshia cf. *K. insolita* (Poulsen)
Kawina sexapugia Ross
Kawina webbi Hintze
Lachnostoma latucelsum Ross
Presbynileus utahensis (Hintze)
Pseudocybele nasuta Ross
Ptyocephalus declivita (Ross)
Ptyocephalus cf. *P. vigilans* Whittington
Stenorhachis genalticurvatus (Hintze)
Trigonocercella acuta Hintze

Brachiopods:
Diparelasma cf. *D. transversa* Ulrich and Cooper
Hesperonomia fontinalis (White)
Hesperonomia cf. *H. dinorthoides* Ulrich and Cooper
Syntrophopsis cf. *S. polita* Ulrich and Cooper
Tritoechia sinuata Ulrich and Cooper

Cephalopods:
Campbelloceras sp.
Catoraphiceras sp.
Endoceras sp.

***HESPERONOMIELLA MINOR* ZONE (="ZONE K" OF HINTZE, 1953)**

The *Hesperonomiella minor* Zone of Hintze (1953, p. 19) is based on a remarkable 0.3-m (1 ft) thick shell bed of white-weathering brachiopods. It occurs in unit 20 of the

Wah Wah Limestone, at 65.5 m (215 – 217 ft) above the base of the J Section of Hintze (1973, p. 29). The level is 902 m (2,959 ft) above the bottom of the composite section. The faunal assemblage occurs below a thin calcareous siltstone bearing a variety of runzel marks. Scattered valves occur higher through a thickness of 6 m (20 ft) in the stratigraphic section.

On the basis of stratigraphic position alone, the *Hesperonomiella minor* Zonal assemblage has been referred, probably incorrectly, to Zone K of Ross (1951, p. 27, 30). In addition to the Ibex area, it occurs as far east as Kanosh, Utah. In Utah the species may be associated with discontinuous facies-controlled carbonate sand bars.

The critical features of the interior of the brachial valve of *Hesperonomiella minor* were poorly known (Ulrich and Cooper, 1938, p. 124) until Hintze made specimens available to Cooper (1956, p. 337, pl. 121H, figs. 20–22). Jensen (1967) also published a description of the interior.

The genus *Hesperonomiella* is represented by *Hesperonomiella porcias* (Walcott) in the Sarbach Formation of the Canadian Rockies (Ulrich and Cooper, 1938, p. 124–125) and by *Hesperonomiella quebecensis* in boulders of the Mystic Conglomerate in southern Quebec (Cooper, 1956, p. 337–338). It has also been reported by Laurie (1980) from Tasmania.

The Zone K of Ross (1951, p. 27, 30) contains a transitional assemblage in northeastern Utah. *Diparelasma* sp. and *Hesperonomia* sp. suggest affinities with Zone J, while the appearance of *Blastoidocrinus* suggests a markedly younger “Chazyan” age. Sprinkle (1971, particularly figure 2, column C) subsequently confirmed that this echinoderm is an indicator of upper Zone L. Ross listed *Notorthis* from his Zone K, but it was a single valve identified with trepidation. The close interrelation of Zones K and L was further discussed by Ross (1968, p. H2–H4).

The seeming absence of Zone K from some sections cannot be taken seriously as an indicator of hiatus, because it was never established as a distinct zone in the first place.

WHITEROCKIAN SERIES

The Whiterockian, originally proposed as a Stage by Cooper (1956), was redefined as a Series in Ross and others (1982). Ross and Ethington (1991) provided a precise definition of the basal stratotype in the Monitor Range, central Nevada, supported by graptolite zonation by Mitchell (1991). The base of the Whiterockian Series marks the top of the Ibexian Series in the Ibexian type area.

RANGERIAN STAGE (NEW)

The Rangerian Stage is proposed here for the interval represented by a Zone L fauna (Ross and Ethington, 1991, fig. 6; Ross and Ethington, 1992, fig. 4A) in the upper Paiute Ridge and Ranger Mountains Members of the Antelope Valley Limestone in the northern Ranger Mountains, Nevada, from which the stage takes its name. This is the lowest stage of the Whiterockian Series. In the Ibex area Zone L is present in the highest 8.5 m (28 ft) of the Wah Wah Limestone, throughout the Juab Limestone, and in the lowermost limestone beds of the Kanosh Shale. In the composite-stratotype section the base of zone L is 902 m (2,966 ft) above the base.

The upper limit of the Rangerian is not a subject for this report. Under consideration is a proposed Kanoshian Stage, to include brachiopod zones M and N , probably with a type section in the Ibex area. Prior to a formal proposal its relationship to the Chazyan must be precisely determined. The base of the Kanoshian in the Ibex section is 974 m (3,194 ft) above the bottom of the composite section.

PARALENORTHIS-ORTHIDIELLA ZONE (=ZONE L)

The *Paralenorthis-Orthidiella* Zone is equivalent to the Zone L of Ross (1951) and the *Orthis subalata* Zone of Hintze (1953, p. 19). At Ibex the brachiopod fauna is not as fully developed as in sections to the west. Here *Anomalorthis juabensis* and species of *Orthidiella* appear in the upper part of the zone. The full faunal complement of the zone is listed by Ross and Ethington (1992, table 1).

Subsequent to the writing of the original manuscript of this report (Ross and others, 1993), Fortey and Droser (1996, particularly table 1) made an important addition to trilobite biostratigraphy of the Rangerian Stage and of Zone L at the Ibex section. With the exception of cursory treatment by Hintze (1953, p. 19), by Ross (1970, pl. 21), and in a master’s thesis by Valusek (1984, p. 133–138), the trilobites of this interval had received little attention. The trilobites described by Fortey and Droser (1996) have been included on plate 1, chart *A* of this publication.

It should be noted that the base of the *Tripodus laevis* conodont Zone essentially coincides with the base of the *Paralenorthis-Orthidiella* Zone.

Brachiopods:
Paralenorthis marshalli (Wilson)
Anomalorthis juabensis Jensen
Anomalorthis lambda Ross
Orthidiella spp.
Syntrophopsis transversa Ulrich and Cooper
Trilobites:
Eleutherocentrus sp.
Parapilekia? sp.
Pseudomera sp.

The trilobites added by Fortey and Droser are *Carolinites ekphymosus* Fortey, *Ectenonotus progenitor* Fortey and Droser, *E. whittingtoni* Ross, *Goniotellina ensifer* Fortey and Droser, *Ischyrotoma stubblefieldi* Ingham, *Kanoshia reticulata* Fortey and Droser, *Kawina wilsoni* Ross, *Madaraspis magnifica* Fortey and Droser, *Petigurus inexpectans* Fortey and Droser, *Psephothenaspis glabrior* Fortey and Droser, *P. microspina* Fortey and Droser, *P. pseudobathyurus* (Ross), *Pseudomera arachnopyge* Fortey and Droser, *Pseudoolenoides aspinosus* Fortey and Droser, *Punka* cf. *P. nitida* (Billings), and *Uromystrom* cf. *U. validum* (Billings).

Echinodermata:
Blastoidocrinus? sp.

CONODONT ZONES

INTRODUCTORY STATEMENT

Miller (1969) was the first to describe conodonts from the type Ibexian strata. Ethington and Clark (1971) summarized the then current knowledge of the Lower Ordovician conodonts of North America, a study that was followed by an overview of the distribution of these fossils in the Ibexian type area and other parts of the Great Basin by Ethington (1978, 1979). A detailed taxonomic and biostratigraphic study of conodonts in the Ibex area of western Utah was presented by Ethington and Clark (1981), whose collecting horizons were keyed into the detailed descriptions of stratigraphic sections of Hintze (1951, 1973). J.F. Miller (1988) has studied the lowest Ibexian conodonts in multiple sections in the type area, and his range charts have been used widely in international and intracontinental correlations. These several reports demonstrated that conodonts are virtually ubiquitous throughout carbonate rocks of the type area of the Ibexian Series.

In Ibexian Series rocks, a sample of no more than several hundred grams usually contains conodonts in sufficient abundance and diversity to allow evaluation of the collection and biostratigraphic placement. Preservation of the specimens ranges from adequate to good. Conodont Alteration Index (CAI) values of about 3.0 are typical for the Ibex area. A composite range chart prepared by Ethington and Clark (1981) shows a near continuum of species introduced in the Ibex sections. Although this sequence of species offered promise of a high-resolution biostratigraphic zonation of the Ibexian strata, Ethington and Clark chose not to establish biozones that might be only of local significance and instead recognized discrete segments within the Ibexian sequence as “intervals” that are characterized by loosely defined faunal associations. Subsequent work in other parts of North America has demonstrated that many conodonts among those known at Ibex occur in consistent sequential order elsewhere, and conodont biozones have been recognized in some parts of the Lower Ordovician. Additional zones for previously unzoned parts of the succession are offered herein. Figure 10 summarizes the older and new biostratigraphic nomenclature.

This discussion for the most part utilizes the taxonomic nomenclature of Ethington and Clark (1981) with some generic reassignments and species synonymies based on later reports. Ranges of conodonts shown on plate 1, chart *B* are taken from the work of Miller (1969, 1984) on lower Ibexian faunas and on that of Ethington and Clark (1981) for the House, Fillmore, and Kanosh Formations. Ranges of the Wah Wah and Juab conodonts are based on unpublished data from Ethington’s recollection of the entire span of these two units in Section J of Hintze (1973). Several major studies of Lower Ordovician conodonts are in press or in progress, and further revisions of nomenclature can be expected. However, the purpose of this report is to demonstrate the general lithic and fossil successions of the type Ibexian, and discussion of taxonomic nuances will detract from that objective.

Conodonts from the lowest part of the Ibexian Series (lower part of the Skullrockian Stage) are cosmopolitan in their distribution, and intercontinental correlation of these strata is not difficult (Miller, 1984). Rocks from the upper part of the Skullrockian Stage (*Rossodus manitouensis* Zone) contain species that are more provincial in their distribution. Strata of the succeeding Stairsian, Tulean, and Blackhillsian Stages contain conodont species of the North American Midcontinent Conodont Province. This faunal province generally is associated with epicratonal and miogeoclinal environments, and intercontinental correlations based on these younger faunas are more difficult. Some species in these younger strata do occur elsewhere so that such correlations are possible at some biostratigraphic levels.

The relationships between conodont and trilobite zones in the Ibexian composite stratotype section is indicated on plate 1, charts *A* and *B*, and in figure 10.

PRE-IBEXIAN CONODONT ZONES

The conodont biostratigraphy of pre-Ibexian strata was discussed by Miller (1969), Miller and others (1982), Miller in Hintze and others (1988), and Miller (1988). Conodonts in pre-Ibexian strata in Utah are represented wholly by coniform elements. Uppermost strata of the Trempeleauan Stage (upper part of the Red Tops Member and lower half of the Lava Dam Member of the Notch Peak Formation) are assigned to the *Eoconodontus* Zone, which consists of two subzones. The lower, the *Eoconodontus notchpeakensis* Subzone, is characterized by *Eoconodontus notchpeakensis* and *Proconodontus muelleri*, species that continue to the top of the overlying subzone, which is characterized by the presence of *Cambrooistodus minutus*. The top of the *Cambrooistodus minutus* Subzone is marked by an abrupt termination of the ranges of conodonts and trilobites. Of the abundant conodonts, only *Eoconodontus notchpeakensis* occurs in younger strata in the Ibex sections. The complete thickness of the *Eoconodontus notchpeakensis* Subzone is not shown on plate 1, but the thickness of the *Cambrooistodus* Subzone is 44.8 m (147 ft).

IBEXIAN CONODONT ZONES

CORDYLODUS PROAVUS ZONE
(=FAUNA A, LOWER PART)

Cordylodus is the oldest ramiform conodont genus, the oldest whose elements display secondary denticles, in North America. Most of the conodont zones of the Skullrockian are named for species of *Cordylodus,* although species whose elements are all coniform are used to recognize several subzones. The lowest observed occurrence of *Cordylodus* Pander is immediately above the bolt and plaque that mark the base of the Ibexian Series and Skullrockian Stage (fig. 9*B*). The base of the *Cordylodus proavus* Zone is 39.1 m (128.3 ft) above the base of the Lava Dam Member in the Lava Dam Five section. The lowest observed occurrence of *Cordylodus andresi* marks the base of the *Cordylodus proavus* Zone. The lowest observed occurrence of *Cordylodus proavus* is 3.7 m (12 ft) higher, and it ranges into younger zones.

The *Cordylodus proavus* Zone occurs in the upper half of the Lava Dam Member of the Notch Peak Formation, and the top of the zone apparently coincides with the top of the member in several sections in the Ibex area. The Zone is divided into three subzones all of which are defined in the Lava Dam Five section. From oldest to youngest, the subzones are (1) the *Hirsutodontus hirsutus* Subzone, defined at 39.1 m (128.3 ft) above the base of the Lava Dam Member and characterized by *Cordylodus andresi, Cordylodus proavus,* and *Hirsutodontus hirsutus*; (2) the *Fryxellodontus inornatus* Subzone, defined at 43.9 m (144 ft) above the base of the Lava Dam Member and characterized by *Cordylodus proavus*, *Fryxellodontus* spp., *Hirsutodontus hirsutus*, and *Hirsutodontus rarus*; and (3) the *Clavohamulus elongatus* Subzone, defined at 67.4 m (221 ft) above the base of the Lava Dam Member and characterized by *Clavohamulus bulbousus, Clavohamulus elongatus, Cordylodus proavus, Fryxellodontus* spp., and *Semiacontiodus nogami.*

The *Cordylodus proavus* Zone can be recognized in many parts of North America and elsewhere in the world (Miller and others, 1982; Miller, 1988, 1992).

CORDYLODUS INTERMEDIUS ZONE
(=FAUNA A, UPPER PART)

Advanced cordylodontiform species are introduced in the overlying *Cordylodus intermedius* Zone in which they are associated with a diverse fauna of species with coniform elements, many of which continue into overlying strata. This zone occurs in the lower part of the House Limestone and includes two subzones. The lower, the *Hirsutodontus simplex* Subzone, begins at the base of the House Limestone in the Lava Dam North section. This horizon is equal to the “50 ft” paint mark above the base of the Lava Dam North traverse. The *Hirsutodontus simplex* Subzone is characterized by an influx of new species with coniform elements, including *Albiconus postcostatus, Hirsutodontus simplex, Monocostodus sevierensis, Semiacontiodus lavadamensis,* and *Utahconus utahensis*. The upper subzone, that of *Clavohamulus hintzei,* begins 20.7 m (68 ft) above the base of the House Limestone in the Lava Dam North section. It is characterized by advanced species of *Cordylodus,* including *Cordylodus drucei* and *Cordylodus intermedius,* that occur most commonly in the upper part of the subzone and continue into overlying strata. The *Clavohamulus hintzei* Subzone varies in thickness within the Ibex area but typically is about 15.2 m (50 ft) thick. In addition to nearly all of the species of the underlying subzone, the *Clavohamulus hintzei* Subzone is characterized by *Clavohamulus hintzei* and *Utahconus tenuis.*

CORDYLODUS LINDSTROMI ZONE
(=FAUNA B, LOWER PART)

Other advanced cordylodontiform and coniform conodonts are introduced in the succeeding *Cordylodus lindstromi* Zone. The taxonomy of *Cordylodus lindstromi* is controversial, and we use the name in the loose sense, including in it elements that Nicoll (1991) described as *Cordylodus prolindstromi.* Thus the base of our *Cordylodus lindstromi* Zone correlates with the *Cordylodus lindstromi* Zone of Nicoll (1991) and with the base of the *Cordylodus prolindstromi* Zone of Shergold and Nicoll (1992) in Australia. In the Ibex area, the *Cordylodus lindstromi* Zone begins 29.9 m (98 ft) above the base of the House Limestone in the Lava Dam North section. It is 11.9 m (39 ft) thick and is characterized by *Cordylodus lindstromi*. Several species with coniform elements continue into this zone from the underlying *Cordylodus intermedius* Zone.

IAPETOGNATHUS ZONE (NEW)
(=FAUNA B, MIDDLE PART)

The *Iapetognathus* Zone begins at 42.7 m (140 ft) above the base of the House Limestone in the Lava Dam North section. It is characterized by elements of *Iapetognathus* n. sp., a complex species that has worldwide distribution. The base of the zone in the Ibexian type area is at the lowest observed occurrence of *Iapetognathus*. The top is at the base of the overlying *Cordylodus angulatus* Zone. The *Iapetognathus* Zone also contains several species with coniform elements that are assigned to “*Acontiodus*,” “*Scolopodus*,” and *Utahconus*. The *Iapetognathus* Zone is 7.9 m (26 ft) thick and occurs in the middle part of the House Limestone. This zone contains several taxa that also occur in the underlying zone, including *Cordylodus lindstromi*. Previously, strata assigned to this new zone were included in the *Cordylodus lindstromi* Zone or the lower part of conodont Fauna B of some previous authors.

Iapetognathus n. sp. is associated with the Tremadocian olenid trilobite *Jujuyaspis borealis* (see Acenolaza and Acenolaza, 1992) in the Drum Mountains, Utah, and in central Texas (Stitt and Miller, 1987), and in the House Limestone north of Skull Rock Pass, central House Range (Miller and others, 1990). A probable association of *Jujuyaspis* and *Iapetognathus* has been reported for the Rocky Mountains of Canada (Westrop and others, 1981). At the time of publication of that report, *Iapetognathus* had not been named, and Ed Landing discussed as New Genus B specimens whose description suggests that they represent what he later named *Iapetognathus*. *Iapetognathus* occurs with earliest Tremadocian graptolites and *Jujuyaspis* at Naersnes near Oslo, Norway (Bruton and others, 1988) and with earliest Tremadocian graptolites in Estonia (Kaljo and others, 1988) and in western Newfoundland (Landing, 1988). These occurrences support a correlation of the base of the Tremadocian Series of the Acado-Baltic faunal province with the base of the *Iapetognathus* Zone in the type area of the Ibexian Series.

CORDYLODUS ANGULATUS ZONE
(=FAUNA B, UPPER PART)

The *Cordylodus angulatus* Zone begins 50.3 m (165 ft) above the base of the House Limestone in the Lava Dam North section. It is 18.3 m (60 ft) thick and includes the most advanced species of *Cordylodus* that occur in the Ibexian as well as a great variety of species with only coniform elements. This zone is characterized by *Cordylodus angulatus* Pander and many species that continue into this zone from underlying strata, for example, *Cordylodus lindstromi* (see further, pl. 1).

ROSSODUS MANITOUENSIS ZONE (=FAUNA C)

The *Rossodus manitouensis* Zone begins 84.4 m (277 ft) above the base of the House Limestone in the Lava Dam North section. It contains a much more diverse conodont assemblage than is present in earlier zones. The base of the zone is marked by the lowest observed occurrence of *Rossodus manitouensis*. *Cordylodus* is represented by occasional specimens of *Cordylodus angulatus* Pander, but many of the taxa that Furnish (1938) reported from the Oneota Formation of the American Midcontinent dominate the conodont faunas of the upper half of the House Limestone. These include "*Acanthodus*" *lineatus*, "*Oistodus*" *triangularis*, *Variabiloconus bassleri*, and *Scolopodus*? *sulcatus*. Less common faunal elements are *Clavohamulus densus* Furnish, "*Paltodus*" *spurius* Ethington and Clark, and *Loxodus bransoni* Furnish. Ethington and Clark (1971) identified this assemblage of conodonts Fauna C, and they (1981) subsequently discussed the upper House strata in which it occurs as the *Loxodus bransoni* Interval. Landing (in Landing and others, 1986) noted that, although *Loxodus bransoni* is persistent through the range of this fauna and widespread geographically, only a few specimens are found in most occurrences and many samples lack the species. He recommended that this biostratigraphic interval be identified as the *Rossodus manitouensis* (= New Genus 3 of Ethington and Clark, 1981) Zone.

Ethington and Clark (1981) observed that the conodonts of the *Rossodus manitouensis* Zone, which flourished during deposition of the upper half of the House Limestone, disappear abruptly at the top of that formation. They are replaced in the lower part of the Fillmore Formation by an almost wholly new population that has low diversity and abundance. They noted that this same succession is seen at many places on and adjacent to the North American craton and inferred that this faunal replacement event might be the most persistent biostratigraphic event for correlation within the Lower Ordovician conodont succession of North America. Ethington and others (1987) further documented this event by comparing its expression in the type Ibexian with the conodont succession in the coeval lower Arbuckle Group in Oklahoma. They suggested that this seeming continent-wide abrupt replacement of a well-established conodont fauna by an impoverished population mimics the trilobite biomeres that have been recognized in the Cambrian of North America. They also reported that significant changes in the invertebrate faunas in the same sections occur at different horizons than the conodont event, so that mutual response to environmental change seems not to be indicated. Additional evidence for this event is provided by Ji and Barnes (1993), who recorded a similar abrupt termination at the top of the range of the conodonts of the *R. manitouensis* Zone in the St. George Group of the Port au Port Peninsula in western Newfoundland.

The horizon of this event is just above the top of the trilobite *Paraplethopeltis* Zone and the boundary between the House Limestone and Fillmore Formation (see Ethington and others, 1987, for details). It lies within the basal part of the *Leiostegium-Kainella* Zone and of the Stairsian Stage.

LOW DIVERSITY INTERVAL (=FAUNA D, LOWER PART)

The conodonts in the lowermost 100 m (318 ft) of the Fillmore Formation occur in very sparse numbers and have low diversity. Principal components of the fauna are *Drepanoistodus basiovalis* (Sergeeva) and a species very similar to and perhaps conspecific with *Scolopodus rex* Lindstrom. This part of the section also has sporadic occurrences of *Colaptoconus quadraplicatus* (Branson and Mehl) and *Eucharodus parallelus* (Branson and Mehl), two species that Ethington and Clark (1971) considered to be fundamental to the assemblage that they identified as conodont Fauna D. These latter species are long ranging in the type Ibexian and elsewhere in Lower Ordovician successions. Frequently they are found to the exclusion of any other conodonts, and, by themselves, are insufficient to characterize a zone. We therefore follow the lead of Ethington and Clark (1981) in not defining a conodont zone for the lower part of the Stairsian Stage; as a result, the stage depends upon the trilobites and brachiopods of the *Leiostegium-Kainella* Zone for definition of its lower boundary and characterization of its lowermost zone. The informal conodont Low Diversity Interval encompasses all but the lowest 6 m (20 ft) of Stairsian Stage (all but the basal *Leiostegium-Kainella* Zone and most of the *Tesselacauda* Zone).

MACERODUS DIANAE ZONE (NEW) (=FAUNA D, MIDDLE PART)

The *Macerodus dianae* Zone comprises the upper part of the basal informal ledge-forming member of the Fillmore Formation (upper part of the *Tesselacauda* Zone through almost all of the *Rossaspis superciliosa* Zone). Its stratigraphic expression corresponds to the range of *Macerodus dianae* Fahraeus and Nowlan beginning at 110 m (350 ft) above the base of the Fillmore and continuing upward to 145 m (460 ft) in the formation. *Macerodus dianae* is associated with *Scolopodus floweri* Repetski (identified as "aff. *Paltodus sexplicatus*" by Ethington and Clark, 1981) in the type area of the Ibexian Series, as well as with long-ranging components of the former conodont Fauna D. This assemblage is present in the Manitou Formation in Colorado and in the Cool Creek Formation in southern Oklahoma (R.L. Ethington, unpub. data) as well as in the El Paso Group of West Texas (Repetski, 1982). Ji and Barnes (1994) found this association of species in the Boat Harbour Formation (St. George Group) on the Port au Port Peninsula in western Newfoundland. *Macerodus* was described initially by Fahraeus and Nowlan (1978) from Bed 8 of the Cow Head Group in western Newfoundland, and Nowlan (1976) recorded its presence in the Baumann Fiord Formation of Devon Island in the Arctic Archipelago of Canada. Williams and others (1994) referred to a *Macerodus dianae* Zone in a report on the biostratigraphic significance of the type Cow Head Group of Newfoundland but did not discuss its stratigraphic limits or characterize its fauna. These widely separated geographic occurrences with consistent biostratigraphic position relative to faunas above and beneath justify recognition of a *Macerodus dianae* Zone, although additional collecting in all of these localities is needed to document its range completely.

ACODUS DELTATUS/ONEOTODUS COSTATUS ZONE (NEW) (=FAUNA D, UPPER PART)

The lowest occurrence in the type Ibexian of the characteristic P elements of *Acodus deltatus* Lindstrom is at 151 m (480 ft) in the Fillmore Formation (425 m above the base of the composite section). *Acodus deltatus* is associated through its range with two species that make their appearance slightly lower in the Fillmore Formation, aff. *Acodus emanuelensis* McTavish (138.7 m; 455 ft) and *Oneotodus costatus* Ethington and Brand (129.5 m; 425 ft) (417 m and 408 m respectively above the base of the composite section). These species, together with *Walliserodus ethingtoni*, aff. *Drepanodus forceps* (Lindstrom), *Oistodus bransoni* Ethington and Clark, and the ubiquitous long-ranging components of conodont Fauna D dominate the conodonts in the lower middle part of the Fillmore Formation. This assemblage of conodont species is a distinct one among the succession of faunas in the Ibexian, and we identify the interval between the lowest observed occurrence of *Acodus deltatus* and the lowest observed occurrence of *Oepikodus communis* (Ethington and Clark) as the *Acodus deltatus/Oneotodus costatus* Zone. It includes almost all of the *Hintzeia celsaora* Zone and much of the *Protopliomerella contracta* Zone, thus encompassing the slope-forming siltstone member, the light-gray ledge-forming member, and the lower 55 m (175 ft) of the informal brown slope and ledge member of the Fillmore Formation.

Recognition of this zone can be made in other regions at the craton margin where *Acodus deltatus* is present, but that species is not widely distributed in the continental interior. Correlation with sections in the shallow-water carbonates of the interior may be possible using *Oneotodus costatus*, which is introduced in the Arbuckle Group in Oklahoma near the base of the Kindblade Formation. *O. costatus* also appears above a thick interval in the middle and upper part of the Cool Creek Formation with faunas of the *Macerodus dianae* Zone (R.L. Ethington, unpub. data). Repetski (1982) reported similar distributions of these species in the type El Paso Group of West Texas. *Acodus deltatus* is present in lower Arenigian strata in Sweden, and its occurrence in this part of the Ibexian provides a tie point with the Lower Ordovician succession of northern Europe.

OEPIKODUS COMMUNIS ZONE (=FAUNA E, LOWER PART)

In a review of paleogeography of conodonts of the Lower Ordovician of North America, Repetski and Ethington (1983) established the *Oepikodus communis* Zone for the rocks containing conodont Fauna E of Ethington and Clark (1971). They suggested the top of this zone be recognized at or near the base of the *Tripodus laevis/Microzarkodina flabellum* Interval of Ethington and Clark (1981) thereby excluding from it the top of the range of Fauna E in the Ibex region as originally envisioned by Ethington and Clark. We herein further restrict the top of the *Oepikodus communis* Zone.

Oepikodus communis was described initially by Ethington and Clark (1964) from the El Paso Group in the Franklin Mountains, West Texas. Subsequently this species has been recognized widely in North America. Its range in the type

Ibexian is from 56.4 m (185 ft) below the top of the informal brown slope and ledge member of the Fillmore Formation through the lower 66.1 m (217 ft) of the Wah Wah Limestone, an interval of 268.9 m (882 ft) of strata; this interval is equivalent to 635–904 m (2,084.6–2966.6 ft) above the base of the composite section. In 1981, Ethington and Clark reported that a diversity of conodont species is introduced into the section within the range of *Oepikodus communis*, and therefore they divided the stratigraphic range of that species into three “Intervals” based upon these other species. We here are restricting the *Oepikodus communis* Zone to the lowest of these (the *Oepikodus communis/Fahraeusodus marathonensis* Interval). The conodonts of the zone include *Oepikodus communis* and *Fahraeusodus marathonensis* (Bradshaw) (formerly “*Microzarkodina*” *marathonensis*) and long-ranging species that continue upward from the underlying zones. The *Oepikodus communis* Zone extends from the lowest occurrence in the section of the named species to the lowest occurrence of ?*Reutterodus andinus* Serpagli at 439 m (1,440 ft) above the base of the Fillmore Formation (718 m (2,354.6 ft) above the base of the composite section). This interval encompasses the upper 56.4 m (185 ft) of the informal brown slope and ledge-forming member of the Fillmore and the lower 25.9 m (85 ft) of the informal calcarenite member. The boundary between shelly fossil zones *Protopliomerella contracta* and *Trigonocerca typica* (the boundary between the Tulean and Blackhillsian Stages) is within this conodont zone in the type Ibexian.

REUTTERODUS ANDINUS ZONE (NEW)
(=FAUNA E, MIDDLE PART)

?*Reutterodus andinus* was reported by Serpagli (1974) from the San Juan Limestone in Precordilleran Argentina. Ethington and Clark (1981) described and illustrated distinctive coniform elements from the Fillmore and Wah Wah Formations whose morphology is closely similar to that of specimens that Serpagli interpreted as “cone-like elements” of the apparatus of *R. andinus*. Ethington and Clark did not find the other elements (unibranched, bibranched) of that reconstructed apparatus and therefore assigned their coniform elements to *R. andinus* with query. The holotype of *R. andinus* Serpagli is what was described in the initial report as a “unibranched element.” Repetski (1982) illustrated specimens from the El Paso Group of Texas that are identical to the coniform elements from the type Ibexian and also reported a few specimens that he identified as unibranched elements. His illustrations of the latter specimens do not show marked differences from the coniform elements, however. This is the only report of these specimens in association with the coniform elements other than in Serpagli’s initial definition of the species. Identical coniform elements have been recovered from many samples from numerous localities in the Great Basin west of the Ibex area (R.L. Ethington, unpub. data), and it is unlikely that the absence of bibranched and unibranched elements from the Ibexian collections is unique to that area. Stouge and Bagnoli (1988) found only the coniform elements in Bed 11 of the Cow Head Group in western Newfoundland, although their collection consisted of only nine specimens from a single sample. As a result we retain the query in the designation of these forms as representatives of *R. andinus*. Should subsequent research demonstrate that *R. andinus* does not contain coniform elements or that the elements reported by Ethington and Clark are not properly assigned to *Reutterodus*, a new generic and specific name will be required for these coniform elements because Serpagli designated another element as the holotype of *R. andinus*.

?*Reutterodus andinus* is a significant part of an association of conodonts in the highest Fillmore Formation through most of the Wah Wah Limestone in the type Ibexian. These species include *Jumudontus gananda* Cooper, *Protoprioniodus aranda* Cooper, and *Juanognathus variabilis* Serpagli, as well as *Oepikodus communis* and *Fahraeusodus marathonensis*, which continue upward from the *Oepikodus communis* Zone beneath. This assemblage is that for which Ethington and Clark proposed the designation conodont Fauna E. The subsequent use of that term by numerous authors to report conodont faunas from elsewhere documents the potential of this faunal association for biostratigraphy.

We establish the ?*Reutterodus andinus* Zone to formalize biostratigraphic correlations using these species. The base of the zone in the type Ibexian is at the lowest occurrence of ?*Reutterodus andinus* at 439 m (1,440 ft) above the base of the Fillmore Formation (718 m or 2,354.6 ft above the base of the composite section). The zone comprises all strata from that horizon through the lower 67.3 m (221 ft) of the overlying Wah Wah Limestone. It includes the upper part of the calcarenite member of the Fillmore, all of the overlying *Calathium* calcisiltite member, and the Wah Wah Limestone through 1.2 m (4 ft) above the distinctive brachiopod coquina of the *Hesperonomiella minor* Zone of Hintze (1953, p. 19).

As now understood, the ?*Reutterodus andinus* Zone encompasses the upper two-thirds of the *Trigonocerca typica* Zone and all of the *Presbynileus ibexensis, Pseudocybele nasuta*, and *Hesperonomiella* Zones. It includes all but the lowest part of the Blackhillsian Stage.

Jumudontus and *Protoprioniodus* are abundant in coeval Australian faunas from the Horn Valley Siltstone (Cooper, 1981), and a few specimens representing these genera are known from the Baltic region in Europe. *Juanognathus* and ?*Reutterodus* provide ties with South America.

WHITEROCKIAN CONODONT ZONES

TRIPODUS LAEVIS ZONE (NEW)
(=FAUNA E, UPPER PART)

Ethington and Clark (1981) assumed the base of the Middle Ordovician to be indicated by the appearance near the bottom of the Kanosh Shale of a distinctive assemblage of conodonts dominated by *Histiodella altifrons* and a variety of species with hyaline elements. This association of species is found at the bottom of the Middle Ordovician sequence in southern Oklahoma and is present in the lower part of the Middle Ordovician Whiterockian Series in central Nevada. These occurrences led them to assign the upper part of the Wah Wah and the Juab Limestones at Ibex to the Lower Ordovician, although Ross (1970) earlier had considered these units to be Whiterockian on the basis of their brachiopod faunas. Recent work in the Roberts Mountains (Finney and Ethington, 1992) and on the type lower Whiterockian in the Monitor Range in central Nevada (Ross and Ethington, 1991, 1992) showed that the lowest occurrences of *Histiodella altifrons* and the associated hyaline conodonts may be diachronous in the Great Basin. These results essentially substantiated Ross's earlier correlation of the highest Wah Wah and Juab with the lower part of the Whiterockian Series.

In the type area of the Ibexian Series, *Tripodus laevis* Bradshaw is present and abundant in the upper 11.3 m (37 ft) of the Wah Wah Limestone and through the overlying Juab Limestone. It is associated through this range with *Protoprioniodus aranda*, *Fahraeusodus marathonensis*, *Juanognathus variabilis*, and occasionally with *Jumudontus gananda*. *Microzarkodina flabellum* (Lindstrom) and a species probably conspecific with *Oepikodus minutus* (McTavish) occur with these species through much of their collective ranges. The same association is present at the base of the type Whiterockian in the Roberts Mountains (Finney and Ethington, 1992) in association with abundant *Histiodella altifrons.* These latter occurrences provide positive evidence for defining the top of the Ibexian in its type area at the base of the *Tripodus laevis* Zone 11.3 m (37 ft) below the top of the Wah Wah Limestone, and 1.2 m (4 ft) above the *Hesperonomiella minor* shell bed.

GRAPTOLITE CORRELATIONS

IBEXIAN GRAPTOLITES

Although graptolites are not abundant in the Ibexian stratotype section, they do occur at several levels. Braithwaite (1976) made extensive collections from the Fillmore Formation, Wah Wah Limestone, Juab Limestone, and overlying Kanosh Shale. He arranged these collections into seven biostratigraphic zones, of which the lower five are Ibexian in age. The possibility of effective correlation with graptolites elsewhere at first seems difficult. However, the graptolites in the Ibexian stratotype occur interbedded with trilobite, brachiopod and conodont assemblages, an advantage lacking in most graptolite-bearing sections.

A comparison with the Cow Head Group of western Newfoundland (James and Stevens, 1986) is helpful in dealing with the upper Ibexian in particular. The sedimentology of the Cow Head with its breccia flows contrasts with the platform-to-ramp facies of the typical Ibexian.

The superb interpretation and exposition of the physical stratigraphy of the Cow Head Group authored by James and Stevens (1986) provided the concrete foundation for work on the graptolites by Williams and Stevens (1988). A convention was established whereby the coarse flow breccias, composed of carbonate clasts, were given even bed numbers and the intervening graptolite-bearing shales were given odd bed numbers. A minimum age for each breccia is established by the youngest trilobite or brachiopod found in a clast. On that basis Bed 12 is known to be of earliest Whiterockian age and Bed 10 is correlative with uppermost Zone G2 and all of Zone H at Ibex. Bed 11 therefore must be older than basal Whiterockian and no older than Bed 10. Bed 11 correlates with Braithwaite's Zone 4; similarly Bed 9 correlates with trilobite Zone G2, establishing the Tulean age of the *Tetragraptus approximatus* graptolite Zone.

Graptolite zones as designated by Braithwaite (1976, fig. 10) are listed in ascending order, as follows:

ZONE 1. Dendrograptidae. Based on long-ranging *Callograptus* spp. and *Dictyonema* spp. (s.l.), this zone extends from the *Bellefontia-Xenostegium* Zone (Zone B) almost through the *Hintzeia celsaora* Zone (Zone G1). *Cactograptus pogonipensis* Braithwaite occurs at the level of Zone D and *Mastigograptus* sp. at the top of Zone F. Unfortunately, there is no cosmopolitan species with which to subdivide or even to characterize this zone as originally defined. A partial solution to this misfortune lies in a collection made on July 28, 1977, by David Skevington and B.D. Erdtmann on an excursion led by Ross up the north tributary canyon of Ninemile Canyon, Antelope Range, central Nevada.

From the resulting collection Erdtmann and Comeau (1980) identified *Anisograptus richardsoni* Bulman. It was collected from the lower part of the Goodwin Formation above the bed crowded with abundant obelloid brachiopods, which in turn overlies the *Caryocaris* beds of the uppermost part of the Windfall Formation. (The coordinates of the locality are UTM 1,000 m grid, Zone 11: E 564,200 m; N 4,339,600 m, Horse Heaven Mtn. 15-minute quadrangle, Nevada.)

Repetski has identified conodonts of the *Rossodus manitouensis* Zone in the uppermost part of the Windfall Formation in the Antelope Range. Ross has identified *Kainella flagricauda* and *Hypermecaspis* sp. in the lower part of the Goodwin immediately above the graptolite locality and considers those beds to belong to trilobite Zone D. Although the locality is well to the west of the Ibex area, it provides a definitive graptolitic fix on this level in the Antelope Range, well above the base of the Ibexian Series. This same level is represented in the southern Rocky Mountains of Canada where Dean (1989, fig. 10) has equated the *Anisograptus richardsoni* Zone with the *Bellefontia-Xenostegium* Zone (trilobite zone B). Therefore the zone is late Skullrockian to Stairsian in age. Based on the work of VandenBerg and Cooper (1992), we conclude that this level correlates with

Australian Lancefield La1b and that it is an interval with wide geographic recognition, as shown by Cooper and Lindholm (1990, p. 506–507, fig. 1, parts I–III; figs. 4, 5).

ZONE 2. *Adelograptus*. This zone is limited to the topmost part of trilobite Zone G1 and all but the topmost part of G2 and is Tulean in age. It includes the appearances of *Dendrograptus* spp. and of *Desmograptus* spp., and the continuation of *Callograptus* spp. and *Dictyonema* spp. *Dictyonema cordillerensis* Braithwaite, *D. fillmorensis* Braithwaite, *Adelograptus novus* (Berry), *Clonograptus* cf. *C. sarmentosus* Moberg, *Cactograptus utahensis* Braithwaite, and *Temnograptus utahensis* Braithwaite are the designated species, and their occurrences are limited to the lower part of Zone G2. Only two of these species have outside distribution.

ZONE 3. *Clonograptus flexilis* (Hall) and *Phyllograptus archaios* Braithwaite are the only two species in this zone; they occur in uppermost trilobite Zone G2. The latter species has no outside distribution and the former has a long range.

In western Newfoundland Fortey (1979) has presented a thorough and beautifully illustrated analysis of the trilobite fauna of the Catoche Formation. He concluded that the age of the formation ranges from highest Zone G2 through Zone H of the type Ibexian or late Tulean to early Blackhillsian. He suggested the possible correlation of the lower Catoche with Berry's (1960) graptolite Zone 4 (Zone of *Tetragraptus* (now=*Pendeograptus*) *fruticosus* 4-branched). On that basis we might conclude that Braithwaite's Zone 3 could be equivalent to the Zone of *P. fruticosus* 4-branched (or Bendigonian 1–2).

ZONE 4. *Didymograptus fillmorensis* Braithwaite–*Didymograptus millardensis* Braithwaite. In addition to the two named species, this zone includes the continuation of *Dendrograptus* sp., and *Dictyonema* sp., as well as the appearance of *Phyllograptus ilicifolius major* and *Phyllograptus griggsi*. The zone is found in the uppermost Fillmore Formation, equivalent to upper trilobite Zone H and all of Zone I or middle Blackhillsian. The two species with outside distribution suggest the *Didymograptus protobifidus* Zone (in the Australian scheme equal to Chewtonian).

ZONE 5. *Tetragraptus*. The zone characterizes the entire Wah Wah Limestone. It includes the continuation of *Dendrograptus* spp., the termination of *Desmograptus* spp., *Dichograptus octobrachiatus*, *Tetragraptus pogonipensis* Braithwaite, *T. ibexensis* Braithwaite, *T. bigsbyi* (Hall), *T. agilis* Braithwaite, *Tetragraptus* sp., *Phyllograptus loringi* White, *P. ilicifolius major, P. griggsi, P. anna longus, P. anna*, and *Didymograptus extensus* (Hall). The age of this zone clearly falls within the range of the Australian Bendigonian Be2 to lower Castlemainian.

ZONE 6. *Didymograptis nitidus* (Hall)–*Didymograptus patulus* (Hall). Both species of this zone occur in the upper part of the Juab Limestone in the basal Whiterock Series.

ANOMALIES AND CORRELATIONS

The stratigraphic range of *Tetragraptus approximatus* in the Australian scheme (VandenBerg and Cooper, 1992, range chart) is La3–Be1. In western Newfoundland Williams and Stevens (1988), in their study of Lower Ordovician graptolites of the Cow Head Group, indicated that *T. approximatus* occurs in Bed 9 of the Ledge section (text-fig. 4) and in Bed 9 of the Jim's Cove section (text-fig. 6) on the Cow Head peninsula. In the Western Brook Pond section (text-fig. 5*) T. approximatus* occurs in Beds 9 and 10, and the base of 11. At Martin Point North (text-fig. 8), it is in Bed 9, and at Martin Point South (text-fig. 9) it was found near the top of Bed 9. At St. Paul's inlet, North Tickle section (text-fig. 10), *T. approximatus* is present through much of Bed 9 and possibly as high as the base of Bed 11. In fact *Tetragraptus approximatus* is an important component of both the *T. approximatus* and *T. akzharensis* Zones, underlying the *Pendeograptus fruticosus* Zone. Nor should one overlook the possibility that the *Pendeograptus fruticosus* and *Tetragraptus approximatus* Zones are partly correlative, as indicated in text-figure 6 of Williams and Stevens (1988).

A close examination of figures 4–10 of Williams and Stevens (1988) reveals not only that (1) *T. approximatus* belongs to Bed 9, and (2) a new Zone of *T. akzharensis* belongs in either the very top of Bed 9 or the bottom of Bed 11, but also that (3) the Zone of *P. fruticosus* is disturbingly fickle because it is in lower Bed 11 (text-fig. 6), or in upper Bed 11 (text-fig. 5), or it may be designated in an interval without any graptolites at all (see their fig. 10) in a section wherein *P. fruticosus* itself occurs in the higher? Zone of *D. bifidus*. We conclude that the graptolites of Cow Head Bed 11 are correlative with upper Zone 3 and Zone 4 of Braithwaite, or very high Ibexian.

Our attention goes to Fortey (1979), who showed that the Catoche Formation, St. George Group, is equivalent to Zones G2 and H at Ibex. James and Stevens (1986) indicated that the youngest trilobites from clasts in Bed 9 also matched G2, that trilobites from Bed 10 (a flow breccia) matched Zones H and possibly I from Ibex, and that brachiopods from Bed 12 are Whiterockian. In other words the key to dating the Cow Head slope facies and the St. George platform facies lies in matching the faunas of the carbonates against the type Ibexian! The odd-numbered beds are the graptolite bearers and they are locked in between the carbonate breccias. Therefore, the position of graptolite zones in the deeper facies is also locked into the Ibexian stratotype.

HISTORICAL PERSPECTIVE

BACKGROUND AND APPEALS FOR TRADITION

Some traditionalists may not favor the introduction of the Ibexian or of these new stage names because they do not realize the inadequacies of the old familiar ones. In support of the correlation chart of Ordovician strata in the United States, Ross and others (1982, p. 5–7) provided a detailed account of the origin, evolution, dislocation, and physical inadequacies of the components of the original Canadian Period of Dana (1874). For the sake of clarity, a synopsis of the material covered by Ross and others is expanded herein.

Teichert and Flower (1983) thought that the term "Canadian" could be applied to rocks of part of the Pogonip Group in western Utah to preserve tradition, and Fortey (1988, p. 43–44) recognized that the base of the "Canadian" is best defined in the Ibexian section. The opinions of these authors reflect their rejection of the inadequacies of the "Canadian" relative to requirements of the International Commission on Stratigraphy (Cowie and others, 1986), which emphasizes biostratigraphy over pure tradition.

ALTERNATIVE VIEWPOINTS

From the 1930's into the 1950's, the stratigraphic section in the Ozark region of Missouri and Arkansas served as the reference section for the Lower Ordovician. Although better than the New York composite sections, even here the units are not all in stratigraphic succession one above another in a single section. In fact, all of the formations are not present in outcrop in any single area. There is no widely held agreement about the identification of formations or stratigraphic equivalents in various outcrop belts (Thompson, 1991).

The formations assigned to the Lower Ordovician in the Ozark region are the following:

Smithville Dolomite (and its Black Rock Limestone Member)
Powell Dolomite
Cotter Dolomite
Jefferson City Dolomite
Roubidoux Formation
Gasconade Dolomite

The Lower Ordovician Series was based on these formations in the 1940's. Cullison (1944) described trilobites from the Roubidoux, Jefferson City, Cotter, and Powell Formations. Each formation was supposed to include a characteristic fauna, largely molluscan, but no range charts other than Cullison's were available. Subsequently there has been no suitable documentation or synthesis of either the physical stratigraphy or biostratigraphy of the Lower Ordovician Ozark succession that could be used as the basis for intraregional correlation, let alone as an interregional standard.

In a paper on ellesmeroceratid cephalopods, Flower (1964) recommended that the Canadian Series be a system, divided into the Gasconadian, Demingian, Jeffersonian, and Cassinian Series. The Gasconadian and Jeffersonian were derived from the Ozark region. The Cassinian came from eastern New York (Fort Cassin Formation and its fauna). Although the Demingian was named for a section south of Deming, New Mexico, it was based largely on the Fort Ann Limestone plus "300 feet of Cutting dolomite." Subsequently, Fisher and Mazzullo (1976) correlated this part of the Cutting Dolomite with the Smith Basin Limestone of Flower (1964). (Compare their figure 8 with Flower's (1964) figure 53.) Flower (1964, and thereafter) included the Smith Basin Limestone in his Gasconadian Series. This inconsistent correlation among authors has tainted the use of the Demingian. In any case, to determine where one of those stages ended and the next began was and is impossible because of the combination of disjunct geographic distribution and poor biostratigraphic control in the reference areas.

Conodonts have the strongest potential for delimiting Ibexian correlatives in the shallow-water sandstone and dolostone facies of southern Missouri and northern Arkansas (Kurtz, 1981, p. 115–117). R.L. Ethington and J.E. Repetski have undertaken systematic stratigraphic collecting of conodonts from the six formations in the Ozark Mountains of Missouri (Repetski and others, 1993). Such work may lead to a better understanding of Lower Ordovician biostratigraphy in the Ozark area.

Wright and others (1987) and Miller (1988) expressed concern that previous usage of the term "Ibex" might disqualify its further application. Widespread use of the Ibexian Series by stratigraphers in North America and abroad indicates that most have been unconcerned about this nomenclatural problem. Previous usages included the little-used Ibex Member of the Ely Springs Dolostone of Budge and Sheehan (1980). Sheehan (written commun. to RJR, March 7, 1989) saw no reason for confusing this Upper Ordovician member with the Lower Ordovician Ibexian Series. The "Ibex Substage of the Cassinian Stage" of LeMone (1975, p. 176–179) was proposed to be equivalent to the single Ross/Hintze trilobite Zone H (=*Trigonocerca typica* Zone of this report) in a stratigraphic classification that has not been used by other stratigraphers. The Permian Ibex Limestone of Texas (Cheney, 1948) is less than one meter thick and is now considered to be a member of the Moran Formation, Wichita Group (Price, 1978).

GEOGRAPHIC PERSPECTIVE

NORTH AMERICA

UTAH AND SOUTHEASTERN IDAHO

In 1951 Ross assumed that the base of the Ordovician was at the base of the Garden City Formation of northern Utah and southeastern Idaho. In the Bear River Range of Utah and Idaho, Landing (1981), Taylor and Landing (1982), and Taylor, Landing, and Gillette (1981) demonstrated that a hiatus representing the lower part of the *Symphysurina* Zone is present between the Garden City Formation and underlying dolostones of the St. Charles Formation. Additionally, they showed that the *Cordylodus proavus* Zone, which is equivalent to the *Missisquoia* Zone and *Eurekia apopsis* Zone, is present in the upper part of the St. Charles Formation.

In 1985 M.E. Taylor and J.E. Repetski reviewed the trilobite and conodont evidence in the Bear River Range and carried it southwestward, through the southern Lakeside Mountains, Stansbury Island, the northern end of the Stansbury Range, to the southern House Range and the type area of the Ibexian Series where deposition is considered to have been more or less continuous. A similar trilobite-conodont succession is present in the Egan Range, east-central Nevada (Taylor, Repetski, and Sprinkle, 1981, fig. 20; Taylor and others, 1989, figs. 6-2, 6-3). The correlations can be extended to mixed carbonate-siliciclastic platform margin, slope, and basin facies in south-central Nevada (Taylor, 1976; Taylor and Cook, 1976; Cook and Taylor, 1977; Miller, 1992; Cook, Taylor, and Miller, 1989; Repetski and Taylor, 1983).

Miller (1984, p. 48–55, fig. 1) presented evidence for a eustatic lowering of sea level, termed the Lange Ranch Eustatic Event (LREE), coinciding with the base of *Hirsutodontus hirsutus* Subzone of the *Cordylodus proavus* Zone. This event has been recognized widely, and Miller (1992) discussed the evidence for it in detail in several depositional settings. In some sections at the level at which evidence for the LREE might be expected, generally shallow water sedimentary characteristics occur, as in central and western North Greenland (Bryant and Smith, 1990).

CANADIAN ROCKY MOUNTAINS

The base of the Ibexian Series is a biostratigraphically correlated level in the Canadian Rockies and other western areas (Derby and others, 1972, faunal unit 2, fig. 2). Dean (1978, p. 4, figs. 3, 4) noted the presence of *Eurekia apopsis* in the basal Silty Member of the Survey Peak Formation in the Canadian Rockies of Alberta. In a stratigraphically controlled and well-illustrated monograph, Dean (1989) demonstrated that virtually every assemblage zone of the Ibexian Series is represented at Wilcox Pass in the Rocky Mountains of Alberta. Westrop and others (1981) and Westrop (1986) provided the documentation of trilobite and conodont distribution in the upper Mistaya and lower Survey Peak Formations from their measured section at Wilcox Pass, near Dean's area of investigation.

Loch and others (1993) discussed details of uppermost Cambrian and lowermost Ordovician biostratigraphy of the Survey Peak Formation in the Mount Wilson and Wilcox Pass sections in Alberta. They provided new data and reinterpreted some earlier published work. Loch and others (1993, fig. 3) recognized the lower part of the Ibexian Series and placed the base of the Ibexian at the base of the *Missisquoia depressa* Subzone of the *Missisquoia* Zone. The underlying *Eurekia apopsis* Subzone of the *Saukia* Zone of Loch and others (1993) correlates with the *Eurekia apopsis* Zone of this report. Our different placement of the base of the Ibexian Series is a difference in definition, not in correlation.

In their detailed study of the upper Rabbitkettle Formation, District of MacKenzie, Canada, Landing and others (1980) correlated their lowest *Missisquoia*-bearing interval and the base of their *Cordylodus proavus* Zone (identified as *Cordylodus oklahomensis* and corrected *in erratum*) with the *Corbinia apopsis* Subzone (=*Eurekia apopsis* Zone of this report) in Texas and Oklahoma. This correlation confirmed the earlier observation of Tipnis and others (1979).

EASTERN CANADA

At Navy Island, New Brunswick, Canada, Landing and others (1978, p. 75–78) demonstrated that *Cordylodus proavus* occurs below *Dictyonema flabelliforme* (now *Rhabdinopora flabelliformis*) and with trilobites of the Acado-Baltic *Westergaardia* Subzone of the *Acerocare* Zone, thereby providing a tie with the Acado-Baltic faunal province.

In western Newfoundland *Cordylodus proavus* Zone conodonts and *Eurekia apopsis* Zone trilobites were reported in both in-place rocks and transported limestone blocks of the Cow Head Group by Fortey and others (1982, p. 95–129) along with a graptolite assigned to *Radiograptus rosieranus flexibilis* Fortey. Deferring to a coincident paper by Rushton (1982), these authors sought to move the Cambrian-Ordovician boundary stratigraphically upward to the lowest occurrence of long-ranging *Dictyonema flabelliformis*. Barnes (1988) corroborated that the *Cordylodus proavus* Zone has been recognized from the slope-facies carbonate deposits of the Cow Head.

Detailed work in the coeval autochthonous platform carbonate sequence of western Newfoundland (upper Port au Port and St. George Groups) clarified Ibexian relationships there (Stouge, 1982; Stouge and Boyce, 1983). From clasts in the debris flow conglomerate of Bed 19 at Green Point, Newfoundland, J.F. Taylor (written commun., April 15, 1997) reported that he has found *Symphysurina* cf. *S. cleora* and other trilobites diagnostic of the basal Ibexian zones in Utah. Bed 19 is below the level of a proposed Cambrian-Ordovician boundary stratotype, on which no final decision has been reached as of April 17, 1997.

EASTERN UNITED STATES

M.E. Taylor and Halley (1974) identified trilobites indicative of both the *Saukiella serotina* Subzone of the *Saukia* Zone and the *Missisquoia* Zone in samples from the upper part of the Whitehall Formation in the Champlain Valley of eastern New York. Repetski (1977) identified the *Cordylodus proavus* Zone in the same unit in that region, as well as North American Midcontinent conodont faunas C (=*Rossodus manitouensis* of this report), D (=Low Diversity Interval, *Macerodus dianae*, and *Acodus deltatus–Oneotodus costatus* Zones of this report), and E (=*Oepikodus communis*

Zone of this report) in overlying formations. These studies show that the Skullrockian and Stairsian Stages can be recognized in platform rocks of the Champlain Valley.

In an important contrast with the carbonate-platform and platform margin faunas of Utah and Alberta, J.F. Taylor and others (1991, particularly fig. 4) found the base of the *Hirsutodontus hirsutus* Subzone of the *Cordylodus proavus* Zone to be equivalent to the *Elkanaspis corrugata* trilobite Zone and to be immediately underlain by strata with geographically widespread *Lotagnostus hedini* in the deep-water, slope facies at Highgate Gorge, Vermont. They called attention to the identical relationship in Kazakhstan (Apollonov and others, 1988, figs. 2 and 3), in southwestern P.R.C. (People's Republic of China; Lu and Lin, 1980, 1984), and northwestern P.R.C. (Wang and others, 1985). Both Apollonov (1991, p. 34–43) and Dubinina (1991, p. 117, 121) have supported these observations in Kazakhstan.

J.F. Taylor and others (1991) demonstrated that Landing's (1983, p. 1149–1167) earlier interpretation that *Cordylodus proavus* appeared earlier in slope settings than on the shelf in Vermont was based on a miscorrelation of a key debris-flow marker bed. Landing (1993) has continued to support his 1983 correlation.

Cordylodus proavus Zone conodonts from low in the Stonehenge Formation of northern New Jersey and eastern and central Pennsylvania (Tipnis and Goodwin, 1972; Karklins and Repetski, 1989; J.E. Repetski, unpub. data) show that the base of the Ibexian locally falls near or at the base of that unit. Most or all of the younger Ibexian conodont zones can be recognized in overlying formations of the Beekmantown Group in this region.

In the central Appalachian region J.F. Taylor and others (1992, p. 414) found that "the most tightly constrained and easily recognized of the three potential Cambrian-Ordovician boundary stratotype levels is the base of the *Cordylodus proavus* Zone." They found evidence of a rapid marine transgression in the lower Stonehenge Limestone in the younger *Cordylodus angulatus* Zone. The *Cordylodus proavus* Zone lies 80 m (262 ft) lower in the stromatolite-rich peritidal beds of the Conococheague Formation, but no distinct signature of the Lange Ranch Eustatic Event is evident. However, they concluded that evidence of shallowing followed by transgression closely paralleled the stratigraphic sequence from St. Charles Formation to Garden City Formation in central and northern Utah and southeastern Idaho (Taylor, Landing, and Gillette, 1981; Taylor and Landing, 1982; Taylor and Repetski, 1985).

Repetski (1985, p. 28) called attention to possible evidence for the Lange Ranch Eustatic Event at the base of the Chepultepec Dolomite at Thorn Hill in eastern Tennessee, but the currently available biostratigraphic evidence is only suggestive. In the southern Appalachians lower Ibexian and underlying Cambrian rocks are in mainly dolomitized carbonate-platform/ramp facies. As a result of unfavorable facies and lack of detailed study in this region, conodont evidence is sparse and macrofossils are almost nonexistent. Thus far, only a few conodont collections (Repetski, 1992, p. 39–46) are available to show the general position of these rocks within the lower part of the Ibexian Series.

J.F. Taylor and others (1996) have demonstrated the usefulness of the Ibexian and its stages in the Frederick Valley of Maryland.

SOUTHERN MIDCONTINENTAL UNITED STATES

Stitt (1971, 1977, 1983) and Derby and others (1991, figs. 5, 6) have assembled a thorough review of the Cambrian and Ordovician of Oklahoma. The position of key basal Ibexian trilobite and conodont species approximately 122 m (400 ft) above the base of the Signal Mountain Limestone is clearly demonstrated at Chandler Creek, Wichita Mountains. Miller (1992) discussed how the Lange Ranch Eustatic Event is manifested in these strata.

Flower (1957, p. 18) named the Jeffersonian Stage of the Canadian Series for dolomitic rocks and chert-mold fossils in the Jefferson City Formation of Missouri. Loch (1995) redefined the Jeffersonian Stage on trilobite faunas in the Kindblade Formation of southern Oklahoma. Loch's redefined Jeffersonian Stage correlates with shelly fossil Zones G-1 and G-2 (*Hintzeia celsaora* and *Protopliomerella contracta* Zones of this report). The *Hintzeia celsaora* and *Protopliomerella contracta* Zones characterize the Tulean Stage of the Ibexian Series in the type area. Loch's data (1995) are further evidence that the Ibexian Series and its stage divisions are recognizable in different facies of Laurentia and the North American Faunal Province. Repetski (1982, 1988) described Ibexian conodonts from West Texas.

Repetski and others (1997) have demonstrated the close applicability of the Ibexian Series and its stages and zones to the stratigraphy of the Ozarks region in southern Missouri.

In the continental-slope deposits of the Ouachita Mountains, west-central Arkansas and eastern Oklahoma, *Cordylodus proavus* Zone conodont faunas have been recovered by Ethington and Repetski and will be instrumental in understanding the stratigraphy of this structurally complex region.

MEXICO

The Lower Ordovician platform succession of mixed carbonate and minor siliciclastic rocks in northeastern and north-central Sonora, Mexico, has little biostratigraphic documentation. Preliminary studies show that it can be correlated readily with platform successions in the central and western United States, including the Ibexian type area (Repetski and others, 1985). To the west, in northern Mexico, Ibexian strata comprise mainly deeper water siliciclastic deposits with sparsely documented graptolites and conodonts from isolated and structurally poorly constrained localities (Gastil and Miller, 1983; Bartolini and others, 1989). In Oaxaca, southern Mexico, the deeper water Tinu Formation contains Upper Cambrian and Lower Ordovician fossil assemblages (Robison and Pantoja-Alor, 1968; Sour and Buitron, 1987). The lowermost Ibexian at Oaxaca contains cosmopolitan trilobites and conodonts assigned to the *Cordylodus proavus* to *Cordylodus angulatus* Zones (Clark in Robison and Pantoja-Alor, 1968). The Oaxaca shelly fossils have affinities with the Acado-Baltic faunal province.

OUTSIDE NORTH AMERICA

SOUTH AMERICA

The thick Upper Cambrian to Middle Ordovician succession in northwestern Argentina correlates well with the type Ibexian where its fauna has been documented. For example, Rao (1988, in Sarmiento and Garcia-Lopez, 1993) reported conodonts of the *Cordylodus proavus* and *Cordylodus intermedius* Zones in Jujuy Province. F.G. Acenolaza (1983) and Acenolaza and Acenolaza (1992) summarized the distribution of trilobites, graptolites, and conodonts in Latin America critical to choosing the lower boundary of the Ordovician System and recommended that the *Cordylodus proavus* Zone be included in the Ordovician.

Lower Ordovician conodonts were summarized by Serpagli (1974), Sarmiento and Garcia-Lopez (1993), and Lehnert (1993) for middle and upper parts of the Ibexian Series in Argentina. Many of the middle Ibexian conodonts reported in Argentina show affinities with the Acado-Baltic faunal province. These faunas are similar to those in outer platform facies in the central and western parts of the Basin and Range province, Western United States. In the upper part of the Ibexian Series, however, numerous species in the San Juan Limestone also occur through the upper part of the Fillmore Formation and Wah Wah Limestone.

SPITSBERGEN

In his classic study of the Ordovician trilobites of Spitsbergen, Fortey (1980, p. 8–17, fig. 3) presented his presumed evidence for the erection of a distinct Valhallan Stage, older than the Whiterockian and younger than the Ibexian Series. Perusal of his figure 3 reveals the flaw in this proposal. It is now known that the *Isograptus victoriae* Zone is overlapped by the *Didymograptus bifidus* Zone. It is also known now that the base of the Whiterockian (*Orthidiella* Zone) coincides with the base of the *Isograptus victoriae* Zone (Finney and Ethington, 1992). Ross and Ethington (1992, p. 146) noted the close parallelism, both faunal and sedimentological, between the upper Valhallan of Spitsbergen and the Whiterockian of Utah and Nevada. The lower Valhallan is clearly of late Ibexian age. The Valhallan fauna is present in the deeper water facies of Ikes Canyon in the Toquima Range, central Nevada. Fortey and Droser (1996, p. 80, table 1) have compared trilobites of the uppermost Ibexian and lower Whiterockian with those of Spitsbergen, particularly those of the upper Olenidsletta Member and Profilbekken Member of the Valhallfona Formation (Fortey, 1980, fig. 1 in pocket (not figure 3)).

WALES

Rushton (1982) reported on the lithologies, trilobites and graptolites within the traditional interpretation of the Tremadoc Series, and (p. 46) noted that *Cordylodus proavus* is associated with *Shumardia alata* within the *Acerocare* Zone at Bryn-llin-fawr. There *Dictyonema* (=*Rhabdinopora*) *flabelliformis* was about 20 m higher (Rushton's fig. 3). These are the same relative positions that are present in Oslo Fjord, where *Boekaspis hirsuta* occurs less than 1.0 m below *Rhabdinopora flabelliformis* (Bruton and others, 1988).

AUSTRALIA

TASMANIA

Laurie (1980, 1991) described an array of brachiopods from Tasmania that are so similar to Ibexian forms from the Basin Ranges that one can hardly avoid the correlation and the environmental similarity of the two areas. *Leptella* and *Archaeorthis* in the lower Karmberg Formation suggest a link with the Ninemile Formation of central Nevada. *Hesperonomiella* in siltstones near Caroline Quarry, Railton area, suggest the Wah Wah Limestone of western Utah. Laurie's discussion (1991, p. 19–21) of brachiopod zonal assemblages from the Florentine Valley Formation leaves little doubt that the formation closely parallels the typical Ibexian Series, from *Apheoorthis* near the base, through *Nanorthis*, *Tritoechia*, and *Leptella*. This succession includes many of the same graptolite, trilobite, and conodont genera and species. Above them is *Hesperonomiella*, which we interpreted (p. 21) as uppermost Ibexian, not necessarily Whiterockian.

Webby and Nicoll (1989) published a new correlation chart for the Ordovician of Australia. This chart indicated the trend in Australian thinking concerning the base of the system. The authors called attention (1989, p. 4) to the ease with which North American terms could be applied to Australian units, and indicated (p. 20–21) their preference for the base of the *Hirsutodontus simplex* Subzone of the *Cordylodus proavus* Zone for the level of the Cambrian-Ordovician boundary. This level is only slightly above the base of the *Symphysurina* Zone in North America. Their chart correctly showed the base of the North American Ibexian Series as being older than the base of the "British" Tremadoc Series.

In his taxonomic revision of *Cordylodus*, Nicoll (1990) recognized the validity of the *Cordylodus proavus* Zone, consisting of three subzones, that of *Hirsutodontus hirsutus* being the oldest. He dispensed with the *Cordylodus intermedius* Zone for taxonomic reasons, replacing it with two zones that were formerly the two constituent subzones of the *Cordylodus intermedius* Zone of Miller (1988), the *Hirsutodontus simplex* Subzone below and the *Clavohamulus hintzei* Subzone above.

QUEENSLAND

Nicoll and Shergold (1991, p. 95–98) discussed conodont biostratigraphy at Black Mountain in western Queensland, Australia, and clarified ranges of key taxa. They noted that the lower boundary of the *Hirsutodontus hirsutus* Subzone of the *Cordylodus proavus* Zone is well below the top of the Ninmaroo Formation and indicative of the base of the Datsonian Series. Their figure 2 shows the stratigraphic position of *Cordylodus primitivus* (=*Cordylodus andresi* of this report), *Fryxellodontus inornatus*, *Hirsutodontus hirsutus*, *Teridontus* sp. B, *Cordylodus proavus*, and *Clavohamulus* spp. between 582 and 632 m (1,852–2,011 ft) above the base of the section. This assemblage clearly correlates with the *Hirsutodontus hirsutus* Subzone of Miller, and is earliest Ibexian in age. Ripperdan and Magaritz, joined by these same two authors (Ripperdan and others, 1992, figs. 1 and 3), showed that the components of this assemblage at Black Mountain appear first at approximately 540 m (1,718 ft), coinciding with a paleomagnetic polarity reversal, believed to be coincident with the eustatic sea level change of the Lange Ranch Eustatic Event. The plotting of first appearance of *Cordylodus proavus* some 40 m (127 ft) higher is peculiar because it seems to be related to an interval that lacks conodonts. In any case, for those seeking physical as well as biostratigraphic confirmation of the importance of the base of the Ibexian Series, this and a corroborating paper by Ripperdan and Kirschvink (1992, fig. 6) are noteworthy. Shergold and Nicoll (1992, p. 86–87) repeated and emphasized the importance of this “event in Cambrian-Ordovician conodont evolution.”

Shergold and Nicoll (1992) showed that the lowest occurrences of *Cordylodus* and *Fryxellodontus inornatus* are coincident, and additional collections from the Black Mountain section confirm this relationship (J.F. Miller, unpub. data, 1991). A relatively thin interval of strata beneath these faunas contains molds of anhydrite, and is barren of conodonts. We suggest that the base of the Datsonian Stage in Australia correlates within the *Fryxellodontus inornatus* Subzone of this report and that the base is slightly younger than the base of the Ibexian Series.

REPUBLIC OF KAZAKHSTAN

Apollonov (1991) reviewed the reasons for the Soviet decision to use the base of the *Cordylodus proavus* Zone, locally underlain by *Lotagnostus hedini*, to mark the base of the Ordovician System in southern Kazakhstan. He also emphasized the inadequacies of the first appearance of *Rhabdinopora flabelliformis* as a boundary indicator. Dubinina (1991) compared Ordovician sections in two different paleoenvironments, the Sarykum section in central Kazakhstan and the Batyrbai section in southern Kazakhstan. In both she reported that *Cordylodus proavus* is underlain by *Lotagnostus hedini* and marked the base of the Ordovician System. The conodont succession is strikingly similar to that at the base of the Ibexian in the type area and in a deep-water succession reported by J.F. Taylor and others (1991) in Vermont.

Subsequent collecting at Batyrbai, southern Kazakhstan, by J.F. Miller (unpub. data, 1990) suggests a slight overlap of ranges of *Lotagnostus hedini* and *Cordylodus primitivus* (=*Cordylodus andresi*, this report) as reported by Apollonov and others (1988). However, specimens are rare and the interval is thin, occurring in thinly bedded lime mudstone, so the slight overlap may be merely an artifact of sampling.

JILIN PROVINCE, PEOPLE’S REPUBLIC OF CHINA

Chen and others (1985, 1988) and Chen (1986) documented ranges of conodonts and other fossils from a section near Dayangcha in northeast P.R.C. Their figure 6 (1988) shows ranges of conodonts in one part of the Xiaoyangqiao composite section. This section was under consideration for a global stratotype for the base of the Ordovician System, but it was not approved in 1992 by a postal ballot of the Cambrian-Ordovician Boundary Working Group of the International Union of Geological Sciences. Approximately the lower 10 m of the Xiaoyangqiao composite section is referred to the *Cambrooistodus* Zone, which correlates directly with the *Cambrooistodus minutus* Subzone of this report. Therefore, these strata are pre-Ibexian in age. Younger strata in the Xiaoyangqiao composite section are referred to the *Cordylodus proavus*, *Cordylodus intermedius*, *Cordylodus lindstromi*, and *Cordylodus angulatus–Chosonodina herfurthi* Zones, which correlate with the Skullrockian Stage.

Chen and others (1988) referred the interval from about 10.0 to 28.5 m to the *Cordylodus proavus* Zone and divided it into lower, middle, and upper parts. The lower part correlates with the *Hirsutodontus hirsutus* Subzone of the *Cordylodus proavus* Zone of this report. The middle part correlates with the *Fryxellodontus inornatus* Subzone of this report. The upper part of the *Cordylodus proavus* Zone at Dayangcha correlates, in part, with the *Clavohamulus elongatus* Subzone of this report, but the upper portion of this subzone at Dayangcha has few conodonts that are biostratigraphically diagnostic. Conodont collections from the Dayangcha section contain *Hirsutodontus simplex* from the stratigraphic interval from which Chen and others (1988, fig. 6) collected samples 10 A(1–6) (J.F. Miller, unpub. data). Chen and others (1988) referred this stratigraphic interval to the upper part of the *Cordylodus proavus* Zone, but the presence of

Hirsutodontus simplex indicates that the interval correlates with the *Cordylodus intermedius* Zone of this report. *Iapetognathus* also occurs at higher stratigraphic levels in the Dayangcha section (J.F. Miller, unpub. data).

Ripperdan and others (1993) reported results of carbon isotope and magnetostratigraphic studies of the Dayangcha section and concluded that several hiatuses (or highly condensed intervals) exist. One hiatus was interpreted to occur at the base of the *Cordylodus proavus* Zone and a second slightly higher hiatus at the base of the second division of the *Cordylodus proavus* Zone (=base of *Fryxellodontus inornatus* Subzone of this report). They (Ripperdan and others, 1993, fig. 5) related the two hiatuses to the two stages of the Lange Ranch Eustatic Event of Miller (1992).

CAMBRIAN-ORDOVICIAN BOUNDARY

Selection of the international boundary stratotype for the Cambrian-Ordovician boundary is under consideration by the Cambrian-Ordovician Boundary Working Group of the International Commission on Stratigraphy, International Union of Geological Sciences. Important summaries of the Working Group's studies are found in Henningsmoen (1973), Bassett and Dean (1982), Lu (1984), Chen (1986), and nine articles in a special issue of Geological Magazine (1988, v. 125, no. 4, p. 323–473). Herein, we have purposely refrained from discussion of the relative merits of boundary stratotype proposals and let the biostratigraphic data of the Ibexian Series speak for themselves.

SUMMARY

The North American Ibexian Series, as represented in the Ibex area by its abundantly fossiliferous and exceptionally well exposed strata in laterally contiguous or closely neighboring typical sections in the southern House and Confusion Ranges of west-central Utah, provides an unrivalled composite stratotype, a standard for biostratigraphic subdivision of and correlation within the interval between the end of the North American Cambrian Croixian Series and the beginning of the lower Middle Ordovician Whiterockian Series.

The composite stratotype of the Ibexian Series is a reference section for precise biochronologic correlation over the entire span of Early Ordovician time. It contains a high-resolution biostratigraphy comprising concurrent ranges of trilobites, conodonts, brachiopods, echinoderms, and other fossils. Although graptolites are not present throughout the section they do occur in some of the shaly intervals and add to the utility of the stratotype.

The base of the Ibexian Series is characterized by a distinctive faunal turnover among conodonts from the *Eoconodontus* Zone to the *Hirsutodontus hirsutus* Subzone of the *Cordylodus proavus* Zone and trilobites from the *Saukiella serotina* Subzone of the *Saukia* Zone to the *Eurekia apopsis* Zone. The boundary meets the rigid requirements of the North American Stratigraphic Code (NACSN, 1983) and the International Commission on Stratigraphy (Cowie and others, 1986) for definition of chronostratigraphic units. The sharp biostratigraphic boundary is also marked by several geochemical anomalies that make the boundary one of the more useful lower Paleozoic horizons for global correlation (Miller and others, 1993).

The upper limit of the Ibexian Series is the base of the Rangerian Stage of the Whiterockian Series, recently shown to be marked by conodonts of the *Tripodus laevis* Zone, trilobites and brachiopods of the *Paralenorthis-Orthidiella* Zone (=Zone L of Ross, 1951) (Ross and Ethington, 1991, 1992), and by graptolites of the *Isograptus victoriae* Zone (Finney and Ethington, 1992).

The type Ibexian is a continuous chronostratigraphic reference section for the Lower Ordovician of North America and of Laurentia. No stratigraphic section in North America surpasses the Ibexian composite-stratotype section in excellence of exposure, abundance of fossils, quality of fossil preservation, and accessibility. A brief perusal of figures 1–7 demonstrates that although the stratotype is not a single vertically stacked sequence of layers, the fortuitous array of incremental sections, either contiguous or in close proximity, contributes to the superlative accessibility of the whole.

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APPENDIXES 1–3. TAXONOMIC NOTES

Trilobite, conodont, and brachiopod taxa reported from the Ibexian stratotype section are listed here with reference to original description and illustration. Echinoderms are listed in Appendix 4.

APPENDIX 1. TRILOBITA

Acheilops masonensis Winston and Nicholls, 1967, p. 77–78, pl. 11, figs. 23–25.

Amblycranium cornutum Ross, 1951, p. 67, pl. 13, figs. 1–9.

Amblycranium? *linearus* Young, 1973, p. 96–97, pl. 4, figs. 9–15.

Amblycranium variabile Ross, 1951, p. 64–66, pl. 13, figs. 10–18.

Aulacoparia venta (Hintze, 1953), p. 134, pl. XVI, figs. 6–11.

Aulacoparina impressa Lochman, 1966, p. 537, pl. 61, figs. 1–11.

Aulacoparina quadrata (Hintze, 1953), p. 133, pl. XVI, figs. 1–4.

Bellefontia chamberlaini Clark, 1935. Ross, 1951, p. 98–99, pl. 24, figs. 1–7; pl. 25, figs. 10–15; pl. 22, figs. 1–2; pl. 23, fig. 4. Hintze, 1953, p. 142, pl. IV, figs. 9–13.

Bellefontia ibexensis Hintze, 1953, p. 141, pl. IV, figs. 1–8.

Benthamaspis diminutiva Hintze, 1953, p. 142, pl. XIII, figs. 9–13.

Benthamaspis obreptus (Lochman, 1966), p. 541–542, pl. 62, figs. 1–7; Ross, 1951, p. 120, pl. 29, figs. 20, 21, 24. Fortey, 1979.

Bolbocephalus sp., Hintze, 1953, p. 143–144, pl. IX, fig. 17.

Carolinites ekphymosus Fortey and Droser, 1996, p.97–98, figs. 14.6, 14.7, 14.17.

Carolinites genacinaca Ross, 1951, p. 84, pl. 18, figs. 25, 26, 28–36. Hintze, 1953, pl. XX, figs. 7–9.

Carolinites genacinaca nevadensis Hintze, 1953, pl. XX, figs. 3–6.

Clelandia utahensis Ross, 1951, p. 117, pl. 29, figs. 1–4, 6–9; Hintze, 1953, p. 147, pl. 4, figs. 15–17.

Corbinia apopsis (Winston and Nicholls, 1967). Westrop and Ludvigsen, 1986; Westrop, 1986. (See *Eurekia apopsis* below.)

Cybelopsis cf. *C. speciosa* Poulsen. Hintze, 1953, p. 152–153, pl. XXV, figs. 5, 6, 8–12.

Diacanthaspis? *trispineus* Young, 1973, p. 98–99, pl. 5, figs. 1–14.

Ectenonotus progenitor Fortey and Droser, 1996, p. 93–94, figs. 16.3, 16.7.

Ectenonotus whittingtoni Ross, 1967. Fortey and Droser, 1996, p. 94, figs. 16.1, 16.2.

Euptychaspis kirki Kobayashi, 1935. Winston and Nicholls, 1967, p. 79, pl. 9, fig. 18.

Euptychaspis typicalis Ulrich *in* Bridge, 1931. Winston and Nicholls, 1967, p. 78, pl. 9, fig. 17.

Eurekia apopsis (Winston and Nicholls, 1967), p. 86, pl. 11, figs. 13, 14, 27, 22. Westrop, 1986, p. 77.

Eurekia longifrons Westrop, 1986, p. 78–79, pl. 6, figs. 1–5.

Goniophrys prima Ross, 1951, p. 81–82, pl. 18, figs. 9, 15, 17–20, 22, and 27.

Goniotelina Whittington and Ross, *in* Whittington, 1953, p. 663–667.

Goniotelina brevus (Hintze, 1953), p. 159–160, pl. XXVI, figs. 7–10.

Goniotelina brighti (Hintze, 1953), p. 158–159, pl. XXVI, figs. 1–6.

Goniotelina ensifer Fortey and Droser, 1996, p.81, fig. 6.

Goniotelina wahwahensis (Hintze, 1953), p. 160–161, pl. XXVI, figs. 11–13.

Goniotelina williamsi (Ross, 1951), p. 69–71, pl. 14, figs. 16–22, 25.

Goniotelina? *plicolabeonus* Young, 1973, p. 99–100, pl. 5, figs. 15–22.

Goniotelus? *unicornis* Young, 1973, p. 100, pl. 4, figs. 21–24.

Heterocaryon tuberculatum Rasetti, 1944, p. 241, pl. 36, fig. 55.

Highgatella cordilleri (Lochman, 1964). Winston and Nicholls, 1967, p. 73, pl. 13, figs. 8, 11, 13.

Hillyardina semicylindrica Ross, 1951, p. 71–72, pl. 16, figs. 1–9.

Hintzeia Harrington, 1957, p. 811.

Hintzeia celsaora (Ross, 1951), p. 135, pl. 35, figs. 1–15; pl. 34, figs. 9–12, 20; pl. 35, fig. 29.

Hintzeia firmimarginis (Hintze, 1953), p. 208, pl. XXII, figs. 1–8.

Hyperbolochilus marginauctum Ross, 1951, p. 77–78, pl. 17, figs. 24–27, 30–31, 34–35.

Hystricurus contractus Ross, 1951, p. 48, pl. 10, figs. 4, 6, 7, 10.

Hystricurus flectimembrus Ross, 1951, p. 48–50, pl. 10, figs. 25, 26, 29–33; pl. 11, figs. 16–18, 20–33.

Hystricurus genalatus Ross, 1951, p. 40–42, pl. 8, figs. 1–13; pl. 9, figs. 1–13, 17–19.

Hystricurus lepidus Hintze, 1953, p. 166–167, pl. VII, figs. 10–12.

Hystricurus millardensis Hintze, 1953, p. 168, pl. VI, figs. 17–21.

Hystricurus oculilunatus Ross, 1951, p. 47–48, pl. 10, figs. 1–3, 5, 8, 9, 12.

Hystricurus paragenalatus Ross, 1951, p. 42–45, pl. 8, figs. 14–26; pl. 9, figs. 1–13, 17–19.

Hystricurus politus Ross, 1951, p. 45–47, pl. 9, figs. 23–24, 27, 28, 32–33; pl. 15, figs. 1–6.

Hystricurus robustus Ross, 1951, p. 51–53, pl. 10, figs. 11, 13–16; pl. 14, fig. 27.

Ischyrotoma blanda (Hintze, 1953), p. 155–156, pl. XIX, figs. 6–8.

Ischyrotoma caudanodosa (Ross, 1951), p. 123–125, pl. 35, figs. 18, 22–28; Hintze, 1953, p. 154, pl. XIX, figs. 5, 10.

Ischyrotoma ovata (Hintze, 1953), p. 155, pl. XIX, figs. 1–4.

Ischyrotoma stubblefieldi Ingham, Curry, and Williams, 1985, p. 494–498, figs. 7–9. Fortey and Droser, 1996, p. 91, fig. 15.

Isoteloides flexus Hintze, 1953, p. 172–173, pl. XVII, figs. 2c, 3–8.

Isoteloides polaris Poulsen, 1927. Hintze, 1953, p. 171–172, pl. XVII, figs. 9–15.

Kanoshia Harrington, 1957, p. 811.

Kanoshia? cf. *K. insolita* (Poulsen, 1927). Hintze, 1953, p. 222, pl. 23, figs. 5–13.

Kanoshia? *depressus* Young, 1973, p. 102, 104, pl. 3, figs. 21–27.

Kanoshia reticulata Fortey and Droser, 1996, p. 94–96, fig. 17.

Kawina sexapugia Ross, 1951, p. 127–129, pl. 35, figs. 6, 7, 11, 17, 19–21. *Kawina*? *sexapugia* Ross, Hintze, 1953, p. 178, pl. XXI, fig. 18.

Kawina unicornica Hintze, 1953, p. 179–180, pl. XXVIII, figs. 1–5.

Kawina vulcanus Billings, 1865. (=*Nieskowskia*? sp. of Hintze, 1953, p. 193, pl. XXVIII, figs. 6, 7).

Kawina webbi Hintze, 1953, p. 178–179, pl. XXI, figs. 15–17.

Kawina wilsoni Ross, 1972. Fortey and Droser, 1996, p.97, figs. 14.15, 14.16.

Lachnostoma latucelsum Ross, 1951, p. 95–97, pl. 21, figs. 13–25; pl. 22, figs. 3, 6–8; pl. 23, figs. 5, 6. Hintze, 1953, p. 187, pl. XVIII, figs. 4–16.

Larifugula leonensis (Winston and Nicholls, 1967), p. 75, pl. 11, figs. 16, 20, 21. Generic reassignment Ludvigsen, 1982, p. 79.

Leiocoryphe platycephala Kobayashi, 1935, p. 49, pl. 8, fig. 2.

Leiostegium (Evansaspis) ceratopygoides (Raymond, 1925) Dean, 1989, p. 30–31, pl. 21, figs. 1–3,5, 6, 8, 9, 11, 12; pl. 22, figs. 1, 2, 4, 6; pl. 42, figs. 1, 5. (also Norford in Aitken and Norford, 1967, p. 181, 183).

Leiostegium formosum Hintze, 1953, p. 189–190, pl. VIII, figs. 8–10. (=*L.* (*E.*) *ceratopygoides*)

Leiostegium manitouensis Walcott, 1925. Ross, 1951, p. 105–106, pl. 27, fig. 1.

Licnocephala bicornuta Ross, 1951, p. 109–111, pl. 28, figs. 12–14.

Licnocephala? *cavigladius* Hintze, 1953, p. 190, pl. X, figs. 1–5.

Macronoda cf. *M. prima* Lochman, 1964. Westrop, 1986, p. 40, pl. 11, figs. 6–8.

Macropyge gladiator Ross, 1951, p. 122–123, pl. 30, figs. 14, 22; pl. 27, figs. 8–10.

Madaraspis magnifica Fortey and Droser, 1996, p. 88–89, fig. 13.

Menoparia genalunata Ross, 1951, p. 88–89, pl. 20, figs. 13–24, 28, 29, 34–35.

Missisquoia depressa Stitt, 1971, p. 25, pl. 8, figs. 5–8.

Missisquoia typicalis Shaw, 1951. Winston and Nicholls, 1967, p. 88–89, pl. 13, figs. 2, 5–6, 10, 12, 15, 18.

Opipeuter angularis (Young, 1973), p. 112–114, pl. 1, figs. 21–22, 25–27. Fortey, 1979, p. 68.

Pachycranium? sp. of Ross, 1951, p. 73, pl. 17, figs. 4–6, 9–11, 14, 15.

Paenebeltella vultulata Ross, 1951, p. 79, pl. 18, figs. 1, 2, 5, 6; pl. 19, fig. 10.

Parabellefontia concinna Hintze, 1953, p. 194–195, pl. III, figs. 1–8.

Parahystricurus bispicatus Hintze, 1953, p. 195–196, pl. VIII, figs. 3–4.

Parahystricurus carinatus Ross, 1951, p. 60, figs. 23–27, 30–32, 35–37.

Parahystricurus fraudator Ross, 1951, p. 58–59, pl. 12, figs. 1–16.

Paraplethopeltis genarectus Hintze, 1953, p. 204, pl. VII, figs. 6–9.

Paraplethopeltis? *genacurvus* Hintze, 1953, p. 202–204, pl. VII, figs. 1–5.

Peltabellia peltabella (Ross, 1951), p. 76–77, pl. 17, figs. 7, 8, 12, 13, 16–22. Whittington, 1953, p. 662.

Peltabellia sp. A of Hintze, 1953, p. 174, 175, pl. X, figs. 7–10.

Petigurus inexpectatus Fortey and Droser, 1996, p. 82, fig. 7.1–7.7.

Plethometopus armatus (Billings, 1860). Rasetti, 1959, p. 383, pl. 53, figs. 1–8; pl. 52, fig. 14.

Presbynileus elongatus (Hintze, 1953), p. 199, pl. XII, figs. 2–5. Hintze, 1954, p. 119.

Presbynileus Hintze, 1954, p. 119.

Presbynileus ibexensis (Hintze, 1953), p. 199, pl. XII, fig. 6–ff. Hintze, 1954, p. 119.

Presbynileus utahensis (Hintze, 1953), p. 200–201, pl. XIII, figs. 1–4. Hintze, 1954, p. 119.

Protopliomerella Harrington, 1957, p. 811–812.

Protopliomerella contracta (Ross, 1951), p. 136–137, pl. 33, figs. 15–19, 22–32. Demeter, 1973, p. 59.

Protopliomerella pauca Demeter, 1973, p. 59–60, pl. 4, figs. 3, 13, 14.

Protopliomerops? *quattuor brevis* Young, 1973, p. 106, pl. 3, figs. 1, 5–7, 9–10.

Protopliomerops? *quattuor* Hintze, 1953, p. 209, pl. XXI, figs. 9–14.

Protopresbynileus Hintze, 1954, p. 119.

Protopresbynileus willdeni (Hintze, 1953), p. 224–225, pl. XV, figs. 14–17; Hintze, 1954, p. 119.

Psalikilopsis cuspidicauda Ross, 1953, p. 639–640, pl. 63, figs. 2–9, 12.

Psalikilopsis Ross, 1953, p. 638.

Psalikilopsis? *alticapitalis* Young, 1973, p. 106–108, pl. 4, figs. 1–8.

Psalikilus paraspinosum Hintze, 1953, p. 213, pl. IX, figs. 4, 5.

Psalikilus pikum Hintze, 1953, p. 214, pl. IX, fig. 1.

Psalikilus spinosum Hintze, 1953, p. 212–213, pl. IX, figs. 3, 6, 7.

Psalikilus typicum Ross, 1951, p. 62–63, pl. 11, figs. 1–5, 8, 9, 13, 14, 19.

Psephothenaspis glabrior Fortey and Droser, 1996, p. 87, fig. 11.

Psephothenaspis microspina Fortey and Droser, 1996, p. 85–86, fig. 10.

Psephothenaspis pseudobathyurus (Ross), 1967, p. D20, pl. 6, figs. 16–23. Fortey and Droser, 1996, figs. 8.2, 8.5, 9.1–9.9.

Pseudoclelandia cornupsittaca Ross, 1951, p. 119, pl. 29, figs. 11, 12, 13, 16, 19.

Pseudoclelandia fluxafissura Ross, 1951, p. 119–120, pl. 29, figs. 14, 17, 18.

Pseudoclelandia lenisora Ross, 1951, pl. 29, figs. 5, 10, 15.

Pseudocybele altinasuta Hintze, 1953, p. 216, pl. XXIV, figs. 1, 2.

Pseudocybele lemurei Hintze, 1953, p. 217, pl. XXIV, figs 3–7.

Pseudocybele nasuta Ross, 1951, p. 137–140, pls. 33, 34; Hintze, 1953, p. 215, pl. XXIV, figs. 8–11.

Pseudohystricurus obesus Ross, 1951, p. 74, pl. 16, figs. 25, 30, 34.

Pseudokainella? *armatus* Hintze, 1953, p. 218, pl. V, figs. 1–5.

Pseudomera arachnopyge Fortey and Droser, 1996, p. 96–97, fig.18.

Pseudoolinoides aspinosus Fortey and Droser, 1996, p. 87–88, fig. 12.

Ptyocephalus Whittington, 1948, p. 567–572.

Ptyocephalus accliva (Hintze, 1953), p. 185–186, pl. XIV, figs. 6, 16, 17; pl. XV, figs. 1, 2. Whittington, 1948, p. 567–572.

Ptyocephalus declivita (Ross, 1951), p. 91–94, pl. 21, figs. 1–12. Hintze, 1953, p. 183, pl. XV, figs. 3, 4, 9–12. Whittington, 1948, p. 567–572.

Ptyocephalus fillmorensis (Hintze, 1953), p. 186. pl. XIV, figs. 1–5.

Ptyocephalus yersini (Hintze, 1953), p. 184–185, pl. XIV, figs. 7–15.

Punka cf. *P. nitida* (Billings), Fortey and Droser, 1996, p. 91, figs. 14.5, 14.7, 14.8–14.10, 14.14.

Remopleuridiella caudalimbata Ross, 1951, p. 86–87, pl. 20, figs. 1–12.

Rossaspis Harrington, 1957, p. 812.

Rossaspis superciliosa (Ross, 1951), p. 133–135, pl. 31, figs. 16–26; pl. 34, figs. 5–8, 19.

Saukiella pepinensis (Owen, 1852). Longacre, 1970, p. 51, pl. 5, figs. 9–11.

Scinocephalus solitecti Ross, 1951, p. 89–91, pl. 20, figs. 25, 26, 27, 30–33, 36–38.

Shumardia exopthalmus Ross, 1967, p. 9–10, pl. 10, figs. 23–33.

Stenorhachis genalticurvatus (Hintze, 1953), p. 173, pl. XVII, figs. 1, 2a, 2b; pl. XVIII, figs. 1–3.

Symphysurina brevispicata Hintze, 1953, p. 236–237, pl. III, figs. 9–17.

Symphysurina bulbosa Lochman, 1964. Stitt, 1977, p. 37, pl. 5, figs. 1–6.

Symphysurina globocapitella Hintze, 1953, p. 232–233, pl. I, figs. 1–9.

Symphysurina sp. B of Ross, 1951, p. 116, pl. 28, figs. 19, 23, 24, 30.

Symphysurina uncaspicata Hintze, 1953, p. 233–234, pl. II, figs. 1–7.

Symphysurina woosteri Walcott, 1925. Ross, 1951, pl. 23, figs. 7–12.

Symphysurina cf. *S. cleora* (Walcott, 1925). Hintze, 1953, p. 234–236, pl. II, figs. 8–11.

Tesselacauda depressa Ross, 1951, p. 130–131, pl. 31, fig. 27–31; pl. 34, figs. 1–4, 18.

Triarthropsis nitida Ulrich *in* Bridge, 1931. Winston and Nicholls, 1967, p. 78, pl. 11, figs. 27–28.

Trigonocerca typica Ross, 1951, p. 104, pl. 26, figs. 5–13. Hintze, 1953, pl. XI, figs. 6–11.

Trigonocerca typica piochensis Hintze, 1953, p. 238, pl. XI, figs. 12–18.

Trigonocercella acuta Hintze, 1953, p. 239–240, pl. XI, figs. 1–5.

Uromystrum cf. *U. validum* (Billings), Fortey and Droser, 1996, p. 91, figs. 14.1–14.4.

Xenostegium cf. *X. acuminiferentis* (Ross, 1951), p. 99–100, pl. 24, figs. 15–18; pl. 25, figs. 6–9. Hintze, 1953, p. 241, pl. V, figs. 19–24.

Xenostegium franklinense Ross, 1951, p. 102, pl. 24, figs. 8–14; pl. 25, figs. 1–6. Hintze, 1953, p. 240, pl. 5, figs. 13–18.

APPENDIX 2. CONODONTA

Acanthodus lineatus (Furnish, 1938), p. 328 p. 41, figs. 33, 34. Ethington and Clark, 1981, p. 17, pl. 1, fig. 7.

Acodus deltatus Lindström, 1955, p. 544, pl. 3, fig. 30. Ethington and Clark, 1981, p. 18–19, pl. 1, text–figs. 1–6.

Acodus emanuelensis McTavish, 1973, p. 40–41, pl. 2, figs. 16–21, text-fig. 3e–i. Ethington and Clark, 1981, p. 19–20, pl. 1, figs. 9–13, text-fig. 5.

aff. *Acodus gladiatus* Lindström, 1955, p. 544–545, pl. 3, figs. 10, 11 (non fig. 12). Ethington and Clark, 1981, p. 20, pl. 1, fig. 14.

Acodus oneotensis Furnish, 1938, p. 325, pl. 42, figs. 26–29. Ethington and Clark, 1981, p. 20–21, pl. 1, fig. 16.

Acodus sp. 1 s.f. Ethington and Clark, 1981, p. 21, pl. 1, fig. 17, text-fig. 6.

Acodus sp. 2 Ethington and Clark, 1981, p. 21, pl. 1, figs. 19, 20.

Acodus sp. 3 Ethington and Clark, 1981, p. 22, pl. 1, figs. 22, 23, text-fig. 8.

Acodus sp. 4 Ethington and Clark, 1981, p. 22–23, pl. 1, fig. 25.

aff. *Acontiodus latus* Pander, 1856. Ethington and Clark, 1981, p. 23–24, pl. 1, fig. 18, text-fig. 9.

?*Acontiodus* sp. Ethington and Clark, 1981, p. 24–25, pl. 1, fig. 21.

Albiconus postcostatus Miller, 1980, p. 8, fig. 2.

Aloxoconus iowensis (Furnish, 1938), p. 325–326, pl. 42, figs. 16–17, text-fig. 1L. Ethington and Clark, 1981, p. 23, pl. 1, fig. 15.

Aloxoconus propinquus (Furnish, 1938), p. 326, pl. 42, figs. 13–15. Ethington and Clark, 1981, p. 24, pl. 1, fig. 26.

Aloxoconus staufferi (Furnish, 1938), p. 326, text-fig. 1K, pl. 42, fig. 11 (only). Ethington and Clark, 1981, p. 24, pl. 1, fig. 24.

Cambrooistodus cambricus (Miller, 1969), p. 431, pl. 66, figs. 8–12. Miller, 1980, p. 9–11, pl. 1, fig. 9, text-figs. 3A, 4E.

Cambrooistodus minutus (Miller, 1969), p. 433, pl. 66, figs. 1–4. Miller, 1980, p. 11, pl. 1, fig. 8, text-fig. 4F.

Chionoconus robustus (Serpagli, 1974), p. 69, pl. 18, figs. 31–4d, pl. 28, figs. 12, 13. Ethington and Clark, 1981, p. 94, pl. 10, figs. 25–27.

Clavohamulus bulbousus (Miller, 1969), p. 435, pl. 64, figs. 1–5.

Clavohamulus densus Furnish, 1938. Ethington and Clark, 1981, p. 30, pl. 2, fig. 21.

Clavohamulus elongatus Miller, 1969, p. 422, pl. 64, figs. 17–18.

Clavohamulus hintzei Miller, 1969, p. 422–423, pl. 64, figs. 19–24.

Clavohamulus sp. Ethington and Clark, 1981, p. 31, pl. 2, fig. 22.

Colaptoconus quadraplicatus (Branson and Mehl, 1933), p. 63, pl. 4, figs. 14, 15. Ethington and Clark, 1981, p. 103–104, pl. 11, figs. 24, 30.

Cordylodus andresi Viira and Sergeeva, 1987, p. 147–148, pl. I, figs. 1–8, pl. II, figs. 1, 2, 4, text-figs. 2-18, 2-33, 2-36, 2-42 to 2-59, 4-28.

Cordylodus angulatus Pander, 1856. Ethington and Clark, 1981, p. 34, pl. 2, fig. 24.

Cordylodus caseyi Druce and Jones, 1971, p. 67–68, pl. 2, figs. 9a–12c, text-figs. 23d, 23e. Ethington and Clark, 1981, p. 31–32, pl. 2, fig. 25.

Cordylodus drucei Miller, 1980, p. 16, pl. 1, figs. 20, 21, 25.

Cordylodus intermedius Furnish, 1938, p. 338, pl. 42, fig. 31. Miller, 1980, p. 17, pl. 1, fig. 16, text-fig. 4L. Ethington and Clark, 1981, p. 32, pl. 2, fig. 17.

Cordylodus lindstromi Druce and Jones, 1971, p. 68–69, pl. 1, figs. 7a–9b, pl. 2, figs. 8a–c, text-fig. 23h. Miller, 1980, p. 18, pl. 1, figs. 18, 19, text-figs 4I, J.

Cordylodus prion Lindström, 1955, p. 552–553, pl. 5, figs. 14–16. Ethington and Clark, 1981, p. 33, pl. 2, figs. 13, 14.

Cordylodus proavus Müller, 1959, p. 448–449, pl. 15, figs. 11, 12, 18, text-fig. 3B. Miller, 1969, p. 424, pl. 65, figs. 37–46. Miller, 1980, p. 19–20, pl. 1, figs. 14, 15. Ethington and Clark, 1981, p. 33–34, pl. 2, figs. 18, 19.

Cordylodus sp. A Ethington and Clark, 1981, p. 35, pl. 2, fig. 26.

Cornuodus longibasis (Lindström, 1955), p. 564, pl. 3, fig. 31. Serpagli, 1974, p. 43, pl. 7, figs. 2a, b, pl. 20, fig. 12.

Cristodus ethingtoni Ji and Barnes, 1994 (=New Genus 2 of Ethington and Clark, 1981), Ethington and Clark, 1981, p. 117, pl. 13, figs. 18–20, 24. Ji and Barnes, 1994, p. 33, pl. 6, figs. 1–4.

Drepanodiform 1 Ethington and Clark, 1981, p. 41, pl. 3, figs. 10, 15.

Drepanodus arcuatus Pander. Ethington and Clark, 1981, p. 43, pl. 3, figs. 22–24, text-fig. 13.

Drepanodus gracilis (Branson and Mehl) *sensu* Lindström, 1955, p. 562–563, pl. 4, fig. 44, pl. 5, figs. 6, 7. Ethington and Clark, 1981, p. 37–38, p. 3, fig. 7, text-fig. 10.

Drepanodus sp. 1 Ethington and Clark, 1981, p. 40, pl. 3, fig. 13, text-fig. 11.

Drepanodus sp. 2 Ethington and Clark, 1981, p. 40, pl. 3, fig. 14, text-fig. 12.

aff. *Drepanoistodus basiovalis* (Sergeeva). Ethington and Clark, 1981, p. 42–43, pl. 3, figs. 25–27, text-fig. 13.

aff. *Drepanoistodus forceps* (Lindström). Ethington and Clark, 1981, p. 43, pl. 3, figs. 22–24, text-fig. 13.

Eoconodontus notchpeakensis (Miller, 1969), p. 438, pl. 66, figs. 13–29. Miller, 1980, p. 22, pl. 1, figs. 10–12, text-figs. 3D, E.

Eucharodus parallelus (Branson and Mehl, 1933), p. 59, pl. 4, fig. 17, Ethington and Clark, 1981, p. 38–39, pl. 3, fig. 8.

Eucharodus simplex (Branson and Mehl) *sensu* Druce and Jones, 1971, p. 74, pl. 13 figs. 1a–4b, text-fig. 24b. Ethington and Clark, 1981, p. 39, pl. 3, fig. 9.

Eucharodus toomeyi (Ethington and Clark, 1964), p. 690, pl. 113, fig. 17, pl. 114, fig. 22, text-fig. 2H. Ethington and Clark, 1981, p. 39–40, pl. 3, fig. 11.

Fahraeusodus marathonensis (Bradshaw, 1969), p. 1151, pl. 137, figs. 13–15, text-figs. 3S, T, U. Ethington and Clark, 1981, p. 55–56, pl. 5, figs. 14, 19, 20, 23, 24, 27.

Fryxellodontus inornatus Miller, 1969, p. 426, pl. 65, figs. 1–10, 12–16, 23–25.

Fryxellodontus lineatus Miller, 1969, p. 429, pl. 65, figs. 17–22, 26–29.

Furnishina Müller, 1959, p. 451.

Hirsutodontus hirsutus Miller, 1969, p. 431, pl. 64, figs. 25, 26, 29–31.

Hirsutodontus rarus Miller, 1969, p. 431, pl. 64, figs. 36–42.

Hirsutodontus simplex (Druce and Jones, 1971), p. 98–99, pl. 6, figs. 1a–5b, text-fig. 31. Miller, 1969, pl. 64, figs. 27, 28, 32–35.

Histiodella altifrons Harris, 1962, p. 208–209, pl. 1, figs. 4a–c. Ethington and Clark, 1981, p. 447, pl. 4, figs. 5–12.

Histiodella donnae Repetski, 1982, p. 25, pl. 8, figs. 6, 7. Ethington and Clark, 1981, p. 50, pl. 5, fig. 18.

Histiodella minutiserrata Mound, 1965, p. 21–22, pl. 3, figs. 1–3. Ethington and Clark, 1981, p. 48–49, pl. 5, fig. 11.

Iapetognathus Landing, 1982, in Fortey and others, 1982 p. 124–126, text-figs. 6, 8.

Iapetognathus sprakersi Landing, Westrop, and Knox, 1996, p. 672–673, figs. 5.1–5.3.

Juanognathus jaanussoni Serpagli, 1974, p. 50–51, pl. 11, figs. 1–12, pl. 23, figs. 1–5, text-fig. 9. Ethington and Clark, 1981, p. 50, pl. 5, figs. 12, 13.

Juanognathus variabilis Serpagli, 1974, p. 49–50, pl. 11, figs. 1–7, pl. 22, figs. 6–17, text-fig. 8. Ethington and Clark, 1981, p. 50–51, pl. 5, figs. 8–10, 17.

Jumudontus gananda Cooper, 1981, p. 170–172, pl. 31, fig. 13. Ethington and Clark, 1981, p. 51–52, pl. 2, figs. 9, 10.

Laurentoscandodus triangularis (Furnish, 1938), p. 330–331, pl. 42, fig. 22, text-fig. 1P. Ethington and Clark, 1981, p. 70–71, pl. 7, figs. 15, 18, 22, 23. Landing, Westrop, and Knox, 1996, p. 673–674, figs. 8.12–8.29, 9.14, 9.18–9.21.

Loxodus bransoni Furnish, 1938, p. 339, pl. 42, figs. 33–34, text-fig. 2A. Ethington and Clark, 1981, p. 52, pl. 5, fig. 15.

Macerodus dianae Fåhraeus and Nowlan, 1978, p. 461, pl. 1, figs. 26, 27. Ethington and Clark, 1981, p. 53–54, pl. 5, fig. 16.

Microzarkodina flabellum (Lindström, 1955), p. 587, pl. 6, figs, 23–25. Ethington and Clark, 1981, p. 54–55, pl. 4, fig. 2, pl. 5, figs. 21, 22, 25, 26.

Monocostodus sevierensis (Miller, 1969), p. 418, pl. 63, figs. 25–31, pl. 64, figs. 49–54. Miller, 1980, p. 26–27, pl. 2, figs. 8, 9; text-fig. 4U.

Oepikodus communis (Ethington and Clark, 1964), p. 690, 692, pl. 6, figs. 18, 22, 25. Ethington and Clark, 1981, p. 61–62, pl. 6, figs. 18, 22, 25.

aff. *Oepikodus minutus* (McTavish, 1973), p. 42–43, pl. 3, figs. 3, 14, 17. Ethington and Clark, 1981, p. 62–65, pl. 6, figs. 19, 23, 24, 26–28.

Oistodus bransoni Ethington and Clark, 1981, p. 65–66, pl. 7, figs. 1–3, 5, 6, text-fig. 17.

Oistodus ectyphus Smith, 1991, p. 46, text-fig. 27a; (=*Oistodus* sp. 2 of Ethington and Clark, 1981, p, 71, pl. 8, fig. 1, text-fig. 18).

Oistodus hunickeni Serpagli, 1974, p. 54–55, pl. 13, figs. 1a–3b, pl. 23, figs. 6, 7. Ethington and Clark, 1981, p. 67, pl. 7, fig. 8.

Oistodus inaequalis Pander, 1856. Ethington and Clark, 1981, p. 67–68, pl. 7, text-fig. 7.

aff. *Oistodus inaequalis* Pander. Ethington and Clark, 1981, p. 68, pl. 7, fig. 8, text-fig. 16.

Oistodus sp. 1 Ethington and Clark, 1981, p. 71, pl. 7, figs. 16, 19–21, text-fig. 17.

Oistodus sp. 4 Ethington and Clark, 1981, p. 72, pl. 8, fig. 3.

Oneotodus costatus Ethington and Brand, 1981, p. 242–245, text-figs. 1B. D, G, H, 2A, D–M; (=aff. *Oneotodus simplex* (Furnish) of Ethington and Clark, 1981, p. 73–74, pl. 8, fig. 7).

aff. *Paltodus*? *jemtlandicus* Löfgren, 1978, p. 65, pl. 4, figs. 1–3, 8. Ethington and Clark, 1981, p. 75, pl. 8, fig. 10, text-fig. 19.

Paltodus spurius Ethington and Clark, 1964, p. 695, pl. 114, figs. 3, 10, text-fig. 28. Ethington and Clark, 1981, p. 76, pl. 8, figs. 9, 13.

Parapanderodus asymmetricus (Barnes and Poplawski, 1973), p. 781–782, pl. 21, figs. 12, 12a, 14, 16, text-fig. 2A. Ethington and Clark, 1981, p. 83–84, pl. 9, figs. 11, 12, 14, 19 (also includes *Scolopodus paracornuformis* Ethington and Clark, 1981, p. 102, pl. 11, fig. 21, text-fig. 25).

Parapanderodus emarginatus (Barnes and Tuke, 1970). Ethington and Clark, 1981, p. 99–100, pl. 11, figs. 15, 16.

Parapanderodus filosus (Ethington and Clark, 1964), p. 699, pl. 114, figs. 12, 17–19. Ethington and Clark, 1981, p. 100, pl. 11, fig. 22.

Parapanderodus striatus (Graves and Ellison), 1941, p. 11, pl. 1, figs. 3, 12 (=“*Scolopodus*” *gracilis* Ethington and Clark, 1981, p. 100–101, pl. 11, figs. 27, 28).

Paroistodus parallelus (Pander, 1856). Ethington and Clark, 1981, p. 100–101, pl. 11, figs. 27, 28.

Phakelodus elongatus (An, 1983 *in* An and others), p. 125, pl. 5, figs. 4, 5. Müller and Hinz, 1991, p. 32, pl. 1, figs. 1–5, 14, 15, 18–20, 22.

Problematoconites perforatus Müller, 1959, p. 471, pl. 15, fig. 17. Müller and Hinz, 1991, p. 36, pl. 23, figs. 1–10, 14, 15, 18–20, 22.

Proconodontus muelleri Miller, 1969, p. 437, pl. 66, figs. 30–40.

Proconodontus serratus Miller, 1969, p. 438, pl. 66, figs. 41–44.

Prooneotodus gallatini (Müller, 1959), p. 457, pl. 13, figs. 5–10, 18. Müller and Hinz, 1991, p. 37, pl. 24, figs. 1–28.

Prooneotodus rotundatus (Druce and Jones, 1971), p. 62–63, pl. 9, figs. 10a–13b, text-figs. 22c, d.

Prosaggitodontus eureka (Müller, 1959), p. 461, pl. 14, fig. 6. Miller, 1969, p, 438, pl. 65, figs. 30–36, text-fig. 5J.

aff. *Protopanderodus arcuatus* (Lindström, 1955), p. 547, pl. 2, figs. 1–4. Ethington and Clark, 1981, p. 83, pl. 9, fig. 10.

Protopanderodus elongatus Serpagli, 1974, p. 73–75, pl. 16, figs. 8–11, pl. 25, figs. 13–16, pl. 30, fig. 4, text-fig. 16. Ethington and Clark, 1981, p. 84, pl. 9, fig. 15.

Protopanderodus gradatus Serpagli, 1974, p. 75–77, pl. 15, figs. 5a–8b, pl. 26, figs. 11–15, pl. 30, figs. 1a, b, text-fig. 17. Ethington and Clark, 1981, p. 84–85, pl. 9, figs. 16, 17, 20, 21.

Protopanderodus leonardii Serpagli, 1974, p. 77–79, pl. 16, figs. 1–4, pl. 27, figs. 12–16. Ethington and Clark, 1981, p. 85, pl. 9, figs. 18, 22, 23.

Protoprioniodus aranda Cooper, 1981, p. 175–176, pl. 30, figs. 1, 6, 7, 10, 12. Ethington and Clark, 1981, p. 86–87, pl. 90, figs. 24–30.

Protoprioniodus papiliosus (van Wamel, 1974), p. 76–77, pl. 1, figs. 18–20. Ethington and Clark, 1981, p. 87–88, pl. 10, fig. 5.

?*Reutterodus andinus* Serpagli, 1974, p. 79–81, pl. 17, figs. 7a, b, 8a–d, pl. 28, figs. 4, 8. Ethington and Clark, 1981, p. 412–423, pl. 19, figs. 4–7.

Reutterodus borealis Repetski, 1982, p. 41–42, pl. 19, figs. 4–7 (=*Reutterodus* sp. Ethington and Clark, 1981, p. 91–92, pl. 10, figs. 14–16, 19).

Rossodus manitouensis Repetski and Ethington, 1983, p. 289–301, figs. 1–4 (=New Genus 3 Ethington and Clark, 1981, p. 118–119, pl. 13, figs. 21–23, 25–27).

Rotundoconus An and Zhang *in* An and others, 1983, p. 135–137.

Scalpellodus striatus Ethington and Clark, 1981, p. 92–93, pl. 10, figs. 23, 24.

Scandodus americanus Serpagli, 1974, p. 291–292, pl. 16, figs. 6a–7b, pl. 26, figs. 16–17, pl. 30, fig. 10, text-fig. 22.

aff. *Scandodus flexuosus* Barnes and Poplawski, 1973, p. 785–786, pl. 2, figs. 1–4, text-fig. 2L. Ethington and Clark, 1981, p. 93–94, pl. 10, figs. 20–22, text-fig. 21.

Scandodus sp. 1 Ethington and Clark, 1981, p. 96–97, pl. 11, figs. 6, 7, text-fig. 22.

Scandodus sp. 2 Ethington and Clark, 1981, p. 97, pl. 11, figs. 8, 9, text-fig. 23.

Scandodus sp. 3 Ethington and Clark, 1981, p. 97–98, pl. 11, fig. 10, text-fig. 24.

Scandodus sp. 4 Ethington and Clark, 1981, pl. 11, fig. 11.

Scandodus sp. 6 Ethington and Clark, 1981, p. 98, pl. 11, figs. 17, 18.

Scolopodus floweri Repetski, 1982, p. 47–48, pl. 24, figs. 7, 9, 10, pl. 25, figs. 1, 4 (reported by Ethington and Clark, 1981, p. 75–76, pl. 8, figs. 5,6, text-fig. 20, as aff. *Paltodus sexplicatus* (Jones) *sensu* Abaimova).

Scolopodus multicostatus Barnes and Tuke, 1970, p. 92–93, pl. 18, figs. 5, 9, 15, 16, text-fig. 6D. Ethington and Clark, 1981, p. 101–102, pl. 11, figs. 19, 20.

aff. *Scolopodus rex* Lindström, 1955, p. 595–596, pl. 3, fig. 32. Ethington and Clark, 1981, p. 104–105, pl. 12, figs. 1, 2.

?*Scolopodus sexplicatus* Jones, 1971, p. 65–67, pl. 5, figs. 4a–c, 7a–c, 8a–c, pl. 9, figs. 4a–c, text-figs. 16a–c. Ethington and Clark, 1981, p. 105, pl. 12, figs. 3,4.

aff. *Scolopodus striatus* Pander, 1856. Ethington and Clark, 1981, p. 105, pl. 12, figs. 5, 6.

Scolopodus sulcatus Furnish, 1938, p. 325–334, pl. 41, figs. 14, 15, pl. 42, figs. 26–29. Ethington and Clark, 1981, p. 105–106, pl. 12, figs. 7, 8. Repetski, 1982, p. 126, text-fig. 2B–E.

?*Scolopodus* sp. Ethington and Clark, 1981, p. 106, pl. 12, figs. 9–11.

Scolopodiform A Ethington and Clark, 1981, p. 106, pl. 12, fig. 27.

Scolopodiform B Ethington and Clark, 1981, p. 106–107, pl. 12, fig. 13, text-fig. 28.

Scolopodiform C Ethington and Clark, 1981, p. 107, pl. 12, fig. 4, text-fig. 29.

Scolopodiform D Ethington and Clark, 1981, p. 107, pl. 12, figs. 15–17, 23, text-fig. 30.

Scolopodiform E Ethington and Clark, 1981, p. 107–108, pl. 12, fig. 18, text-fig. 31.

Semiacontiodus lavadamensis (Miller, 1969), p. 420, pl. 64, figs. 55–61. Miller, 1980, p. 33, pl. 2, fig. 4.

Semiacontiodus nogamii Miller, 1969, p. 421, pl. 63, figs. 11–20, 41–50. Miller, 1980, p. 32, pl. 2, figs. 10–12, text-figs. 4V, W.

Teridontus nakamurai (Nogami, 1967), p. 216–217, pl. 1, figs. 9–13, text-figs. 3A–E. Miller, 1980, p. 34, pl. 2, figs. 15, 16, text-fig. 4O.

Toxotodus amphigyus Smith, 1991, p. 64–65, text-figs. 37a–d.

Tripodus laevis Bradshaw, 1969, p. 1164, pl. 135, figs. 9, 10. Ethington and Clark, 1981, p. 110–112, pl. 122, figs. 24, 25, 27–29, text-fig. 112.

Tropodus comptus (Branson and Mehl, 1933), p. 61, pl. 4, fig. 9. Ethington and Clark, 1981, p. 114–116, pl. 13, figs. 6, 7, 11–13, text-fig. 34.

Ulrichodina abnormalis (Branson and Mehl, 1933), p. 57, pl. 4, figs. 24, 25. Ethington and Clark, 1981, p. 112, pl. 12, fig. 31.

Ulrichodina cristata Harris and Harris, 1965, p. 40–41, pl. 1, figs. 5a–d. Ethington and Clark, 1981, p. 112–113, pl. 12, figs. 22, 30.

Ulrichodina deflexa Furnish, 1938, p. 335–336, pl. 41, figs. 23–24. Ethington and Clark, 1981, p. 113, pl. 13, figs. 1, 2.

Ulrichodina? *simplex* Ethington and Clark, 1981, p. 113, pl. 13, figs. 3, 4, 9.

?*Ulrichodina wisconsinensis* Furnish, 1938, p. 335, pl. 41, figs. 19, 20. Ethington and Clark, 1981, p. 113–114, pl. 13, fig. 15.

?*Ulrichodina* sp. Ethington and Clark, 1981, p. 114, pl. 13, fig. 8.

Utahconus tenuis Miller, 1980, p. 36, pl. 2, figs. 5–7.

Utahconus utahensis (Miller, 1969), p. 436, pl. 63, figs. 21–24, 33–40, pl. 64, figs. 46–48. Miller, 1980, p. 35, pl. 2, figs. 1, 2, text-figs. 3B, F, G.

Variabiloconus bassleri (Furnish, 1938), p. 331, pl. 42, fig. 1. Ethington and Clark, 1981, p. 116–117, pl. 8, figs. 11–12.

?*Walliserodus ethingtoni* (Fåhraeus) *sensu* Löfgren, 1978, p. 114–116, pl. 4, figs. 27–35, text-fig. 33. Ethington and Clark, 1981, p. 116–117, pl. 13, figs. 10, 14–16, text-fig. 35.

Westergaardodina Müller, 1959, p. 465–467.

? New Genus 1 Ethington and Clark, 1981, p. 117, pl. 13, fig. 17.

APPENDIX 3. BRACHIOPODA

Diparelasma rowelli Ross, 1968, p. H7, pl. 2, figs. 3–10, 13.

Diparelasma cf. *D. transversa* Ulrich and Cooper, 1938. Ross, 1968, p. H8, pl. 1, figs. 14–17; pl. 2, figs. 1, 2.

Hesperonomia fontinalis (White). Ross, 1968, p. H5, pl. 1, figs. 1–9.

Hesperonomia cf. *H. dinorthoides* Ulrich and Cooper, 1938. Ross, 1968, p. H5–H6, pl. 1, figs. 10–13.

Syntrophopsis cf. *S. polita* Ulrich and Cooper, 1938, p. 237–238, pl. 51C, figs. 23, 24, 27, 30, 31.

Tritoechia loganensis Ross, 1968, p. H8–H9, pl. 3, figs. 8–18.

Hesperonomiella minor (Walcott). Ulrich and Cooper, 1938, p. 124, pl. 21, fig. 28. Cooper, 1956, p. 337, pl. 121H, figs. 20, 22). Jensen, 1967, p. 84–85, pl. 2, figs. 16–19.

APPENDIX 4. ECHINODERM BIOSTRATIGRAPHY

BY JAMES SPRINKLE[1] *AND* THOMAS E. GUENSBURG[2]

INTRODUCTION

In this section, we plot stratigraphic ranges of echinoderms from the Lower and Middle Ordovician Fillmore Formation, Wah Wah Limestone, Kanosh Shale, and Lehman Formation in the Ibex area of western Utah (pl. 1, chart *C*). Relatively few echinoderms previously have been reported or described from these units. (See Lane, 1970; Paul, 1972; Kelly and Ausich, 1978, 1979; Hintze, 1979; Guensburg and Sprinkle, 1990, 1992a; Blake and Guensburg, 1993.) We have also included comments on the stratigraphy and physical correlations of Lower Ordovician stratigraphic sections in western Utah based on findings made during our recent field work (James Sprinkle and T.E. Guensburg, unpub. data, 1989–91).

IBEX AREA, WESTERN UTAH

Our field work in western Utah during the summers of 1989–1991 concentrated on the Fillmore Formation and the base of the overlying Wah Wah Limestone. A total of 140 partial or complete echinoderms were collected from these units at 25 localities, nearly half of which were along or near measured sections described by Hintze (1973). Other echinoderm localities where tied to nearby measured sections and Hintze's composite section by using distinctive mound or reef horizons, measurements from key features in his informal members (1973, p. 10–11), and by direct tracing of beds along strike.

The Fillmore Formation is a thick shallow-water unit containing a wide variety of lithologies (Hintze, 1973; Dattilo, 1988, 1993), including flat-pebble conglomerates, limy siltstones, mega-ripplemarked grainstones, sponge-algal mounds, and interbedded micrites or shales. Although echinoderm debris is common, especially in coarser lithofacies throughout the formation, complete echinoderm specimens are rare, widely scattered, and sometimes difficult to collect. We collected complete echinoderms at specific horizons throughout the Fillmore (pl. 1, chart *C*). Gaps between productive horizons are characterized by poor exposure and (or) unfavorable lithofacies. Two distinct echinoderm assemblages were found in different lithologies of the Fillmore, implying that substrate was an important factor in the diversification of echinoderms during the Ordovician radiation (Sprinkle and Guensburg, 1991; Guensburg and Sprinkle, 1992a, 1992b). Seventy-eight specimens of crinoids make that group dominant in the Fillmore echinoderm fauna (Guensburg and Sprinkle, 1990, 1992a). The crinoids are found almost exclusively on hardgrounds developed on sponge-algal mounds, flat-pebble conglomerates, and grainstones, along with less common edrioasteroids and eocrinoids. This association was noted previously by Dattilo (1988). In contrast, other common echinoderm groups, such as mitrate stylophorans and rhombiferans, are found primarily in micrites, shales, and limy siltstones that originated as soft substrates.

Most of the echinoderms from the Fillmore Formation and Wah Wah Limestone are undescribed and are currently being studied. At least 25 genera are present (pl. 1), along with several other distinctive but still unidentified plates, stems, attachment holdfasts, and arm fragments. Another medium-sized echinoderm fauna containing at least 10 genera has been collected from the Middle Ordovician Kanosh Shale (see Wilson and others, 1992, table 2), and two additional echinoderms have been found in the overlying Lehman Formation and are currently being described in separate papers (Blake and Guensburg, 1993; Guensburg and Sprinkle, 1994).

While attempting to correlate different parts of the Fillmore section during our recent field work, we discovered a long-standing problem in one of the correlations originally made by Braithwaite (1969, 1976) and adopted by Church (1974, 1991) and Dattilo (1988). Braithwaite (1976, p. 57–58) had several inconsistencies in the usage of "fossil localities" (his fig. 3) and "collection sites" (his pl. 20) vs. "collection localities" and in the location of the base of graptolite Zones 2 and 3 (his fig. 10) vs. measurements above the base of the Fillmore for collection localities 4 and 11. More importantly, Braithwaite's correlations from the U.S. Highway 6–50 first roadcut at Skull Rock Pass (collection locality 4) west to the Pyramid and Amphitheater Sections (collection localities 9 and 10) are too low by about 42 m (138 ft) according to our measurements. We suggest that Church's (1974, 1991) mound horizon at the Pyramid Section is about 240 m (787 ft) above the base of the Fillmore Formation near the top of the slope-forming shaly siltstone member in the lower part of trilobite Zone G-2 (see Hintze, 1973). This change has also affected the stratigraphic occurrence of *Pogonipocrinus*, which was found on the mound horizon at this locality (Kelly and Ausich, 1978). The age of this crinoid therefore becomes Early Arenig rather than Tremadoc by British usage.

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TAXONOMIC NOTES ON ECHINODERMATA

Archaetaxocrinus lanei Lewis, 1981, p. 236–237, pl. 1, fig. 9 (=*Cupulocrinus* sp. A Lane, 1970).

Atopocrinus priscus Lane, 1970, p. 15, pl. 1, figs. 4–6, text-fig. 2F–J.

Blastoidocrinus? sp. A of Billings, 1859. See Sprinkle, 1973a, p. 144–155; Wilson and others, 1992, p. 26, table 2.

Blastoidocrinus? sp. B of Billings, 1859. See Sprinkle, 1973a, p. 144–155; Wilson and others, 1992, p. 26, table 2.

Bockia n. sp. Hecker, 1938. See Bockelie, 1981, p. 127–138, figs. 2–9.

Cheirocystella antiqua Paul, 1972, p. 33–37, pl. 1, figs. 1–4, text-figs. 7–9.

Hoplocrinus sp. A of Lane, 1970, p. 12, pl. 1, figs. 2, 3.

Hybocrinus sp. of Billings, 1857. See Brower and Veinus, 1974, p. 30–37.

Hybocrinus sp. A of Lane, 1970, p. 9–12, pl. 1, fig. 8, text-fig. 2E. Plotted as “large conical disparid” on plate 1, chart *C*, herein.

Ibexocrinus lepton Lane, 1970, p. 12–14, pl. 1, fig. 1, text-fig. 2B–C.

Mandalacystis n. sp. See Lewis and others, 1987, p. 1233–1235, figs. 1–7; Wilson and others, 1992, p. 26, table 2.

Pogonipocrinus antiquus (Kelly and Ausich, 1978), p. 916–919, figs. 1A–D. Kelly and Ausich, 1979, p. 1433.

Protopalaeaster starfish. See Wilson and others, 1992, p. 26, table 2; Blake and Guensburg, 1993, p. 112, fig. 1.6.

An Ibexian (Lower Ordovician) Reference Section in the Southern Egan Range, Nevada, for a Conodont-Based Chronostratigraphy

By Walter C. Sweet *and* Celeste M. Tolbert

EARLY PALEOZOIC BIOCHRONOLOGY OF THE GREAT BASIN, WESTERN UNITED STATES

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CONTENTS

FIGURES

An Ibexian (Lower Ordovician) Reference Section in the Southern Egan Range, Nevada, for a Conodont-Based Chronostratigraphy

By Walter C. Sweet[1] *and* Celeste M. Tolbert[2]

ABSTRACT

A long section of Pogonip Group strata, just south of Shingle Pass in the southern Egan Range, Nevada, is established as the reference section for the Ibexian Series (Lower Ordovician) in a graphically assembled, conodont-based chronostratigraphy for the North American Ordovician. The 2,924 feet (892 meters) of dominantly carbonate strata in this section, between the base of the House Limestone and a level 64 feet (19.5 meters) above the base of the Kanosh Shale, were sampled in 1985 at approximately 7-meter intervals, and conodont elements representing 121 species of 59 genera have been collected from acid-insoluble residues of these samples. All samples were productive of conodonts, which have a color-alteration index (CAI) between 3.5 and 4. The distribution of conodont species is used graphically to demonstrate correlation between the Shingle Pass section, sections in the Ibex district of western Utah, and a section of the El Paso Group in the southern Franklin Mountains, Texas.

INTRODUCTION

A long, continuous surface section through the Pogonip Group in the southern Egan Range, Lincoln County, Nevada, is established here as the reference section for the Ibexian (Lower Ordovician) segment of a graphically compiled, conodont-based chronostratigraphic framework for the Ordovician of North America. This section (fig. 1) is situated about 3.5 mi (5.6 km) east of Nevada Highway 318 and about 1 mi (1.6 km) south of the unpaved, unnumbered road that extends through Shingle Pass and connects Highway 318 with U.S. Highway 93, some 20 mi (32 km) to the east. The section, herein identified as the Shingle Pass section, is exposed in, and on the flanks of, a broad northwest-projecting salient of the southern Egan Range, in sections 25 and 36, T. 8 N., R. 62 E., and section 30, T. 8 N., R. 63 E., northwestern Lincoln County, Nevada (Shingle Pass, Nevada, 7.5-minute quadrangle).

In the Shingle Pass section, the Pogonip Group is directly and conformably underlain by the stratotype of the Whipple Cave Formation (Kellogg, 1963), a sequence of thick-bedded, stromatolitic, lime grainstones and wackestones primarily of Late Cambrian age, but including nearly 70 m of Early Ordovician strata at the top. The distribution of conodonts in the upper part of the Whipple Cave and lowermost part of the Pogonip in Sawmill Canyon, in the central Egan Range, about 25 mi north of Shingle Pass, is reliably documented in a recent report (Taylor and others, 1989), and this has made duplication of that work in this study unnecessary. Also, the Pogonip Group in the Shingle Pass section was not sampled above a level in the lower part of the Kanosh Formation because that part of the Pogonip is difficult of access and Whiterockian in age.

In this report we summarize the lithic stratigraphy of the Shingle Pass section, document the distribution of conodonts in it, and demonstrate its utility as an Ibexian reference section by plotting on biaxial graphs the ranges of conodonts common to the Shingle Pass section and important sections in the Ibex district of western Millard County, Utah, and in the southern Franklin Mountains of Texas. A detailed description of that part of the Shingle Pass section studied in detail is provided in Appendix 1. Appendix 2 lists ranges of 210 conodont species in the Shingle Pass section and in the other Ibexian sections we compare with it. Appendix 3 gives the composite standard-equivalent ranges of those species, and Appendix 4 includes notes on taxonomy of the conodont species represented.

ACKNOWLEDGMENTS

Joseph R. Wilson, then of Ohio Wesleyan University (Delaware, Ohio), assisted the junior author in the field in August 1985, when the Shingle Pass section was measured

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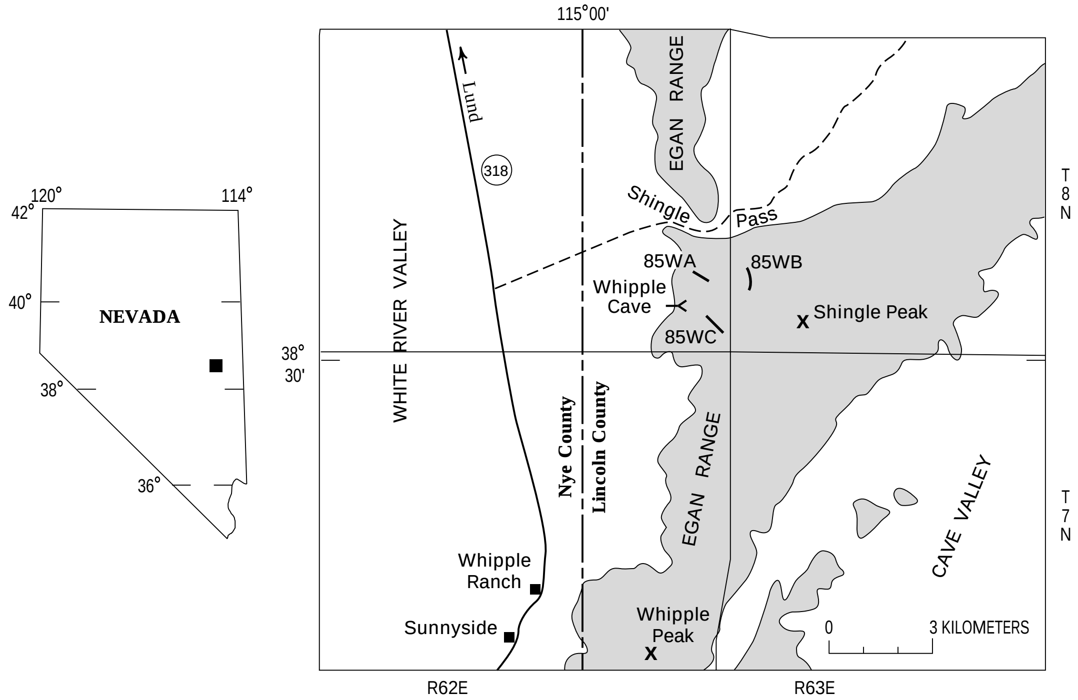

Figure 1. Index map showing location of the three subsections (85WA, 85WB, 85WB) that compose the Shingle Pass section of this report.

and sampled. Y.B. Kim processed many of our carbonate samples in acid and helped concentrate the acid-insoluble residues. John E. Repetski, of the U.S. Geological Survey, Reston, Virginia, discussed identification of many conodont species and allowed extended access to his bulk collections from the El Paso Group, Texas. Professor Raymond L. Ethington, University of Missouri-Columbia, made conodont collections from the Ibex district, Utah, available for study and kindly discussed many of the problems associated with the identification of species represented in them. The help and assistance of all these persons are gratefully acknowledged. The illustrations were enhanced by the graphic skills of Carol Quesenberry, USGS.

STRATIGRAPHY

THE IBEXIAN SERIES

The Ibexian Series was proposed (Ross and others, 1982) as a substitute for Canadian Series, the lowest major division of the North American Ordovician, because the Canadian was deemed to have been poorly defined originally and inconsistently used subsequently. However, as Hintze's (in Ross and others, 1982) description of the type section indicates, the Ibexian includes much less of the North American Lower Ordovician than do most usages of Canadian, which embrace substantial parts of units now included in the younger Whiterockian Series. In brief, the Ibexian is not a one-for-one substitute for the Canadian, but a more precisely defined chronostratigraphic unit, with a well-known succession of fossils and a designated and well-described type section in the Ibex district of Millard County, western Utah.

In the type area of the Ibexian Series, Hintze (in Ross and others, 1982) placed the base of the Ibexian in the uppermost beds of the Notch Peak Formation, at the base of the *Missisquoia* trilobite Zone, which, following then-current North American practice, also marked the base of the Ordovician System. The top of the Ibexian is the base of the overlying Whiterockian Series, which Hintze (in Ross and others, 1982) and Ethington and Clark (1982) both placed at the base of the Kanosh Shale in the Ibexian type area. Ross (in Ross and others, 1982) and others, however, have argued that the Whiterockian base be sited in the Ibex district at the level in the Wah Wah Limestone (Hintze, 1988) at which *Orthambonites subalata* Ulrich and Cooper first occurs, for that brachiopod is regarded as the lowest representative of Cooper's (1956) *Orthidiella* Zone, the basal biozone of the typical Whiterockian Series. In the type area of the Ibexian, this level is also very close to the base of Ethington and Clark's (1982) *Tripodus laevis* conodont Zone, and the same relation holds in the type section of the Whiterockian Series (Ross and Ethington, 1991, 1992).

Data on the distribution of trilobites and conodonts in the upper part of the Whipple Cave Formation and lowermost part of the House Limestone in a section in Sawmill Canyon, some 25 mi (40 km) northwest of Shingle Pass

(Taylor and others, 1989) suggest that the base of the Ibexian there is about 70 m below the base of the House Limestone, and this is almost certainly the situation in the Shingle Pass section. Because of the currency and evident thoroughness of the sequence established in Sawmill Canyon, we have not attempted to duplicate that part of the succession in the Shingle Pass section, although it may someday be desirable to do so. Hence the base of the Ibexian cannot at present be located precisely in the Shingle Pass section. We note that although Hintze (in Ross and others, 1982) drew the base of the type Ibexian at the base of the *Missisquoia* trilobite Zone, he did so obviously to make the Ibexian base coincident with the base of the Ordovician System. No formal international definition of the Ordovician base has yet been recommended or approved, however, although it seems likely from reports of recent deliberations that in making such a recommendation the distribution of conodonts, not trilobites or other fossils, will be the guiding criterion.

In the Shingle Pass section, the conodont species *Tripodus laevis* appears abruptly and in abundance in the upper third of the Shingle Limestone, 134 m below the base of the Kanosh Shale. We use this level to mark the base of the Whiterockian Series, and thus the top of the Ibexian. We note also that Kellogg (1963) reported *Orthambonites subalata* Ulrich and Cooper from near the top of the Shingle Limestone at a locality 0.4 mi (0.6 km) northeast of the main ridge, Shingle Pass.

Thus, in the Shingle Pass section, the Ibexian Series includes the House Limestone, the Parker Spring Formation, the lower two-thirds of the Shingle Limestone, and probably, depending on the level at which the Ordovician base is ultimately sited, the uppermost 70 m or so of the subjacent Whipple Cave Formation.

LITHOSTRATIGRAPHY

For more than 40 years, Great Basin stratigraphers have included Ordovician rocks below the widespread Eureka Quartzite in the Pogonip Group, which was revised, subdivided into formations, and stabilized in content by Hintze (1951). In the Ibex district of western Utah, Hintze divided the Pogonip, in ascending order, into House Limestone, Fillmore Limestone, Wah Wah Limestone, Juab Limestone, Kanosh Shale, and Lehman Formation; and in 1952, he recognized the same succession in the Shingle Pass section of eastern Nevada (his Sunnyside section). Later, however, in the southern Egan Range, Kellogg (1963) divided Pogonip strata between the House Limestone and Kanosh Shale into just two lithic units, a lower, poorly exposed, slope-forming succession of thin-bedded carbonates and shales, the Parker Spring Formation; and an upper, cliff-forming unit of more thickly bedded carbonates, the Shingle Limestone. In his 1963 report, Kellogg also defined and described the Whipple Cave Formation, a thick succession of mostly Upper Cambrian carbonate rocks immediately below the Pogonip Group, and with a stratotype just below the House Limestone in the Shingle Pass section. Kellogg's lithic subdivisions are the ones recognized in this report, which focuses primarily on the distribution of conodonts and not on lithostratigraphic details. However, in order to locate our bulk samples in appropriate lithostratigraphic context, we include a detailed distribution of the Shingle Pass section in Appendix 1.

It should be noted that Hintze (1952, p. 60–76) measured, described, and reported on the identity of trilobites and other megafossils in some 21 samples collected at widely spaced stratigraphic intervals from the Whipple Cave Formation and Pogonip Group in the Shingle Pass (his Sunnyside) section. Also, in a recent guidebook contribution, Droser and Sheehan (p. 83–85 in Cooper, ed., 1995) included additional information about Ibexian strata at Shingle Pass, but focused primarily on the Shingle Limestone and its sponge mounds.

In his report, Hintze (1952) was able to recognize in the Shingle Pass section the equivalents of all the Pogonip formations he defined in the Ibex district of western Utah. However, we suspect that, in doing so, he may have relied somewhat more on the distribution of trilobites and other guide fossils than on details of the lithic succession. Droser and Sheehan, and the junior author of this report, on the other hand, paid principal attention to the succession of rock types in the Shingle Pass section. Hence, unit thicknesses given in these previous reports differ considerably from one another, and that makes it difficult to integrate into a single scheme all the information they contain. Here, we comment only that, compared with the typical Ibexian, the Shingle Pass section appears to be complete and not interrupted by the erosional gap at the level of the Juab Formation shown by Droser and Sheehan. The Juab Formation was recognized at Shingle Pass by Hintze (1952), and our collections from the upper part of the Shingle Limestone include conodonts typical of that unit. Further, no discontinuity is indicated graphically in the upper part of the Shingle Limestone, as we recognize it in this report.

CONODONT BIOSTRATIGRAPHY

In August 1985, the junior author (Wilson, 1988) measured and described the Shingle Pass section, between the base of the House Limestone and a point 19.5 m above the base of the Kanosh Shale, which was recognized in the field as the level at which receptaculitids appear in fine-grained, dominantly calcareous beds. As the section was measured, bulk limestone samples were also collected at 20-ft (6.1-m) intervals. These samples, 119 in number, were returned to our laboratory in Columbus, Ohio, where they were crushed, and 1 kg of each was processed in a 10 percent solution of acetic acid. Every one of the samples yielded well-preserved conodont elements, and it is on these specimens that we base the following discussion of conodont biostratigraphy. Bulk collections are kept in the micropaleontological collections of the Department of Geological Sciences, The Ohio State University, where they are identified by the prefixes 85WA, 85WB, and 85WC.

Ibexian rocks in the type area of western Utah are divided into a succession of 11 conodont-defined biozones, which are named and characterized in a report by Ross and others (1993; this volume, chapter A). Although equivalents of at least nine of these zones are recognizable in the Shingle Pass section, we have not used them as the principal tool in correlating the two successions. Instead, we have followed a correlation strategy that was devised by Shaw (1964) and which is demonstrated in a variety of different situations by contributors to a recent volume (Mann and Lane, 1995) on graphic correlation.

Use of the graphic procedure in assembling a network of closely correlated sections requires data on the measured distributions of fossils in all the sections that are potential contributors to the network. One long section in which fossil ranges are well controlled is selected as *standard reference section* (SRS), and additional sections are compared with it by plotting the first and last occurrences of common species as points in a biaxial graph. On such a graph, the equation of a *line of correlation* (LOC) fit to the array of points on or closely adjacent to the interface between first- and last-occurrence sectors of the graph helps determine the most reasonable relationship between the SRS and another data set being considered, and provides the means of translating ranges in the second section into terms of the SRS. Following comparison of the second section with the SRS, a *composite standard* (CS) is created by selecting from the two range-data sets the lowest and highest ranges for each species. The resultant data set, or CS, which is composed of the best information from the two initial data sets, is then used as the basis for comparing a third section and creating a new CS after that graphic episode. Customarily all the sections considered in the initial round of graphic correlation are recorrelated with CS's composed of the best data from all the other sections of the network for as many rounds as it takes to reach a stable CS.

In this report we are concerned primarily with demonstrating the relationship between the Shingle Pass section and sections in the type area of the Ibexian Series. However, because the Shingle Pass and Ibexian type sections are closely spaced geographically and developed in similar litho- and biofacies, we consider it desirable to compare the results of the graphic assembly of those sections with one in a more distant location that is known to be of generally comparable age but developed in somewhat different facies. For such a comparison, we selected the section of El Paso Group strata exposed along Scenic Drive, in El Paso, Texas. Conodonts from the Scenic Drive section were described and illustrated by Repetski (1982), who provided scaled data in his report on the ranges of all the species represented.

CORRELATION WITH IBEXIAN SECTIONS ELSEWHERE

Our objective in this report is to establish the Shingle Pass section as the reference section for the Ibexian Series in a graphically assembled framework of carefully sampled sections that is the basis for a conodont-based Ordovician chronostratigraphy (Sweet, 1984; 1995a, 1995b). Thus it is important first to show how rocks in the Shingle Pass section correlate with those in sections in the Ibex area of western Millard County, Utah, that make up the composite Ibexian stratotype (Ross and others, 1993).

CORRELATION WITH THE COMPOSITE-STRATOTYPE SECTION IN THE IBEXIAN TYPE AREA

Data on the measured ranges of conodonts in the Ibex area are from three sources, Ethington and Clark (1982), Ethington and others (1987), and Hintze and others (1988). We take information from these three sources at face value, with modification only of the names used for several taxa.[3]

Ethington and Clark (1982) based their monographic study of conodonts from the Ibex area on nearly 27,000 discrete elements recovered from acid residues of 758 carbonate samples collected at 4- to 24-ft intervals from sections at 11 localities in western Millard County, Utah. Sections sampled by Ethington and Clark include Hintze's (1951, 1973) A, B, C, E, H, M, ST, J, K, and CP Sections, which were assembled, following information in Hintze's reports, to form a continuous sequence from just below the base of the House Limestone to the top of the Crystal Peak Dolomite. Ethington and Clark evidently used this assembly as the basis for the composite range chart included as figure 3 in their 1982 report, and Sweet (1995b) used it with minor modification in a preliminary graphic correlation of Ibex area and Shingle Pass sections. In this report, however, we follow a somewhat more conservative procedure, which is explained in the following paragraphs.

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[3] The variation in measurement units in this report is attributable to the use by various workers in the area of feet or of meters and the present authors' concern for precise reporting of previous studies. One foot=0.3048 m.

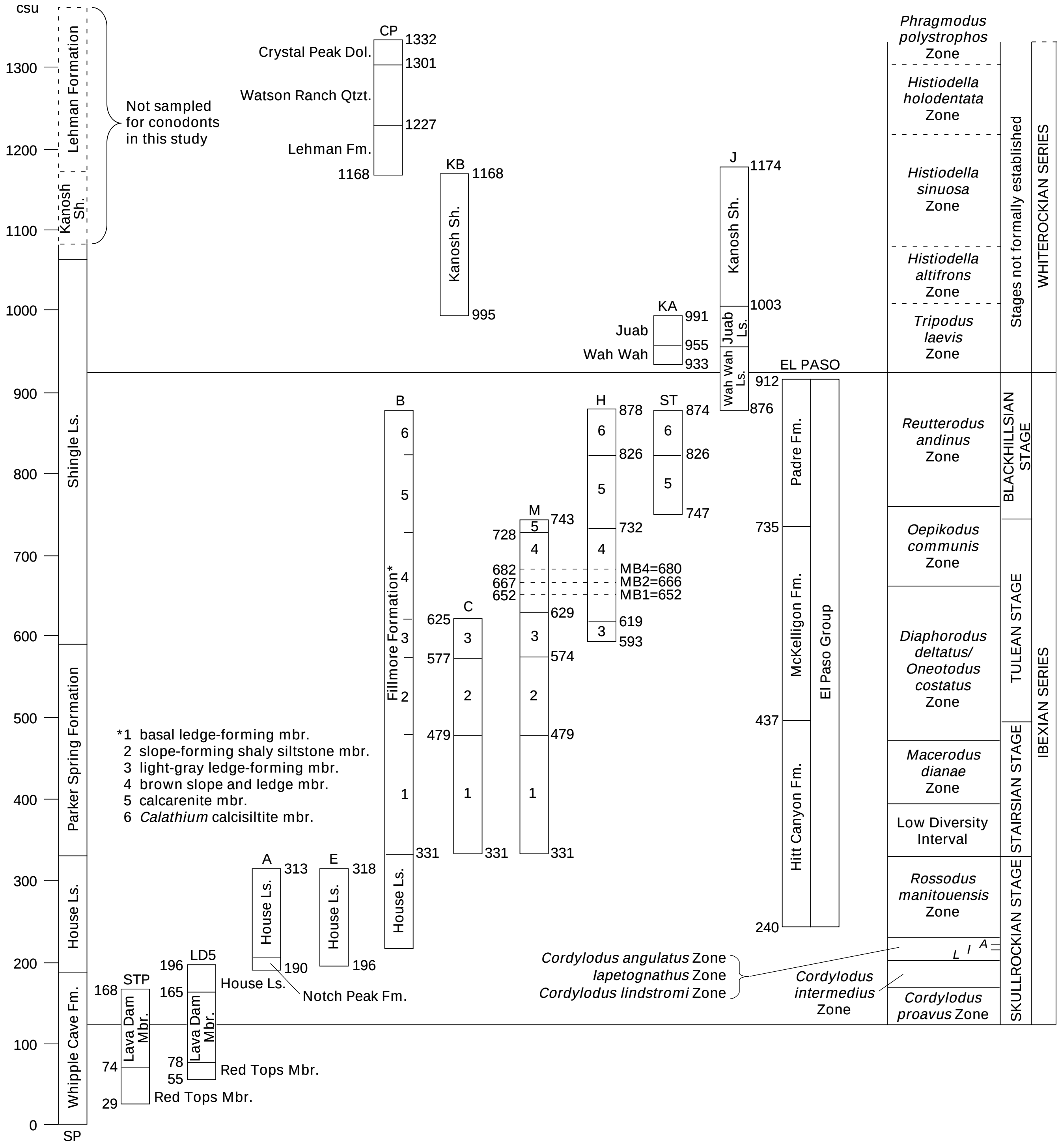

Figure 2. Correlation of Ibex-area sections STP, LD5, A, E, B, C, M, H, ST, J, KA, KB, and CP with Shingle Pass (SP) and Scenic Drive (El Paso) sections. Vertical scale is in composite standard units (csu), each equivalent to 1 m in the SP section. Thicknesses of lithic and biostratigraphic units are those determined by graphic correlation with SP, which is SRS for this compilation. Numbers at contacts are SP-equivalent levels (for example, the Fillmore Formation base in Ibex-area sections B, C, and M is at 331 csu in the CS, or projects to a level 331 m above the base of SP). In effecting correlations between Ibex-area sections M and H, Hintze (1973) used marker beds here labeled MB1, MB2, and MB4.

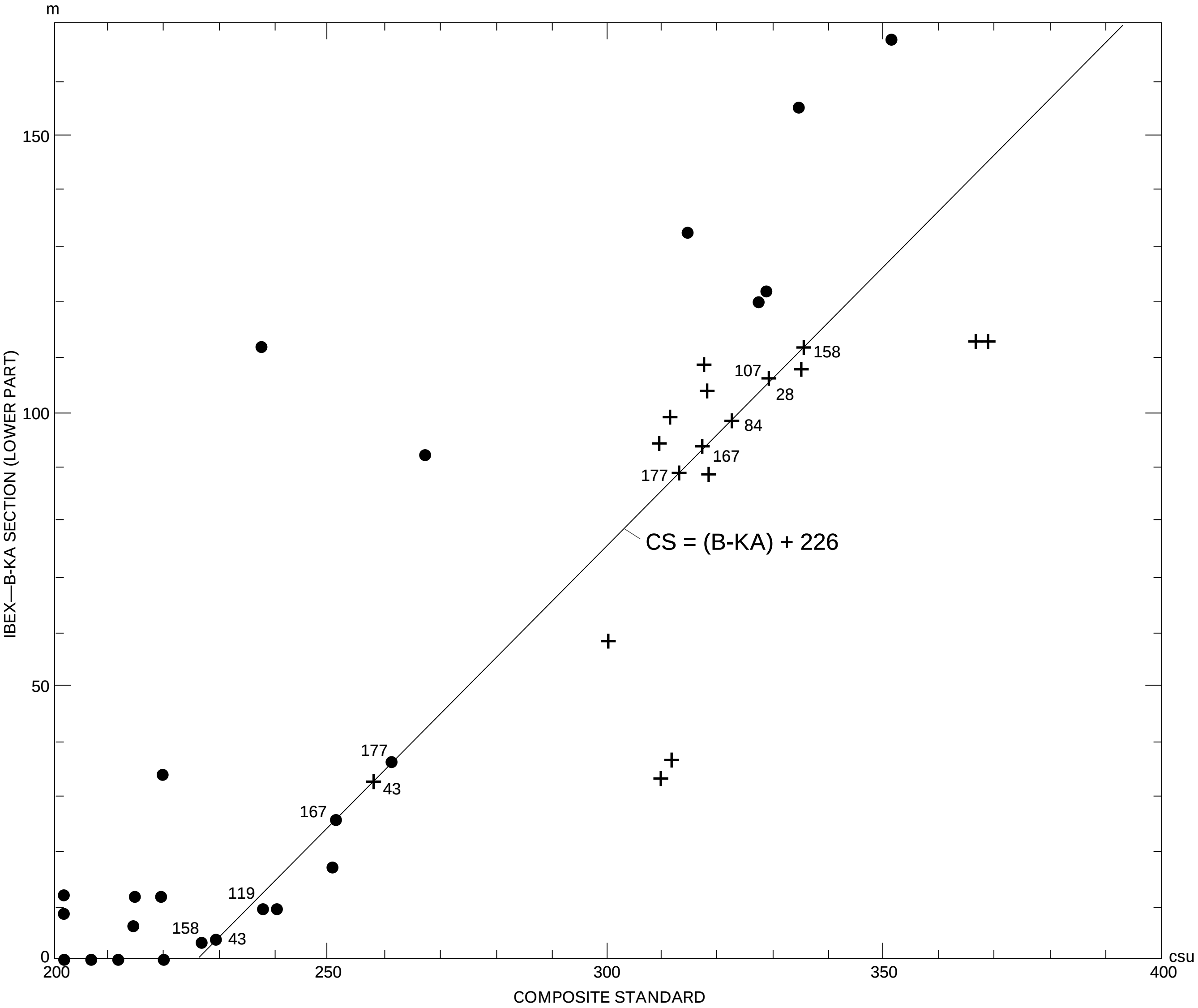

Figure 3. Graphic correlation of the lower 170 m of Ibex-area composite section B-KA with a composite standard (CS) composed of maximized range data from Ibex-area sections STP, LD5, A, and E; the Scenic Drive section in El Paso, Texas; and the Shingle Pass section, which is the standard reference section (SRS). Dots are range bases; crosses are range tops. Numbers by dots and crosses refer to the conodont species listed in Appendixes 2 and 3 and identify only those points composing the array to which the line of correlation (LOC) has been fit.

In figure 2, we follow Hintze (1951, 1973) in linking his B, C, M, H, ST, J, and KA Sections into a single sequence, 948 m thick, which ranges upward to the top of the Kanosh Shale from a point 105 m below the top of the House Limestone. Ranges of conodonts in this segment of the Ibex composite section, which we designate B-KA, have been assembled from Ethington and Clark (1982) and Ethington and others (1987) and are given in Appendix 2, in which we also include ranges of the same conodont species in the Shingle Pass section and in a section along Scenic Drive in the southern Franklin Mountains, in El Paso, Texas.

In figures 3 and 4 we plot the first and last occurrences of conodont species common to Ibex-area composite section B-KA and a CS composed of range data from Ibex-area sections STP, LD5, A, and E, the Shingle Pass section, and the Scenic Drive section in El Paso, Texas. Although the arrays of points plotted in these two graphs exhibit modest dispersion, a majority of the first occurrences plot above and to the left of a line with the equation SP=(B-KA)+226, and most last occurrences plot below and to the right of that line. The array to which we have fit the line in figures 3 and 4 is composed of the 31 points that plot on or very close to the interface between first-occurrence and last-occurrence sectors of the graph. The array is clearly rectilinear, which suggests that composite section B-KA very closely approximates a single, unbroken sequence. This may also be taken as

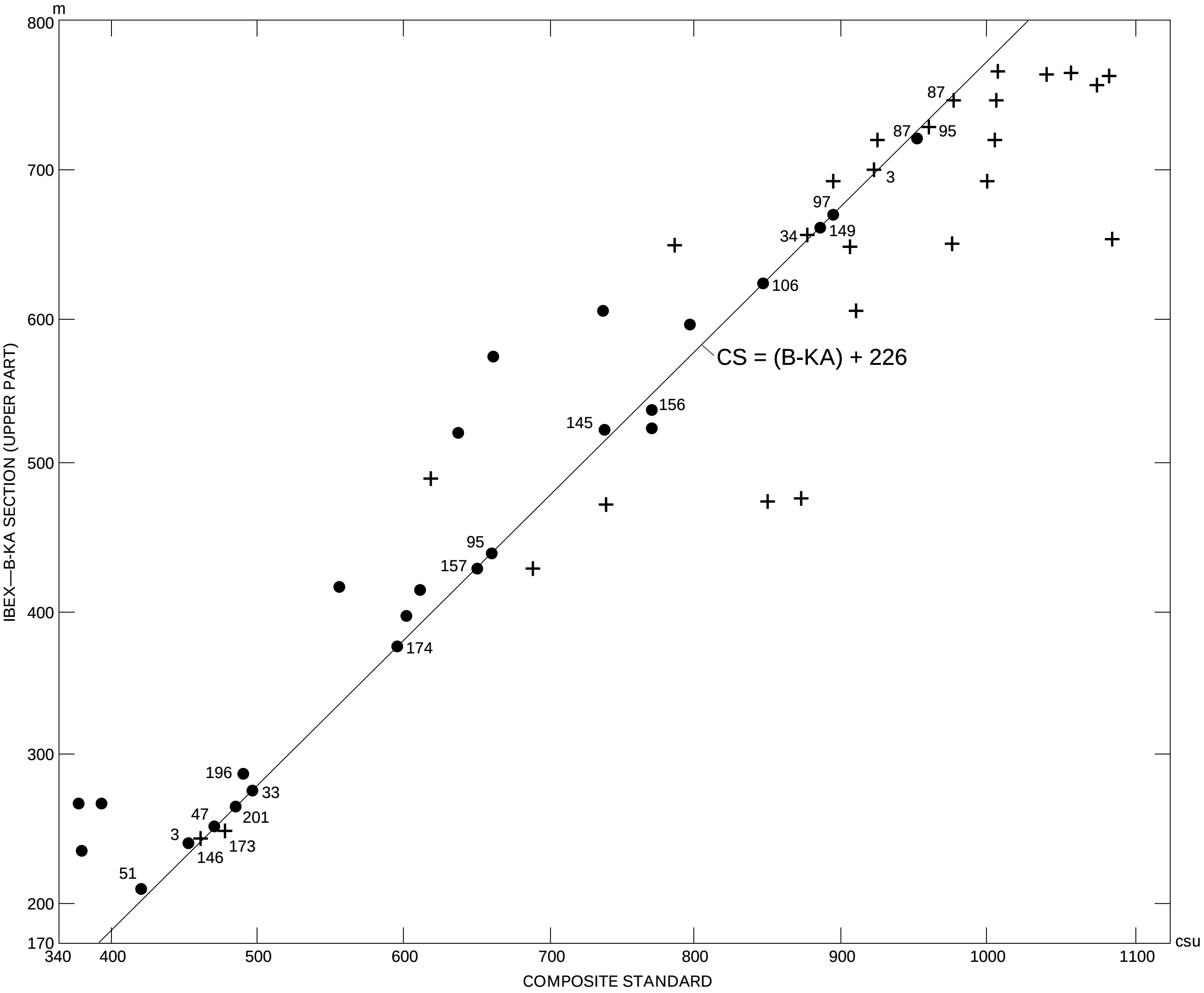

Figure 4. Graphic correlation of the upper 593 m of Ibex-area composite section B-KA with a composite standard (CS) composed of maximized range data from the Scenic Drive section, El Paso, Texas, and the Shingle Pass section, which is SRS. Dots are range bases; crosses are range tops. Numbers by dots and crosses refer to the conodont species listed in Appendixes 2 and 3 and identify only those points composing the array to which the line of correlation (LOC) has been fit.

support for our decision to treat seven of the Ibex-area sections as a single succession for the purpose of establishing correlation with Ibexian rocks elsewhere.

In the graph of figure 3, it should be noted that crosses marking the upper range limits of four conodont species plot above and well to the left of the LOC, in a sector of the graph otherwise dominated by first occurrences (dots). At first we interpreted the anomalous position of these upper range limits as indicative of a discontinuity in the section, at about the level of the House Limestone/Fillmore Limestone contact. However, neither we nor Ethington and others (1987) have been able to detect any physical evidence in the field of such a discontinuity. Consequently, it seems reasonable to conclude that these surprisingly high “tops” merely record upper range limits in section B-KA that are higher than in any other section we have thus far considered. They might, of course, be the results of reworking; but we discount this possibility because other ranges, established from the same samples, appear to be congruent with a LOC based on many other range limits established and closely controlled in either the Shingle Pass or Scenic Drive sections.

Initially, we included Hintze’s A Section, the stratotype of the House Limestone, in the assembly just described, by assuming that rock accumulated at an essentially uniform rate throughout the Ibex area and that the top of section A equated with the base of section C, which Hintze (1973)

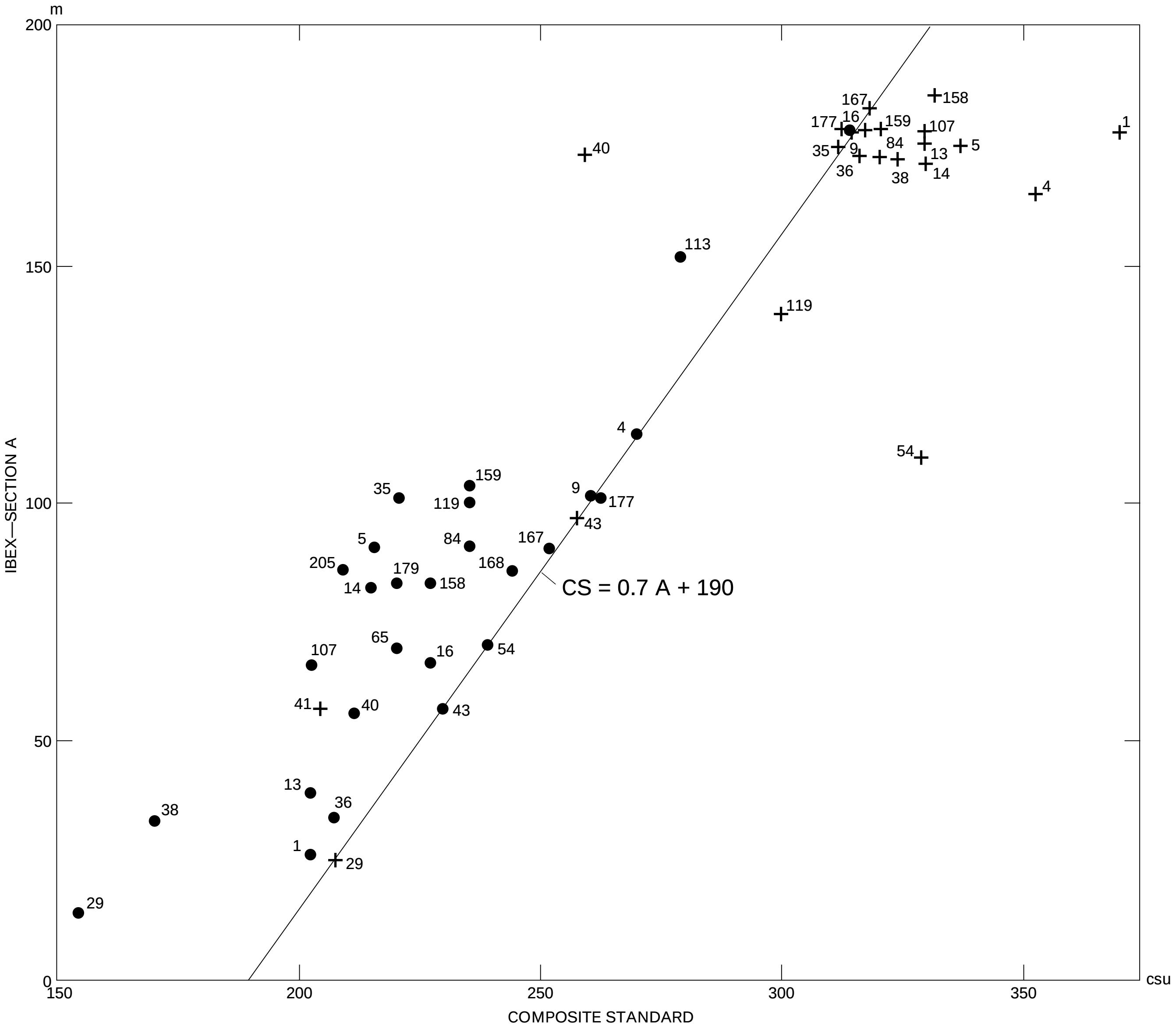

Figure 5. Graphic correlation of Ibex-area section A with a composite standard composed of maximized range data from the Shingle Pass and Scenic Drive sections and Ibex-area sections STP, LD5, E, and lower B-KA. Dots are range bases; crosses are range tops. Numbers by dots and crosses refer to conodont species identified in Appendixes 2 and 3.

determined to be coeval with the top of the House Limestone in section B. However, inclusion in the Ibex-area composite of conodont range data from section A introduced a puzzling amount of dispersion into the lower part of the graphic array, and this suggested that section A should be correlated independently with a composite section that included information from the Shingle Pass section, an Ibex-area assembly composed of data from sections B, C, M, H, ST, J, and KA, and a section of El Paso Group strata along Scenic Drive, in El Paso, Texas (Repetski, 1982).

Figure 5, a graph that relates Ibex-area section A to a composite standard that includes information from all the sections mentioned in a preceding paragraph, suggests that the rate of rock accumulation may have been somewhat greater in the vicinity of section A than to the south in section B-KA. Thus, in figure 2 we show the position of Hintze's A Section as indicated graphically in figure 5. Note that the top of the House Limestone in Ibex-area section A is at a level some 18 m lower in the framework that controls the CS than the top of the House Limestone in Ibex-area sections B, C, and M.

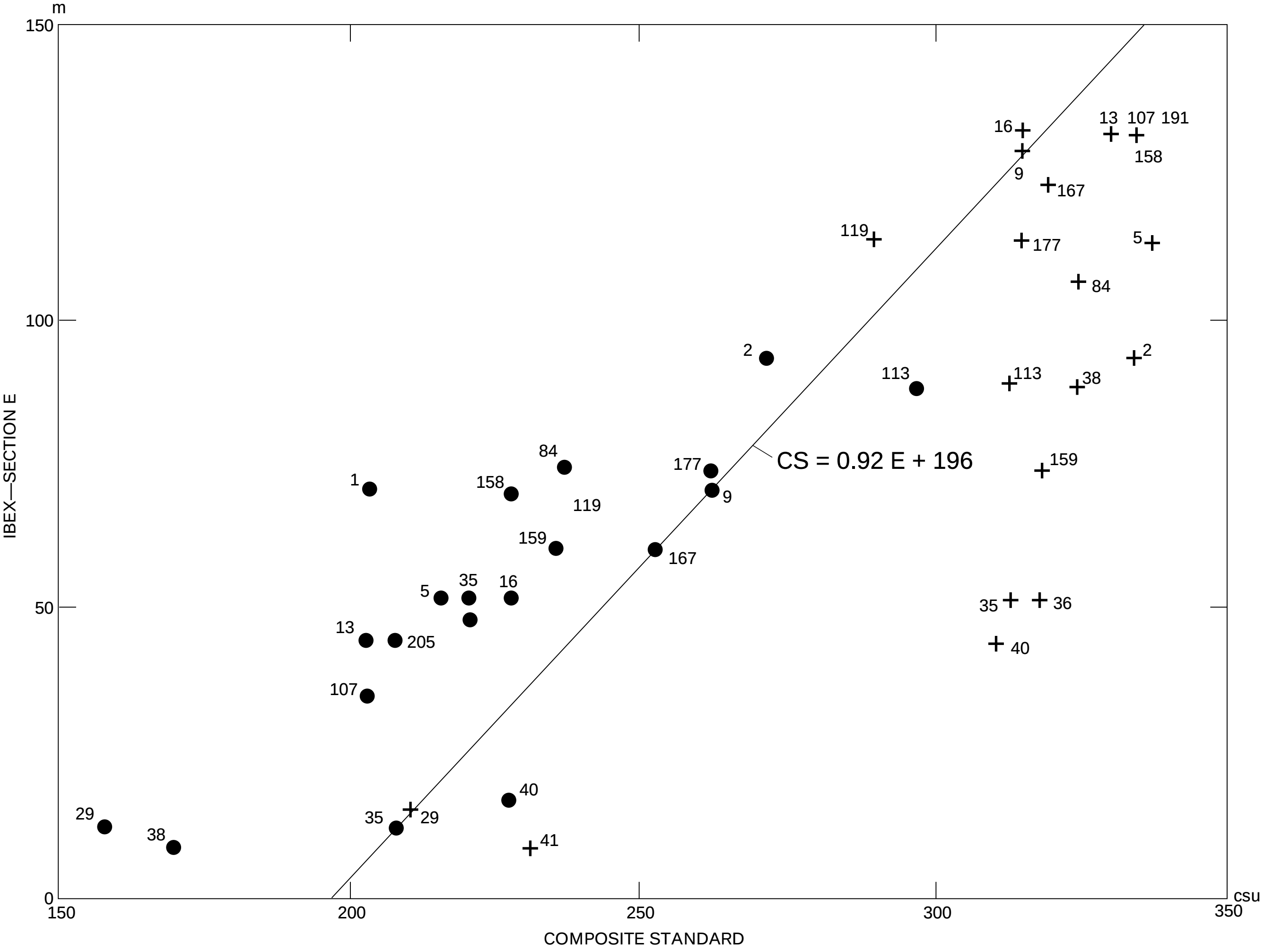

Figure 6. Graphic correlation of Ibex-area section E with a composite standard composed of maximized range data from the Shingle Pass and Scenic Drive sections, and from Ibex-area sections STP, LD5, A, and lower B-KA. Dots are range bases; crosses are range tops. Numbers by dots and crosses refer to conodont species identified in Appendixes 2 and 3.

Hintze's (1951) E Section, in the Wilden Hills, is also isolated from the body of composite section B-KA, and we show its relationship to the graphically compiled composite standard in figure 6. Note that the rate of rock accumulation in the vicinity of Ibex-area section E was also apparently somewhat greater than elsewhere in the Ibex area, or in the Shingle Pass section, which is the standard reference section for the composite standard. In figure 2 we show section E in the position indicated graphically in figure 6.

In their study of the Notch Peak Formation, Hintze and others (1988) reported the distribution of conodonts in sections at three localities in the Ibex area. Range data for two of these, the Steamboat Pass and Lava Dam 5 sections, are summarized in Appendix 2 and are used graphically in figures 7 and 8 to illustrate the relations of these two sections to a composite section that includes information from the Shingle Pass and Sawmill Canyon sections, the Ibex-area sections mentioned in preceding paragraphs, and an El Paso Group section in the southern Franklin Mountains, Texas. The positions of these sections indicated by graphic correlation are shown in figure 2.

In figure 2 the Ibex-area sections just discussed are assembled in a chart, the vertical scale of which is that of the Shingle Pass–Sawmill Canyon succession, which is the SRS for the CS with which we have compared Ibex-area sections graphically. Sections in this assembly include the stratotype of the Ibexian Series base (39.1 m above the base of the Lava Dam Member in Ibex-area section LD5), as well as the basal stratotypes of all Ibexian stages and conodont biozones. The top of the Ibexian Series, defined as the base of the Whiterockian Stage, is not included objectively in the sections assembled in figure 2. It is drawn in that figure at the level of first occurrence of the conodont *Tripodus laevis* in the Shingle Pass-based CS.

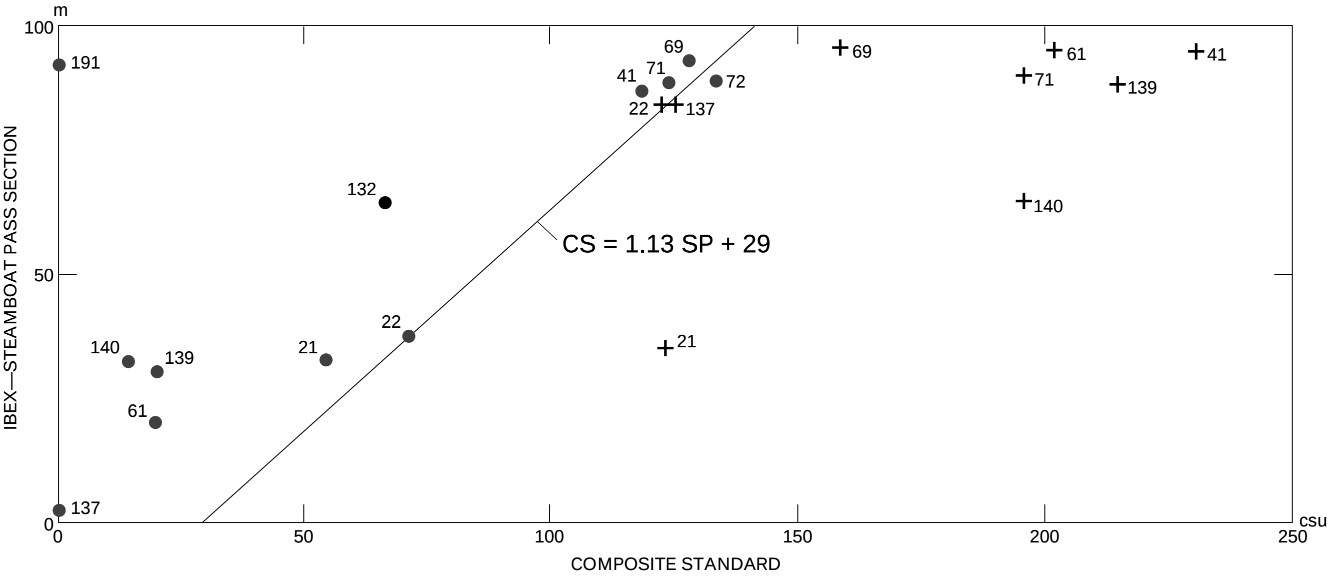

Figure 7. Graphic correlation of the Ibex-area Steamboat Pass (STP) section with a composite standard composed of maximized range data from Ibex-area sections LD5, A, and E, and from the Shingle Pass and Scenic Drive sections. Dots are range bases; crosses are range tops. Numbers by dots and crosses refer to conodont species listed in Appendixes 2 and 3.

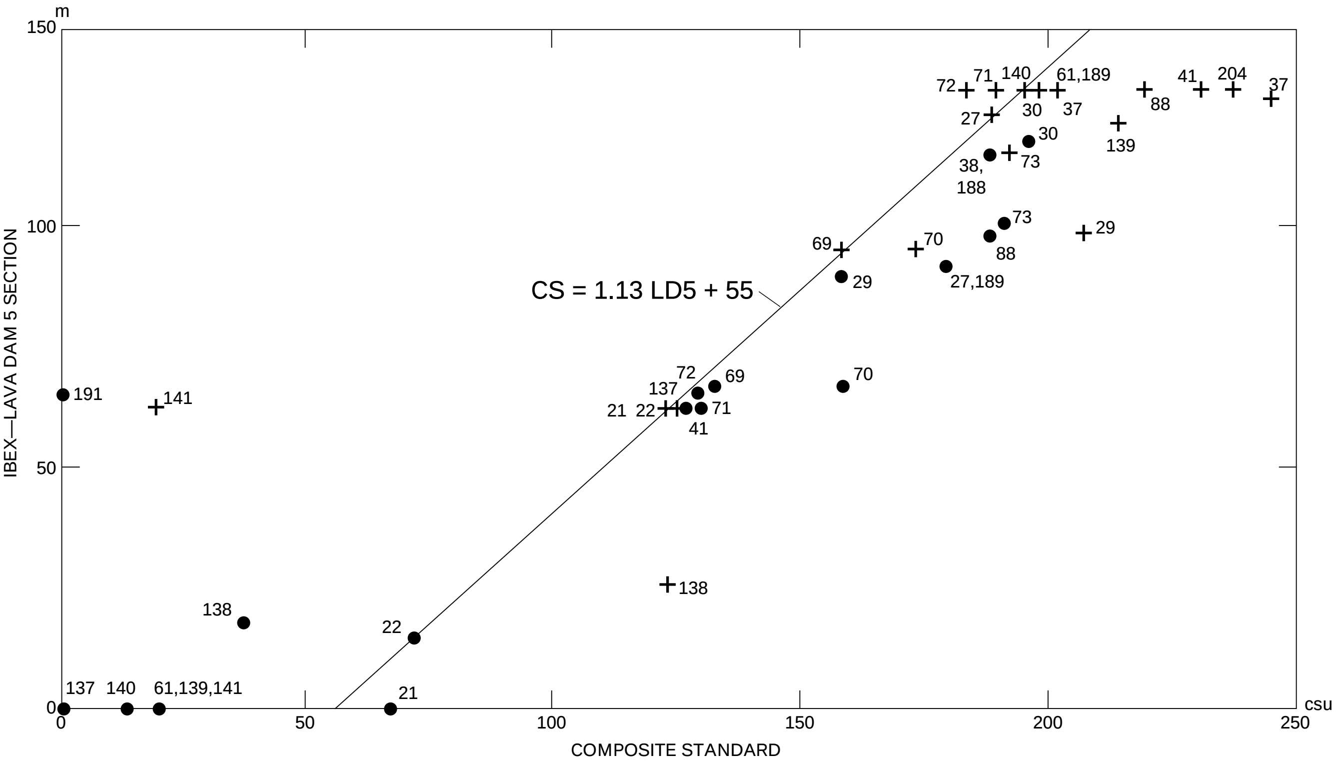

Figure 8. Graphic correlation of the Ibex-area Lava Dam 5 section with a composite standard composed of maximized range data from the Shingle Pass and Scenic Drive sections and from Ibex-area sections STP, A, E, and lower B-KA. Dots are range bases; crosses are range tops. Numbers by dots and crosses refer to conodont species listed in Appendixes 2 and 3.

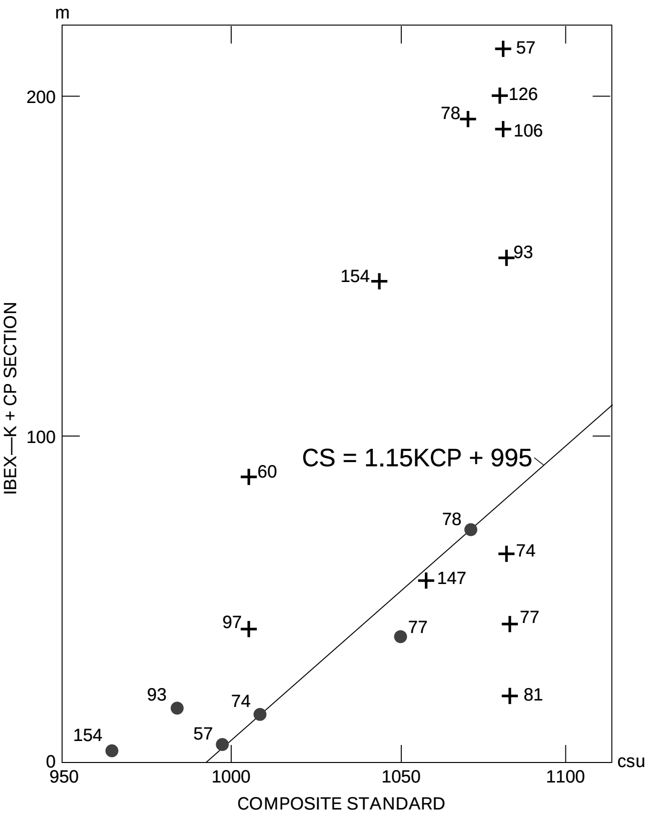

Figure 9. Graphic correlation of Ibex-area sections K and CP with a composite standard composed of maximized range data from the Shingle Pass section and the uppermost part of Ibex-area section B-KA. Dots are range bases; crosses are range tops. Numbers by dots and crosses refer to conodont species listed in Appendixes 2 and 3.

Ethington and Clark's (1982) monograph on Ibex-area conodonts also includes information on the nature and ranges of some 45 conodont species in Whiterockian strata in Hintze's (1973) sections J, K, and CP. Although our studies have focused primarily on biostratigraphic characterization and correlation of Ibexian strata, we include a graph (fig. 9) that shows the relations between rocks in Ibex-area sections K and CP and those in the upper 150 m or so of the Shingle Pass-based CS. This graph is included largely to provide a biostratigraphic cap for the Ibexian Series and to enable its subsequent incorporation into a composite standard that will include the entire Ordovician System (Sweet, 1995a, 1995b). In figure 2, Hintze's Ibex-area sections K (our KB) and CP are shown in relation to other Ibex-area sections.

CORRELATION WITH THE EL PASO GROUP, TEXAS

Collections from Pogonip Group strata in the Shingle Pass and Ibex-area sections contain representatives of at least two-thirds of the conodont species described by Repetski (1982) from the El Paso Group exposed along Scenic Drive, in the southern Franklin Mountains, in El Paso, Texas. Ranges of those species are included in Appendix 2 of this report and are used graphically in figure 10 to effect a correlation between the El Paso Group and a CS that includes information from the Shingle Pass and Ibex-area sections described in preceding sections of this report.

In the graph of figure 10, a line of correlation (LOC) is fit to the rectilinear array of 27 points that defines the interface between the first-occurrence and last-occurrence sectors of the graph. With only two exceptions, these points are the range limits of well-known, widely distributed species about whose physical attributes there is little question. Thus, we regard the correlation indicated in figure 10 to be the one best supported by the evidence presently available.

In figure 10, last occurrences of only three species and first occurrences of only five plot at significant distances away from the LOC. For the most part, these points represent the first or last occurrences of species that are either rare or absent in one or another of the sections contributing to the composite standard, or they are the range limits of species about which there is still a considerable taxonomic question. Slope of the LOC indicates that El Paso Group strata accumulated at a slower rate than did those in the Ibex or Shingle Pass areas, and sedimentologic data (Hayes and Cone, 1975) suggest deposition was probably in much shallower water. Thus faunal differences in the Early Ordovician likely were appreciable between the two regions compared in this report, and reliable correlations between them will have to depend on the distribution of the more or less cosmopolitan species we have utilized in figure 10.

SUMMARY

Graphic analysis demonstrates that the Shingle Pass section (augmented by information from a well-controlled section in Sawmill Canyon), in the southern Egan Range, Nevada, provides an excellent template for assembly of information from sections in the Ibex area of western Millard County, Utah, and along Scenic Drive in El Paso, Texas. That the Shingle Pass succession can be used as a template for relating post-Ibexian rocks in the Ibex area to older strata also appears possible, thereby enabling establishment of a well-controlled local composite standard that extends from a level well below the base of the Ordovician System to a point well above the base of the Whiterockian Series. Such a local composite standard will be of great utility in building the pan-Ordovician CS outlined recently by Sweet (1995a, 1995b).

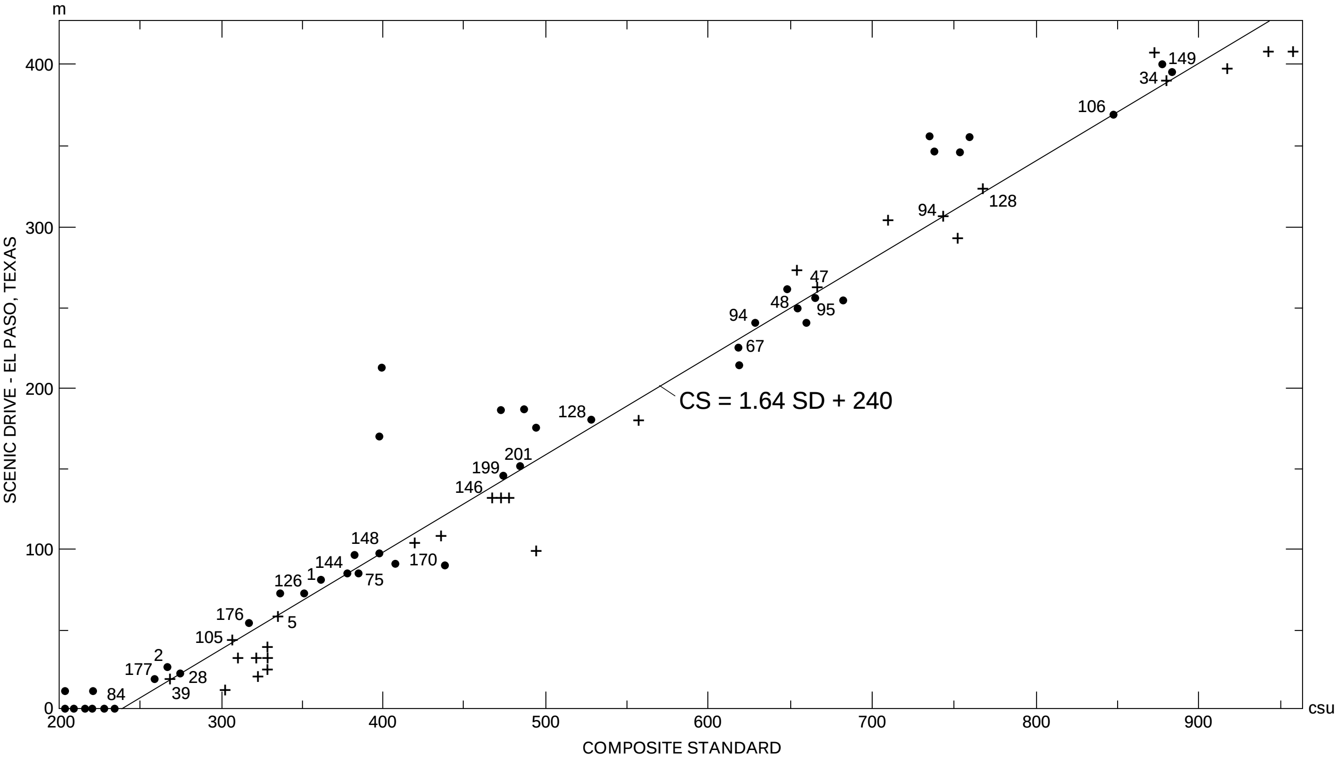

Figure 10. Graphic correlation of the Scenic Drive section, in El Paso, Texas, with a composite standard composed of maximized range data from the Shingle Pass and Ibex-area sections. Dots are range bases; crosses are range tops. Numbers by dots and crosses refer to conodont species listed in Appendixes 2 and 3, but only points in the array to which the LOC is fit are identified by number.

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APPENDIX 1. SHINGLE PASS SECTION

Section measured perpendicular to strike, in stratigraphically continuous traverses at three different sites on northwest-trending ridge immediately south of Shingle Pass road, in the southern Egan Range, Nevada. Subsections are designated 85WA, 85WB, and 85WC, but sample designations are given in terms of footage above base of subsection 85WA, which is also the local base of the House Limestone. Sample 85WB-751, for example, is from a limestone bed 751 feet above the base of the House Limestone, in subsection 85WB.

SUBSECTION 85WC

Section of upper part of Shingle Limestone and lowermost Kanosh Shale in NEcSEc sec. 36, T. 8 N., R. 62 E. (Shingle Pass, Nevada 7.5-minute quadrangle).

	Thickness (feet)	*Cumulative thickness (feet)*
Kanosh Shale (lower 64 ft measured; overlying part covered).		
Limestone, medium-dark-gray, medium-bedded; receptaculitids, cephalopods; thin covered intervals (85WC-2924; 85WC-2893)	39	2924
Limestone, medium-dark-gray, medium-bedded; receptaculitids; few burrows; thin covered intervals (85WC-2873)	25	2885
Shingle Limestone (1,539 ft; 26 percent covered).		
Limestone, medium-dark-gray; weathers yellowish orange; medium bedded, poorly developed beds; brachiopods, trilobites; thin covered intervals (85WC-2848; 85WC-2820)	55	2860
Covered	4	2805
Limestone, medium-dark-gray; weathers yellowish orange; very thin bedded to thin bedded; mottled; few clasts (85WC-2801)	2	2801
Covered	124	2799
Limestone, medium-gray; weathers grayish orange and pale yellowish orange; very thin bedded to thin bedded; mottled; sponges, silicified burrows; thin covered intervals (85WC-2674; 85WC-2653; 85WC-2638)	42	2675
Limestone, medium-gray; weathers yellowish orange; very thin bedded to thin bedded; mottled; sponges, gastropods, brachiopods, cephalopods (85WC-2620; 85WC-2602)	34	2633
Limestone, medium-gray to medium-dark-gray, thin-bedded; mottled; brachiopods, gastropods	12	2599
Limestone, medium-gray to medium-dark-gray, thin-bedded; few fossils (85WC-2569; 85WC-2542; 85WC-2520)	82	2587
Limestone, medium-gray to medium-dark-gray, thin-bedded; gastropods, cephalopods, brachiopods, crinoids, trilobites, sponges; burrows (85WC-2500; 85WC-2480)	35	2505
Limestone, medium-gray to medium-dark-gray, very thin bedded to medium-bedded; fossiliferous (85WC-2460)	30	2470
Limestone, medium-gray to medium-dark-gray; weathers grayish orange; very thin bedded to thin bedded (85WC-2440; 85WC-2420 with first occurrence of *Tripodus laevis*)	30	2440
Limestone, medium-dark-gray, very thin bedded to medium-bedded; bioclastic layers (85WC-2404)	28	2410
Limestone, medium-gray, weakly developed beds; massive appearance; fossiliferous (85WC-2380)	12	2382

	Thickness (feet)	*Cumulative thickness (feet)*
Shingle Limestone—Continued		
Limestone, medium-gray, thin- to medium-bedded; contorted beds; bioclastic layers; trilobites, sponges, crinoids	9	2370
Limestone, light- to medium-gray, thin- to medium-bedded; contorted beds; bioclastic layers, trilobites; silicified burrows (85WC-2360; 85WC-2333; 85WC-2316; 85WC-2298)	76	2361
Limestone, medium-dark-gray, very thin bedded; irregular bedding; trilobites; silicified burrows (85WC-2278)	20	2285
Limestone, medium-gray; weathers pale yellowish orange; thickly laminated to very thin bedded; mottled; bioclastic layers; trilobites; silicified burrows (85WC-2260)	11	2265
Limestone, medium-gray, very thin bedded to thin-bedded; irregular bedding planes; light-brownish-gray clasts; bioclastic layers; trilobites; silicified burrows (85WC-2238)	20	2254
Limestone, brownish-gray to medium-gray, thin- to medium-bedded; irregular bedding planes; mottled; tabular to spherical clasts; very fossiliferous: gastropods, cephalopods, trilobites, brachiopods, abundant sponges; silicified burrows (85WC-2220)	19	2234
Limestone, light- to medium-gray, thin- to medium-bedded; mottled; thin bioclastic layers (85WC-2198)	17	2215
Covered	25	2198
Limestone, medium-gray; weathers pale orange; very thin bedded to medium bedded; mottled; sparry; bioclastic layers; gastropods, cephalopods, trilobites (85WC-2173)	1	2173
Covered	145	2172
Limestone, olive-black to medium-dark-gray, medium-bedded to thick-bedded (85WC-2020)	10	2027
Limestone, medium-gray, medium-bedded; sparry; bioclastic layers; abundant sponges; thin covered intervals	17	2017
Limestone, light- to medium-light-gray; weathers moderate red; medium bedded; intraclast and bioclastic layers (85WC-2000)	1	2000
Covered	6	1999
Limestone, medium-dark-gray and grayish-orange, thin-bedded; trilobites, cephalopods, crinoids	1	1993
Limestone, medium-dark-gray and grayish-orange, thin- to medium-bedded; mottled; gastropods, brachiopods, silicified burrows	5	1992
Covered	4	1987
Limestone, medium-light- to medium-gray, thin-bedded; intraclasts	1	1983

SUBSECTION 85WB

Section of Parker Spring Formation and lower part of Shingle Limestone in SWcNWc sec. 30, T. 8 N., R. 63 E. (Shingle Pass, Nevada, 7.5-minute quadrangle). Although offset below 85WC, section is continuous with 85WC.

	Thickness (feet)	*Cumulative thickness (feet)*
Shingle Limestone		
Covered	2	1982
Limestone, interbedded medium-light-gray and medium-gray to medium-dark-gray, thinly laminated to medium-bedded; intraclast and bioclastic layers; chert lenses; very fossiliferous: gastropods, brachiopods, cephalopods, crinoids, trilobites; thin covered intervals (85WB-1980; 85WB-1957; 5WB-1940)	42	1980

	Thickness (feet)	Cumulative thickness (feet)
Shingle Limestone—Continued		
Covered	26	1938
Limestone, medium-light-gray; weathers very light to light brownish gray; thin to medium bedded; rounded clasts, weathers light brown to moderate red; tabular clasts oriented parallel to bedding; very fossiliferous, gastropods, crinoids, trilobites; thin covered intervals (85WB-1912; 85WB-1896; 85WB-1874; 85WB-1860)	52	1912
Covered	2	1860
Limestone, medium-light-gray; weathers moderate red; thickly laminated to medium bedded; tabular clasts; bioclastic layers; silicified burrows; stromatolites? (85WB-1840)	23	1858
Limestone, medium-light-gray; weathers moderate red; very thin bedded to medium bedded; few chert and bioclastic layers; cephalopods, gastropods, silicified burrows (85WB-1820; 85WB-1800; 85WB-1780)	74	1835
Limestone, medium-light-gray, medium-bedded; burrowed (85WB-1760)	6	1761
Limestone, medium-light-gray; weathers grayish orange to moderate red; medium bedded; burrowed, some silicified burrows	2	1755
Limestone, medium-light-gray, medium-bedded; some intraclasts; burrowed	3	1753
Limestone, medium-light-gray; weathers grayish orange to moderate red; medium bedded; heavily burrowed; some silicified burrows	10	1750
Limestone, medium-gray, thickly laminated to medium-bedded, burrowed; gastropods (85WB-1740; 85WB-1721)	25	1740
Limestone, medium-gray; weathers grayish orange to moderate red; thickly laminated to medium bedded; chert layers; gastropods, brachiopods; silicified burrows (85WB-1700; 85WB-1680; 85WB-1661)	68	1715
Limestone, medium-dark-gray, thickly laminated to medium-bedded; chert layers; silicified burrows (85WB-1640)	26	1647
Limestone, medium-gray; weathers moderate red and grayish yellow; very thin bedded to medium bedded; wavy bedding planes; silicified burrows (85WB-1621; 85WB-1602)	36	1621
Limestone, medium-gray, thin- to medium-bedded; chert layers; silicified burrows (85WB-1580; 85WB-1559; 85WB-1540)	48	1585
Limestone, medium-dark-gray; weathers yellowish gray to dark brown; thickly laminated; brachiopods, gastropods; burrowed (85B-1521)	18	1537
Limestone, medium-dark-gray; weathers yellowish gray to dark brown; thickly laminated to medium bedded; gastropods (85WB-1503)	34	1519
Limestone, medium-gray, medium-bedded, burrowed	1	1485
Limestone, medium-dark-gray; weathers yellowish gray to dark brown; thickly laminated; burrowed (85WB-1483)	9	1484
Limestone, medium-dark-gray, very thin bedded; bioturbated; gastropods, brachiopods; base of high cliff	3	1475
Covered	2	1472
Limestone, medium-gray, thin- to thick-bedded; mottled	2	1470
Shingle Limestone—Continued		
Limestone, medium-gray, thinly laminated; base of low cliff (85WB-1467 at base)	1	1468
Covered	34	1467
Limestone, medium-gray, thin-bedded; mottled; bioclastic (85WB-1432 at base)	1	1433
Covered	30	1432
Limestone, medium-gray, thin- to thick-bedded; mottled (85WB-1402; 85WB-1385)	35	1402
Limestone, medium-gray; weathers grayish orange; thinly to thickly laminated; laminations destroyed by burrows in places; silicified laminae and burrows (85WB-1361)	15	1367
Limestone, medium-gray; weathers grayish orange gray; thin to thick bedded; mottled; few intraclasts; localized chert layers; brachiopods; burrowed (85WB-1343)	22	1352
Limestone, medium-gray, thinly laminated to thick-bedded; chert; weathers orangish brown; burrows; gastropods; stromatolites; laminae continuous through stromatolites and chert	9	1330
Parker Spring Formation (851 ft; 81 percent covered).		
Limestone, medium-gray, thin- to medium-bedded; mottled; bioturbated; burrowed (85WB-1320)	1	1321
Limestone, medium-gray, very thin bedded to thin-bedded; intraclast layers with tabular clasts parallel to bedding	2	1320
Covered. Probably shale; forms slope	10	1318
Limestone, medium-gray, medium-bedded; intraclast layers with bioclastic matrix (85WB-1306)	3	1308
Covered. Probably shale; forms slope	20	1305
Limestone, medium- to dark-gray, thickly laminated	1	1285
Covered. Probably shale; forms slope	5	1284
Limestone, medium-gray, medium-bedded; intraclast layers with clasts parallel to bedding, bioclastic matrix (85WB-1277 at base)	2	1279
Covered. Probably shale; forms slope	12	1277
Limestone, medium-gray, thickly laminated; crossbeds; intraclast layers with rounded clasts	2	1265
Covered. Probably shale; forms slope	8	1263
Limestone, medium-gray, very thin bedded to thin-bedded; intraclast layers	1	1255
Covered. Probably shale; forms slope	1	1254
Limestone, medium-gray, very thin bedded to thin-bedded; intraclast layers; minor bioclastic material (85WB-1253)	1	1253
Covered. Probably shale; forms slope	4	1252
Limestone, medium-gray to dark-gray, thickly laminated to medium-bedded; intraclast layers; bioturbated	2	1248
Covered. Probably shale; forms slope	29	1246
Limestone, medium-gray, medium-bedded; intraclast layers with clasts in random orientation (85WB-1217)	2	1217
Covered. Probably shale; forms slope	8	1215
Limestone and chert interlayered; limestone medium-gray, thickly laminated to very thin bedded; bioturbated; few intraclasts	2	1207
Covered. Probably shale; forms slope	3	1205

	Thickness (feet)	*Cumulative thickness (feet)*
Parker Springs Formation—Continued		
Limestone, medium-gray, thin- to medium-bedded; intraclast layers with rounded and tabular clasts in random orientation, bioclastic matrix; minor chert (85WB-1200 at base)	2	1202
Covered. Probably shale; forms slope	24	1200
Limestone, medium-gray, thin- to medium-bedded; intraclast layers with tabular clasts oriented subparallel to bedding (85WB-1175)	2	1176
Covered. Probably shale; forms slope	48	1174
Limestone, medium-light-gray to medium-gray, medium-bedded; intraclast layers with clasts subparallel to bedding (85WB-1126)	1	1126
Covered. Probably shale; forms slope	21	1125
Limestone, medium-light-gray to medium-gray, thin- to medium-bedded; intraclast layers with tabular and rounded clasts oriented subparallel with bedding in bioclastic matrix; pelecypods (85WB-1103)	2	1104
Covered. Probably shale; forms slope	53	1102
Limestone, medium-gray, medium-bedded; intraclast layers with randomly oriented tabular and rounded clasts	1	1049
Covered. Probably shale; forms slope	3	1048
Limestone, medium-gray, medium-bedded; intraclast layers with randomly oriented tabular and rounded clasts; thin covered intervals	2	1045
Limestone, medium-gray, medium-bedded; intraclast layers with randomly oriented tabular and rounded clasts; pelecypods (85WB-1042 at base)	1	1043
Covered. Probably shale; forms slope	2	1042
Limestone, medium-gray, medium-bedded; intraclast layers with randomly oriented tabular and rounded clasts	1	1040
Covered. Probably shale; forms slope	16	1039
Limestone, medium-gray, medium-bedded; intraclast layers with tabular and rounded clasts (85WB-1022 at base)	1	1023
Covered. Probably shale; forms slope	9	1022
Limestone, medium-gray to medium-dark-gray, medium-bedded; intraclast layers with bioclastic matrix; gastropods (85WB-1012 at base)	1	1013
Covered. Probably shale; forms slope	20	1012
Limestone, medium-gray, thin-bedded, intraclast layers (85WB-991 at base)	1	992
Covered. Probably shale; forms slope	22	991
Limestone, medium-gray, medium-bedded; intraclast layers with clasts parallel to bedding (85WB-968 at base)	1	969
Covered. Probably shale; forms slope	13	968
Limestone, medium-gray to medium-dark-gray, medium-bedded; intraclast layers with clasts parallel to bedding	1	955
Covered. Probably shale; forms slope	3	954
Limestone, medium-gray to medium-dark-gray, medium-bedded	1	951
Covered. Probably shale; forms slope	9	950
Limestone, medium-gray to medium-dark-gray, medium-bedded; intraclast layers with bioclastic matrix; cephalopods, pelecypods (85WB-941)	3	941
Covered. Probably shale; forms slope	6	938
Parker Springs Formation—Continued		
Limestone, medium to medium-dark-gray, thin- to medium-bedded; intraclast layers with bioclastic matrix and clasts parallel to bedding	1	932
Covered. Probably shale; forms slope	9	931
Limestone, medium-gray to dark-olive-gray, thin- to medium-bedded; intraclast layers with tabular clasts parallel to bedding; bioclastic layers (85WB-921)	2	922
Covered. Probably shale; forms slope	14	920
Limestone, medium-light-gray to medium-gray, thin- to medium-bedded; intraclast layers with tabular clasts subparallel to bedding; minor bioclastic material (85WB-906)	5	906
Covered. Probably shale; forms slope	32	901
Limestone, medium-light-gray to medium-gray, medium-bedded; intraclast layers (85WB-868)	2	869
Covered. Probably shale; forms slope	30	867
Limestone, medium-gray, medium-bedded; bioclastic; trilobites	1	837
Limestone, medium-gray, very thin bedded to thin-bedded; some bioclastic layers (85WB-836)	3	836
Limestone, medium-light-gray to medium-gray, thin- to medium-bedded; intraclast layers with tabular clasts oriented primarily parallel to bedding	3	833
Covered. Probably shale; forms slope	19	830
Limestone, medium-light-gray to medium-gray, thin- to medium-bedded; intraclast layers with rounded and a few tabular clasts	1	811
Limestone, medium-light-gray to medium-gray, thin- to medium-bedded; intraclast layers with tabular clasts oriented subparallel to bedding	1	810
Covered. Probably mostly shale; forms slope; single thin limestone bed exposed 19 ft above base (85WB-799)	29	809
Limestone, medium-light-gray to medium-gray, thin-bedded; sparry in places; intraclast layers with clasts parallel to bedding; bioclastic layers, pelecypods	1	780
Covered. Probably shale; forms slope	19	779
Limestone, medium-light-gray to medium-gray, thin- to medium-bedded; intraclast layers with tabular clasts parallel to bedding; bioclastic layers with pelecypods, gastropods, cephalopods (85WB-751)	10	760
Covered. Probably shale; forms slope	9	750
Limestone, medium-gray, thin- to medium-bedded; intraclast layers with tabular clasts; bioclastic layers (85WB-739 at base)	2	741
Covered. Probably mostly shale; forms slope	11	739
Limestone, gray, medium-bedded; intraclast layers	1	728
Covered. Probably shale; forms slope	6	727
Limestone, gray, medium-bedded; intraclast layers	1	721
Covered. Probably shale; forms slope	8	720
Limestone, medium-light-gray, thin-bedded; intraclast layers; minor bioclastic layers; limestone beds draped over chert cores (85WB-712)	2	712
Limestone, medium-light-gray to medium-gray, thickly laminated to thin-bedded; intraclast layers with sparry matrix; discontinuous chert layers (85WB-683 at base)	27	710
Covered. Probably shale; forms slope	39	683

	Thickness (feet)	*Cumulative thickness (feet)*
Parker Springs Formation—Continued		
Limestone, medium-light-gray to medium-gray, thickly laminated to thin-bedded; intraclast layers with bioclastic and sparry matrix and clasts subparallel to bedding; minor chert nodules and stringers (85WB-640)	5	644
Covered. Probably shale; forms slope	8	639
Limestone, medium-light-gray to medium-gray, very thin bedded; sparry; intraclast layers (85WB-630)	1	631
Covered. Probably shale; forms slope	56	630
Limestone, medium-light-gray; intraclast layers with clasts parallel to bedding and surrounded by sparry calcite (85WB-573 at base)	1	574
Covered. Probably shale; forms slope	8	573
Limestone, medium-light-gray, medium-bedded; sparry; intraclast layers	1	565
Covered. Probably shale; forms slope	26	564
Limestone, medium-gray, medium-bedded; interbedded intraclast and bioclastic layers (85WB-538)	1	538
Covered. Probably shale; forms slope	10	537
Limestone, medium-light-gray to medium-gray; laminated; interbedded intraclast and bioclastic layers; trilobites (85WB-518)	10	527
Limestone, medium-gray, thinly laminated to medium-bedded; sparry; intraclast layers; chert stringers and layers	11	517
Covered. Probably shale; forms slope	4	506
Limestone, medium-gray, thick-bedded; intraclast layers up to 8 in. thick with clasts subparallel to bedding and chert coating some clasts; chert nodules and stringers; thin bioclastic layers (85WB-501)	3	502
Limestone, medium-gray, thin-bedded; intraclast layers	10	499
Shale, light-brownish-gray, thinly laminated	1	489
Limestone, medium-light-gray to medium-gray; laminated; intraclast layers with randomly oriented clasts; few thin covered intervals	6	488
Limestone, light-gray to light-brownish-gray; intraclast layers with clasts subparallel to bedding in bioclastic and sparry matrix	2	482
Limestone, light-gray to light-brownish-gray, very thin bedded to medium-bedded; bedding uniform, with sparry matrix; chert nodules and stringers (85WB-480)	10	480

SUBSECTION 85WA

Section of House Limestone in center of sec. 25, T. 8 N., R. 62 E. (Shingle Pass, Nevada 7.5-minute quadrangle).

	Thickness (feet)	*Cumulative thickness (feet)*
House Limestone (470 ft; completely exposed).		
Limestone, gray, thin- to medium-bedded; forms ledge; chert stringers	6	470
Limestone, gray, thin- to medium-bedded; bioclastic layers up to 5 in. thick; intraclast layers with bioclastic matrix (85WA-455)	10	464
Limestone, gray, red-stained; intraclast layers with rotated clasts in bioclastic matrix (85WA-435)	20	454
House Limestone—Continued		
Limestone, gray, red-stained; thin- to medium-bedded; a few intraclast layers interbedded with bioclastic layers; minor contortion	10	434
Limestone, light-gray to brownish-gray, thin- to medium-bedded; sparry matrix; bioclastic layers	4	424
Limestone, medium-gray to medium-dark-gray, very thin bedded to medium-bedded; intraclastic and bioclastic layers; gastropods abundant (85WA-420; 85WA-401)	20	420
Limestone, medium-gray; few intraclast layers; bioclastic layers;?worm trails (85WA-379; 85WA-363)	40	400
Limestone, light-gray to medium-light-gray, very thin bedded to medium-bedded; sparry; some bioclastic layers	4	360
Limestone, gray; sparry; fractured and brecciated; some intraclast layers with rounded clasts; gastropods (85WA-342; 85WA-320)	42	356
Limestone, medium-gray, very thin bedded to medium-bedded; sparry calcite filling joints and fractures; gastropods (85WA-300)	19	314
Limestone, light-gray to medium-light-gray, thinly laminated to medium-bedded; bioclastic layers	15	295
Limestone, medium-gray, thickly laminated to medium-bedded; sparry; intraclasts in some layers; some bioclastic layers; less chert than below (85WA-280; 85WA-263; 85WA-240)	52	280
Limestone, medium-gray, thin- to medium-bedded; sparry; chert in discrete units; brecciated; burrowed	8	228
Limestone, gray; thin to medium beds with randomly oriented intraclasts; chert content approximately 60 percent; forms ridge; brecciated, includes rotated limestone blocks; some chert nodules and ribbony chert layers; chert decreases rapidly away from ridge crest (85WA-220; 85WA-200)	37	220
Limestone, gray; possibly crossbedded; tabular intraclasts in some layers parallel to bedding; chert content 50 percent (85WA-180)	10	183
Limestone and chert, as below, with ribbony chert layers and some intraclasts	13	173
Limestone, gray; bedding variable, bedding planes wavy; sparry; chert more than 50 percent but localized, in layers; brecciated intervals of chert and limestone (85WA-159)	20	160
Limestone, light-gray; tabular and rounded interclasts; some bedding planes wavy; 25 percent chert; chert localized and in layers; some layers brecciated	18	140
Limestone, light-gray, thickly laminated to very thin bedded; 10 percent chert (85WA-120)	4	122
Limestone, light-gray, thickly laminated to thin-bedded; sparry calcite filling joints	8	118
Limestone, light-gray, thickly laminated to very thin bedded; chert layers and nodules; numerous bioclastic layers; burrowed	10	110
Limestone, light-gray; wavy bedding; chert stringers and nodules; less chert than in units below (85WA-99)	18	100
Limestone, light-gray; finely laminated; bioclastic layer 8 in. thick; laminae discontinuous, contorted (85WA-82)	2	82

	Thickness (feet)	*Cumulative thickness (feet)*
House Limestone—Continued		
Limestone, light-gray; thinly laminated; wavy bedding planes; less chert than below, bioclastic layers more numerous; brachiopods, crinoid stem fragments (85WA-60)	24	80
Limestone, light-gray; thinly laminated; chert beds up to 4 in. thick	16	56
Limestone, light-gray; beds thinly laminated; bedding planes wavy; sparry; chert layers; rippled (85WA-40)	2	40
House Limestone—Continued		
Limestone, medium-light-gray to medium-gray; thin- to medium-bedded; some bedding planes wavy; chert stringers, nodules and beds; bioclastic beds up to 4 in. thick; poorly preserved brachiopods, crinoid stem fragments; burrowed (85WA-23; 85WA-00)	38	38

Whipple Cave Formation (not measured).

Contact between Whipple Cave Formation and House Limestone well exposed. Whipple Cave is dolomite below contact.

APPENDIX 2. RANGES (IN METERS) OF CONODONT SPECIES IN IBEXIAN SECTIONS AT EIGHT LOCALITIES

Localities identified in column headings are:

SHINGLE: Shingle Pass, Nevada (data new in this report)

STP: Steamboat Pass, Nevada (data from Hintze and others, 1988)

LD5: Lava Dam 5 (data from Hintze and others, 1988)

A: Hintze’s (1951) Ibex-area section A (data from Ethington and Clark, 1982)

E: Hintze’s (1951) Ibex-area section E (data from Ethington and Clark, 1982)

B-KA: Composite of Hintze’s (1951, 1973) Ibex-area sections B, C, M, H, ST, J, and K as indicated in figure 2 of this report (data from Ethington and Clark, 1982)

K-CP: Composite of Hintze’s (1973) Ibex-area K and CP Sections as indicated in figure 2 of this report (data from Ethington and Clark, 1982)

“Ref” refers to places in which the reader may find descriptions and (or) illustrations of the named conodont species.

E&C82 = Ethington and Clark, 1982
Rep 82 = Repetski, 1982
App4 = Appendix 4, this report

#	Species	Ref	SHINGLE	STP	LD5	A	E	B-KA	K-CP	ElPaso
			[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]
1	Acanthodus lineatus	E&C82	202-364			27-176	70-133	9-109		0-79
2	A. uncinatus	E&C82	270-288				94	?95-109		24
3	Acodus? aff A. emanuelensis	E&C82	455-923					244-696		
4	aff. A. gladiatus	E&C82	270-353			114-163				
5	"A." oneotensis	E&C82	215-336			91-173	52-114	7-105		0-55
6	A. sp. 1	E&C82						142-190		
7	?A. sp. 2	E&C82						195-204		
8	?A. sp. 3	E&C82						248-395		
9	A. sp. 4	E&C82				101-176	70-129			
10	"Acontiodus" aff "A" latus	E&C82						216-248		
11	"A." sp.	E&C82							43-304	
12	Albiconus postcostatus	App4			99-122					
13	Aloxoconus? iowensis	App4	202-306			40-173	45-133	12-106		6.-24
14	A.? propinquus	App4	215-318			84-170		12-106		6.-37
15	A. staufferi	App4	485-492							
16	?A. staufferi	App4				67-176	52-133	0-86		
17	Bergstroemognathus sp.	App4	715-768							
18	Belodella robusta	E&C82							195-284	
19	?aff Belodina sp.	E&C82							280	
20	?Bryantodina sp.	E&C82							267-270	
21	Cambrooistodus cambricus	App4	69-123	33	0-60					
22	C. minutus	App4	71-123	37-83	14-60					
23	Chionoconus robustus	App4	928-1082					690-718		
24	Chirognathus sp.	E&C82							270-288	
25	Chosonodina herfurthi	E&C82	301-312							
26	C. rigsbyi	E&C82							166-213	
27	Clavohamulus bulbousus	App4	180-187		90-118					
28	C. densus	E&C82	275-329					91-104		18-31
29	C. elongatus	E&C82	158-186		88-96	15-23	12.0-13			
30	C. hintzei	App4	196-198		115-125					
31	C. lemonei	Rep82	397							171-305
32	C. primitus	E&C82				23				
33	C. n. sp.	E&C82	499					279-285		
34	Colaptoconus quadraplicatus	App4	336-853					120-653		55-390
35	Cordylodus angulatus	E&C82	220-312			102-173	52	34		0-31
36	C. caseyi	E&C82	208			35-171	13-52	0-91		
37	C. drucei	App4	202-245		121-122					
38	C. intermedius	E&C82	188-312		112-125	34-171	9.0-89	0-97		0-18
39	C. lindstromi	Rep82	202-270							12.-18
40	C. prion	E&C82				57-171	17-45	0-32		
41	C. proavus	E&C82		87-94	61-125	0-57	5.0-9			
42	C. rotundatus	Rep82	207-312							0-31
43	C. sp. A	E&C82				56-96		3.0-32		
44	Cornuodus longibasis	App4	318-648					443-477		92-384
45	Cristodus loxoides	Rep82	397-751							214-293
46	Dapsilodus? nevadensis	E&C82							288-292	
47	Diaphorodus deltatus	App4	471-665					251-648		189-263
48	D. delicatus	App4	654-873							250-407
49	D. russoi	App4	1059							171-201
50	Dischidognathus primus	E&C82							186-198	
51	?Drepanodus arcuatus	E&C82	434-999					212-690		110-409

52	D. gracilis	E&C82						265-642		122-406
53	D. cf. D. planus	Rep82	896-974							
54	"D." simplex	E&C82				70-109		12-102		
55	D. sp. 1	E&C82						107-677		
56	D.? sp. 2	E&C82						160-724		
57	Drepanoistodus angulensis	E&C82	999-1082						2-213	
58	?D. angulensis	E&C82							267-293	
59	D. cf. basiovalis	E&C82	381-999					107-250		
60	D. aff. forceps	E&C82	381-1006					238-763	2.-84	98-409
61	Eoconodontus notchpeakensis	App4	20-202	21-94	0-125					
62	Erismodus asymmetricus	E&C82							267-293	
63	Erraticodon aff balticus	E&C82							154-293	
64	?Erraticodon sp.	E&C82							154-170	
65	Eucharodus parallelus	App4	220-984			70-109		12-741		0-390
66	E, toomeyi	App4	485-757					556-650		110-406
67	Fahraeusodus marathonensis	App4	618-1072					416-758		226-390
68	Falodus sp.	E&C82							151-172	
69	Fryxellodontus inornatus	App4	140-158	92-94	65-92					
70	F. lineatus	App4	158-174		65-93					
71	Hirsutodontus hirsutus	App4	174-190	89	61-125					
72	H. rarus	App4	134-184	89	63-125					
73	H. simplex	App4	190-192		98-112					
74	Histiodella altifrons	E&C82	1006-1082						12.-59	
75	H. donnae	Rep82	384-414					267		85-98
76	H. holodentata	E&C82							192-213	
77	H. minutiserrata	E&C82	1050-1082						36	
78	H. sinuosa	E&C82	1072						69-192	
79	Iapetognathus preaengensis	App4	202-215							
80	Juanognathus hayesi	Rep82								397-401
81	J. jaanussoni	E&C82	896-1082					653-763	2.-12	401-409
82	J. variabilis	E&C82	684-1006					577-718		256-409
83	Jumudontus gananda	E&C82	773-1006					527-741		348-406
84	Loxodus bransoni	E&C82	257-323			91-171	74-107	9.0-96		0-31
85	?aff Loxodus sp.	E&C82							186-202	
86	Macerodus dianae	E&C82						212-245		92-134
87	Microzarkodina flabellum	E&C82	953-974					724-743		
88	Monocostodus sevierensis	App4	188-220		96-125					
89	Multioistodus auritus	E&C82							15-150	
90	?M. auritus	E&C82							195	
91	M. subdentatus	E&C82							172-204	
92	M. sp.	E&C82							195	
93	Neomultioistodus compresus	App4	984-1082						15-150	
94	Oelandodus sp. cf. O. costatus	Rep82	629-745							244-305
95	Oepikodus communis	E&C82	672-959					440-726		256-409
96	O. sp. cf. O. evae	App4	995							
97	aff. O.? minutus	E&C82	896-1006					665-763	2.-38	
98	Oistodus bransoni	E&C82	556-782?					419-648		
99	O. cristatus	E&C82							84-129	
100	"O." hunickeni	E&C82						650-724		
101	"O." inaequalis	E&C82						253-684		
102	aff. "O." inaequalis	E&C82						206-565		98-401
103	O. cf. O. lanceolatus	Rep82								360-409
104	O.? lecheguillensis	Rep82								116-134

105	"O." mehli	Rep82	202-306							0-43
106	O. multicorrugatus	App4	853-1082					622-733	0-189	372-401
107	"O." triangularis	E&C82	202-329			66-176	35-133	0-105		
108	O. sp. 1	E&C82						650-757		
109	"O." sp. 2	E&C82						523-550		
110	"O." sp. 3	E&C82						577		
111	"O." sp. 4	E&C82							38-127	
112	"O." sp. 5	E&C82						3.-32		
113	"O." sp. 6	E&C82				151-174	89			
114	Oneotodus costatus	App4	492-715					288-648		177-406
115	O. simplex	App4	336-466					235-247		0-98
116	Paltodus sp. cf. P. deltifer	App4	318-353							
117	P. sp. cf. P. subaequalis	App4	397-533							
118	aff. P. jemtlandicus	E&C82						151-244		
119	"P." spurius	E&C82	238-257			101-139	70-114	9.-56		6.-12
120	Panderodus spp.	E&C82							281-293	
121	?P. sp.	E&C82							195	
122	Paracordylodus gracilis	Rep82	381-672							98-134
123	Parapanderodus asymmetricus	A pp4	739-1082					608-763		348-401
124	P. emarginatus	App4	618-1082					398-650		220-406
125	P. paracornuformis	App4						653-768	20	
126	P. striatus	App4	353-1082					166-763	9-198	73-409
127	Paraprioniodus costatus	E&C82							63-119	
128	Paraserratognathus abruptus	App4	526-768							182-323
129	Paroistodus numarcuatus?	App4	323-406							
130	P. originalis?	App4	896-1044							
131	P. parallelus	E&C82	485-974					267-650		92-409
132	Phakelodus tenuis	App4	66	65						
133	?Phragmodus flexuosus	E&C82							267-293	
134	?Plectodina sp.	E&C82							267	
135	Polonodus corbatoi	App4	612-618							
136	Prioniodus sp.	App4	648-660							
137	Proconodontus muelleri	App4	0-125	2.0-83	0-60					
138	P. serratus	App4	37-123		17-23					
139	Prooneotodus gallatini	App4	20-215	31-87	0-118					
140	P. rotundatus	App4	15-196	32-63	0-125					
141	Prosagittodontus eureka	App4	20		0-60					
142	Protopanderodus aff arcuatus	E&C82						565-584		
143	P. elongatus	E&C82	794-891					596-653		
144	P. elongatus of Repetski 82	Rep82	381-434							85-110
145	P. gradatus	E&C82	739-1082					521-758	2-195	360-409
146	P.? leei	Rep82	336-444					153-241		73-134
147	P. leonardii	E&C82	660-1059					521-763	4.-52	244-406
148	P.? n.spp.1+2 of Repetski 82	Rep82	397-556							98-183
149	Protoprioniodus aranda	E&C82	896-999					658-758		397-409
150	P. nyinti	App4	896-1006							
151	P. papiliosus	E&C82						677		
152	P. simplicissimus?	App4	502-853							
153	P.? n. sp.	App4	984							
154	Pteracontiodus cryptodens	E&C82	965-1044						0-144	
155	P. gracilis	E&C82							170-192	
156	?Reutterodus andinus	E&C82	773-923					532-718		360-409
157	R.? borealis	Rep82	648-660					431-471		263-372

158	Rossodus manitouensis	App4	227-336			84-183	70-133	3-109		0-31
159	?R. manitouensis	App4				104-176	60-74	9.-91		
160	R.? n. sp.	App4	245-251							
161	Scalpellodus striatus	E&C82						230-646		
162	aff "Scandodus" flexuosus	E&C82						111-632		0-189
163	S. sinuosus	E&C82							4-219	
164	"S." sp. 1	E&C82						448-648		
165	"S." sp. 3	E&C82						229-648		
166	"S." sp. 4	E&C82							28-52	
167	"S." sp. 5	E&C82				91-181	60-123	25-91		
168	"S." sp. 6	E&C82				87-176		17-193		
169	"Scolopodus" acontiodiformis	Rep82	245-251							55-406
170	"S." bolites	Rep82	406-419							92-104
171	S. cornutiformis	E&C82						107-110		214-336
172	"S." filosus	E&C82	329-853					119-606		73-409
173	S. floweri	Rep82	434-477					233-244		31-134
174	S. multicostatus	E&C82	593-618					373-487		
175	"S." peselephantis	E&C82						431-648		
176	aff S. rex	E&C82	318-654					131-427		55-275
177	?"S." sexplicatus	E&C82				101-176	74-114	35-87		18-31
178	S. sp. aff. S. striatus	E&C82						547-600		
179	"S." sulcatus	E&C82	220-556			84-170	86-92	210-328		12.-79
180	"S." triangularis	App4	336-1082							
181	?S. sp.	E&C82						547-649		
182	Scolopodiform A of E&C82	E&C82						177-236		
183	Scolopodiform B of E&C82	E&C82	794-891					443-601		
184	Scolopodiform C of E&C82	E&C82	697-928					204-547		
185	Scolopodiform D of E&C82	E&C82						275-653		
186	Scolopodiform E of E&C82	E&C82						268-637		
187	Scolopodiform F of E&C82	E&C82						161-754		
188	Semiacontiodus lavadamensis	App4	188		112-121					
189	S. nogamii	App4	180-202		90-125					
190	Stolodus stola	E&C82						635-653		
191	Teridontus nakamurai	App4	0-318	92-94	63-125	7-176	3-133	0-102		
192	Toxotodus amphigyus	App4						?715		
193	T. carlae	App4								220-409
194	"Trichonodella" ? sp. Mound	App4	301							
195	Tripodus laevis	E&C82	928-1082					717-760		
196	Tropodus comptus	App4	485-891					265-690		189-397
197	Ulrichodina abnormalis	E&C82						263-623		232-409
198	U. cristata	E&C82	768					321-638		
199	U. deflexa	E&C82						247-288		146-207
200	U.? simplex	E&C82						373-638		
201	?U. wisconsinensis	E&C82	485-709					265-471		153-305
202	?U. sp.	E&C82						222		
203	Utahconus tenuis	App4			116-125					
204	U. utahensis	App4	188-238		96-125					
205	Variabiloconus bassleri	App4	208-364			87-176	45-133	0-109		0-79
206	?Walliserodus ethingtoni	E&C82	548-800					298-620		
207	N. genus 1	E&C82						118-190		
208	N. genus 2	E&C82						443-605		
209	N. genus 4	E&C82							160	
210	N. genus 5	E&C82							?292	

APPENDIX 3. COMPOSITE STANDARD-EQUIVALENT RANGES OF CONODONT SPECIES LISTED IN APPENDIX 2

Sections identified in Appendix 2. The column headed CS lists composite-standard ranges as determined in this report.

#	Species	SHINGLE	STP	LD5	A	E	B-KA	K-CP	ElPaso	CS
		[csu]	[csu]	[csu]	[csu]	[csu]	[csu]	[csu]	[csu]	[csu]
1	**Acanthodus lineatus**	202-364			209-314	260-318	235-335		240-370	202-370
2	**A. uncinatus**	270-288				282	321-335		279	270-335
3	**Acodus? aff A. emanuelensis**	455-923					470-922			455-922
4	**aff A. gladiatus**	270-353			270-305					270-353
5	**"A." oneotensis**	215-336			254-312	244-301	233-331		240-330	215-336
6	**A. sp. 1**						368-416			368-416
7	**?A. sp. 2**						421-430			421-430
8	**?A. sp. 3**						474-621			474-621
9	**A. sp. 4**				261-314	260-315				260-315
10	**"Acontiodus" aff. A. latus**						442-474			442-474
11	**"A. " sp.**							1044-1345		1044-1345
12	**Albiconus postcostatus**			167-193						167-193
13	**Aloxoconus? iowensis**	202-306			218-312	237-318	238-332		250-279	202-332
14	**A.? propinquus**	215-318			249-309		238-332		250-301	215-332
15	**A. staufferi**	485-492								485-492
16	**?A. staufferi**				237-314	244-318	226-312			226-318
17	**Bergstroemognathus sp.**	715-768								715-768
18	**Belodella robusta**							1219-1322		1219-1322
19	**?aff Belodina sp.**							1317		1317
20	**?Bryantodina sp.**							1302-1306		1302-1306
21	**Cambrooistodus cambricus**	69-123	66	55-123						55-123
22	**C. minutus**	71-123	71-123	71-123						71-123
23	**Chionoconus robustus**	928-1082					916-944			916-1082
24	**Chirognathus sp.**							1306-1326		1306-1326
25	**Chosonodina herfurthi**	301-312								301-312
26	**C. rigbyi**							1186-1240		1186-1240
27	**Clavohamulus bulbousus**	180-187		157-188						157-188
28	**C. densus**	275-329					317-330		270-291	270-330
29	**C.elongatus**	158-186		154-163	201-207	207-208				154-208
30	**C. hintzei**	196-198		185-196						185-198
31	**C. lemonei**	397							520-740	397-740
32	**C. primitus**				207					207
33	**C. n. sp.**	499					505-511			499-511
34	**Colaptoconus quadraplicatus**	336-853					346-879		330-880	330-880
35	**Cordylodus angulatus**	220-312			262-312	244	260		240-291	220-312
36	**C. caseyi**	208			215-309	208-244	226-317			208-317
37	**C. drucei**	202-245		192-193						192-245
38	**C. intermedius**	188-312		170-196	214-309	204-278	226-323		240-270	170-323
39	**C. lindstromi**	202-270							260-270	202-270
40	**C. prion**				230-309	212-237	226-258			212-309
41	**C. proavus**		127-135	118-196	190-230	201-204				118-230
42	**C. rotundatus**	207-312							240-291	207-312
43	**C. sp. A**				230-258		229-258			229-258
44	**Cornuodus longibasis**	318-648					669-703		391-870	318-870
45	**Cristodus loxoides**	397-751							591-721	397-751
46	**Dapsilodus? nevadensis**							1326-1331		1326-1331
47	**Diaphorodus deltatus**	471-665					477-874		550-671	471-874
48	**D. delicatus**	654-873							650-907	650-907
49	**D. russoi**	1059							520-568	520-1059
50	**Dischidognathus primus**							1209-1223		1209-1223
51	**?Drepanodus arcuatus**	434-999					438-916		420-911	420-999

52	D. gracilis						491-868		440-906	440-906
53	D.planus	896-974								896-974
54	"D." simplex				230-267		238-328			238-328
55	D. sp. 1						333-903			333-903
56	D.? sp. 2						386-950			386-950
57	Drepanoistodus angulensis	999-1082						997-1240		997-1240
58	?D. angulensis							1275-1332		1275-1332
59	D. cf. basiovalis	381-999					333-476			334-999
60	D. aff. forceps	381-1006					464-989	997-1092	401-911	381-1092
61	Eoconodontus notchpeakensis	20-202	53-135	55-196						20-202
62	Erismodus asymmetricus							1275-1332		1275-1332
63	Erraticodon aff balticus							1172-1332		1172-1332
64	?Erraticodon sp.							1172-1191		1172-1191
65	Eucharodus parallelus	220-984			239-267		238-967		240-880	220-984
66	E. toomeyi	485-757					782-876		420-906	420-906
67	Fahraeusodus marathonensis	618-1072					642-984		611-880	611-1072
68	Falodus sp.							1169-1193		1169-1193
69	Fryxellodontus inornatus	140-158	133-135	128-159						128-159
70	F. lineatus	158-174		128-160						128-174
71	Hirsutodontus hirsutus	174-190	130	124-196						124-196
72	H. rarus	134-184	130	126-196						126-196
73	H. simplex	190-192		166-184						166-192
74	Histiodella altifrons	1006-1082						1009-1063		1006-1082
75	H. donnae	384-414					493		379-401	379-493
76	H. holodentata							1216-1240		1216-1240
77	H. minutiserrata	1050-1082						1036		1036-1082
78	H. sinuosa	1072						1074-1216		1072-1216
79	Iapetognathus preaengensis	202-215								202-215
80	Juanognathus hayesi								891-898	891-896
81	J. jaanussoni	896-1082					879-989	997-1009	898-911	879-1082
82	J. variabilis	684-1006					803-944		660-911	660-1006
83	Jumudontus gananda	773-1006					753-967		811-906	753-1006
84	Loxodus bransoni	257-323			254-309	264-294	235-322		240-291	235-323
85	?aff Loxodus sp.							1209-1227		1209-1227
86	Macerodus dianae						438-471		391-460	391-471
87	Microzarkodina flabellum	953-974					950-968			950-974
88	Monocostodus sevierensis	188-220		163-196						163-220
89	Multioistodus auritus							1012-1168		1012-1168
90	?M. auritus							1219		1209
91	M. subdentatus							1193-1230		1193-1230
92	M. sp.							1219		1209
93	Neomultioistodus compressus	984-1082						1012-1168		984-1168
94	Oelandodus sp. cf. O. costatus	629-745							640-740	629-745
95	Oepikodus communis	672-959					666-952		660-911	660-959
96	O. sp. cf. O. evae	995								995
97	aff. O.? minutus	896-1006					891-989	997-1039		891-1039
98	Oistodus bransoni	556-782?					645-874			556-874
99	O. cristatus							1092-1143		1092-1143
100	"O." hunickeni						876-950			876-950
101	"O." inaequalis						479-910			479-910
102	aff. "O." inaequalis						432-791		401-898	401-898
103	O. cf. O. lanceolatus								830-911	830-911
104	O.? lecheguillensis								430-460	430-460

105	"O." mehli	202-306							240-311	202-311
106	O. multicorrugatus	853-1082					848-959	995-1212	850-898	848-1212
107	"O." triangularis	202-329			237-314	228-318	226-331			202-331
108	O. sp. 1						876-983			876-983
109	"O." sp. 2						749-776			749-776
110	"O." sp. 3						803			804
111	"O." sp. 4							1039-1141		1039-1141
112	"O." sp. 5						229-258			229-258
113	"O." sp. 6				296-312	278				278-312
114	Oneotodus costatus	492-715					514-874		530-906	492-906
115	O. simplex	336-466					461-473		240-401	240-473
116	Paltodus sp. cf. P. deltifer	318-353								318-353
117	P. sp. cf. P. subaequalis	397-533								397-533
118	aff. P. jemtlandicus						378-470			378-470
119	"P." spurius	238-257			261-288	260-301	235-282		250-260	235-301
120	Panderodus spp.							1318-1332		1318-1332
121	?P. sp.							1219		1219
122	Paracordylodus gracilis	381-672							401-460	381-672
123	Parapanderodus asymmetricus	739-1082					834-989		811-898	739-1082
124	P. emarginatus	618-1082					624-876		601-906	601-1082
125	P. paracornuformis						879-994	1018		879-1018
126	P. striatus	353-1082					392-989	1005-1223	360-911	353-1223
127	Paraprioniodus costatus							1067-1132		1067-1132
128	Paraserratognathus abruptus	526-768							538-770	526-770
129	Paroistodus numarcuatus?	323-406								323-406
130	P. originalis?	896-1044								896-1044
131	P. parallelus	485-974					493-876		391-911	391-974
132	Phakelodus tenuis	66	102							66-102
133	?Phragmodus flexuosus							1302-1332		1302-1332
134	?Plectodina sp.							1302		1302
135	Polonodus corbatoi	612-618								612-618
136	Prioniodus sp.	648-660								648-660
137	Proconodontus muelleri	0-125	31-123	55-123						0-125
138	P. serratus	37-123		74-81						37-123
139	Prooneotodus gallatini	20-215	64-127	55-188						20-215
140	P. rotundatus	15-196	65-100	55-196						15-196
141	Prosagittodontus eureka	20		55-123						20-123
142	Protopanderodus aff. arcuatus						791-810			792-810
143	P. elongatus	794-891					822-879			794-891
144	P. elongatus of Repetski 82	381-434							379-420	379-434
145	P. gradatus	739-1082					747-984	997-1219	830-911	739-1219
146	P.? leei	336-444					379-467		360-460	336-467
147	P. leonardii	660-1059					747-989	1000-1055	640-906	640-1059
148	P.? n.spp.1+2 of Repetski 82	397-556							401-540	397-556
149	Protoprioniodus aranda	896-999					884-984		891-911	884-999
150	P. nyinti	896-1006								896-1006
151	P. papiliosus						903			903
152	P. simplicissimus?	502-853								502-853
153	P.? n. sp.	984								984
154	Pteracontiodus cryptodens	965-1044						995-1161		965-1161
155	P. gracilis							1191-1216		1181-1216
156	?Reutterodus andinus	773-923					758-944		830-911	758-944
157	R.? borealis	648-660					657-697		671-850	648-850

158	Rossodus manitouensis	227-336			249-319	260-318	229-335		240-291	227-336
159	?R. manitouensis				263-314	251-264	235-317			235-317
160	R.? n. sp.	245-251								245-251
161	Scalpellodus striatus						456-872			456-872
162	aff "Scandodus" flexuosus						337-858		240-550	240-858
163	S. sinuosus							1000-1247		1000-1247
164	"S." sp. 1						674-874			674-874
165	"S." sp. 3						455-874			455-874
166	"S." sp. 4							1027-1055		1027-1055
167	"S." sp. 5				254-317	251-309	251-317			251-317
168	"S." sp. 6				251-314		243-419			243-419
169	"Scolopodus" acontiodiformis	245-251							330-906	245-906
170	"S." bolites	406-419							391-411	391-419
171	S. cornutiformis						333-336		591-791	333-791
172	"S." filosus	329-853					345-832		360-911	329-911
173	S. floweri	434-477					459-470		291-460	291-477
174	S. multicostatus	593-618					599-713			593-713
175	"S." peselephantis						657-874			657-874
176	aff S. rex	318-654					357-653		330-691	318-691
177	?"S." sexplicatus				261-314	264-301	261-313		270-291	261-314
178	S. sp. aff. S. striatus						773-826			773-826
179	"S." sulcatus	220-556			249-309	275-281	436-554		260-370	220-554
180	"S." triangularis	336-1082								336-1082
181	?S. sp.						773-875			773-875
182	Scolopodiform A of E&C82						403-462			403-472
183	Scolopodiform B of E&C82	794-891					669-827			669-827
184	Scolopodiform C of E&C82	697-928					430-773			430-928
185	Scolopodiform D of E&C82						501-879			501-879
186	Scolopodiform E of E&C82						494-863			494-863
187	Scolopodiform F of E&C82						387-980			387-980
188	Semiacontiodus lavadamensis	188		182-192						182-192
189	S. nogamii	180-202		157-196						157-202
190	Stolodus stola						861-879			861-879
191	Teridontus nakamurai	0-318	133-135	126-196	195-314	197-318	226-328			0-328
192	Toxotodus amphigyus						?941			?941
193	T. carlae								601-911	601-911
194	"Trichonodella" ? sp. Mound	301								301
195	Tripodus laevis	928-1082					943-986			928-1082
196	Tropodus comptus	485-891					491-916		550-891	485-916
197	Ulrichodina abnormalis						489-849		620-911	489-911
198	U. cristata	768					547-864			547-864
199	U. deflexa						473-514		479-579	473-579
200	U.? simplex						599-864			599-864
201	?U. wisconsinensis	485-709					491-697		491-740	485-740
202	?U. sp.						448			448
203	Utahconus tenuis			186-196						186-196
204	U. utahensis	188-238		163-196						163-238
205	Variabiloconus bassleri	208-364			251-314	237-318	226-335		240-370	208-370
206	?Walliserodus ethingtoni	548-800					524-846			524-846
207	N. genus 1						344-416			344-416
208	N. genus 2						669-831			669-831
209	N. genus 4							1179		1179
210	N. genus 5							?1331		?1331

APPENDIX 4. TAXONOMIC NOTES

A majority of the conodonts considered in this report are identified and named according to the schemes described in monographs by Ethington and Clark (1982) and Repetski (1982), which include illustrations of typical forms. In Appendix 2, the notations "E&C82" and "Rep82," which follow the names in the column headed "Species", indicate that the species are described and illustrated in either Ethington and Clark (1982) or Repetski (1982). Names in Appendix 2 followed by the notation "App4" are those of conodont species that either were not described and illustrated in Ethington and Clark or Repetski, or were included under different names in one or both of those reports. References to illustrations and descriptions of those forms follow in this appendix.

We do not consider taxonomic questions in detail, propose many revisions, or make any major changes. On the contrary, we have been concerned primarily that the names we use refer to the same entities subsumed under those names in reports on the stratigraphic sections with which we compare the Shingle Pass section.

Acanthodus lineatus (Furnish, 1938). Typical forms are illustrated by Ethington and Clark (1982, pl. 1, fig. 7) and Repetski (1982, pl. 1, figs. 1, 3).

Acanthodus uncinatus Furnish, 1938. See Ethington and Clark (1982, pl. 1, fig. 8) and Repetski (1982, pl. 1, fig. 4).

Albiconus postcostatus Miller, 1980, p. 8, figure 2.

Aloxoconus? *iowensis* (Furnish, 1938) and *Aloxoconus*? *propinquus* (Furnish, 1938). Albid coniform representatives of these common Lower Ordovician species were originally referred to *Acontiodus*, a practice that has been followed by most subsequent authors. Smith (1991) based *Aloxoconus* on *Acontiodus staufferi* Furnish (1938), whose distinctive coniform elements are hyaline, not albid, but also included *Acontiodus iowensi* Furnish and *Acontiodus propinquus* Furnish, both with elements that are solidly albid above the base. Numerous specimens from the House Limestone in the Shingle Pass section are clearly conspecific with Furnish's species. Although it is unlikely that either species is referable to *Acontiodus* Pander, 1856, we question reference to *Aloxoconus* because it has been customary to assign considerable taxonomic weight to the presence or absence of white matter in conodont elements and it has not been possible to verify Smith's (1991, p. 19) assertion that *A.*? *iowensis* evolved into *A. staufferi*, and that this development involved, among other things, a loss of white matter.

Bergstroemognathus sp. Single specimens in two samples from the mid-portion of the Shingle Limestone are components of the apparatus of an indeterminate species of *Bergstroemognathus*, which was established by Serpagli (1974, p. 39–40) for *B. extensus* (Graves and Ellison, 1941).

Cambrooistodus cambricus (Miller, 1969), p. 431, pl. 66, figs. 8–12 (as *Oistodus cambricus*). Miller, 1980, p. 9–11, text-figure 3A, 4E; pl. 1, figure 9.

Cambrooistodus minutus (Miller, 1969), p. 433, pl. 66, figs. 1–4 (as *Oistodus minutus*). Miller, 1980, p. 11, text-figure 4F; pl. 1, figure 8.

Chionoconus robustus (Serpagli, 1974), p. 85, pl. 18, figs. 3, 4; pl. 28, figs. 12, 13 (as "*Scandodus*" *robustus*). Ethington and Clark, 1982, p. 94, pl. 10, figs. 25–27 (as "*Scandodus*" *robustus*).

Clavohamulus bulbousus (Miller, 1969), p. 435, pl. 64, figs. 1–5 (as *Oneotodus bulbousus*).

Clavohamulus hintzei Miller, 1969, p. 422–423, pl. 64, figs. 19–24.

Colaptoconus quadraplicatus (Branson and Mehl, 1933). Coniform elements typical of this widely distributed Lower Ordovician species were originally referred to *Scolopodus*, later to *Glyptoconus* Kennedy, 1980, and most recently to *Colaptoconus* Kennedy, 1994, a new name for *Glyptoconus* Kennedy, 1980, *non* Moellendorff, 1894. Kennedy's (1980) concept of the species is followed here. Typical representatives are illustrated by Kennedy (1980, pl. 1, figs. 39–45).

Cordylodus. Every sample, from the base to 122 m above the base of the House Limestone, contains dolabrate ramiform elements that represent species of *Cordylodus*. We have assigned these elements to seven species, at least three of which appear first in the upper Whipple Cave Formation (Miller, *in* Taylor and others, 1989). Although the stratigraphic distribution of *Cordylodus* is considered critical to definition of the base of the Ordovician System and Ibexian Series, species-level taxonomy is in a state of flux (for example, Nicoll, 1990, 1991, 1992a). Species are identified here in terms of the concepts discussed by Miller (1980), Ethington and Clark (1982), and Repetski (1982), whose reports include synonymies and illustrations of typical specimens.

Cordylodus drucei Miller, 1980, p. 16, 17, text-figure 4K, M; pl. 1, figs. 17?, 20, 21, 25.

Cornuodus longibasis (Lindström, 1955), p. 564, pl. 3, fig. 31. Ethington and Clark, 1982, p. 100, pl. 11, figs. 23, 25, 29 (as ?"*Scolopodus*" aff. "*S.*" *filosus*). Repetski, 1982, p. 40, pl. 17, figs. 11, 12 (as *Protopanderodus longibasis*).

Diaphorodus. Kennedy (1980) established *Diaphorodus* for multielement species previously referred to *Acodus* Pander, 1856, a genus whose place in a modern taxonomy for conodonts may always be obscure. Sweet (1988) concluded that *Diaphorodus* and *Tripodus* Bradshaw, 1969 (as reconstructed by Ethington and Clark, 1982) "*** are based on different, but probably congeneric species***" and thus regarded *Diaphorodus* as a junior synonym of *Tripodus*. This is not the place to explore that conclusion, or for further revision of the generic concepts involved; hence the only change we advocate is reference to *Diaphorodus* of the species described by Ethington and Clark (1982) and Repetski (1982) as *Acodus deltatus* and *A. delicatus*, and the species described by Serpagli (1974) as *A.*? *russoi.*

Diaphorodus delicatus (Branson and Mehl, 1933). In Shingle Pass collections this species is represented by only a few elements, the most distinctive a geniculate coniform element that probably occupied the M position in the apparatus and has a very short posterior extension of the base. Kennedy (1980) assembled form species originally described by Branson and Mehl (1933) and provided an extensive synonymy, but his illustrations of type material and associated forms from the Jefferson City Formation of Missouri leave much to be desired. Better illustrations are provided by McTavish (1973, pl. 1, figs. 1–9, 12–14), who was the first to reconstruct *D. delicatus* but referred it to *Acodus deltatus deltatus* Lindström. Repetski (1982) recognized *D. delicatus* (as *Acodus delicatus*) in his collections from the El Paso Group of Texas, where the species has essentially the same range as in the Shingle Pass section. Ibex district ranges suggest that Ethington and Clark (1982) may have included representatives of *D. delicatus* in the upper part of the range of a species for which they used the name *Acodus deltatus*. The Ibex district specimens illustrated, however, are referable to *D. deltatus,* not *D. delicatus.*

Diaphorodus deltatus (Lindström, 1955). A recurrent group of elements similar or identical to those assembled by Ethington and Clark (1982, p. 18–19, text-fig. 4; pl. 1, figs. 1–6) in *Acodus deltatus* Lindström, 1955, characterizes Shingle Pass collections from 138 m above the base of the Parker Spring Formation to 72 m above the base of the Shingle Limestone. Above the latter level, elements of *Diaphorodus* are less abundant and for a few meters appear to represent both *D. delicatus* and *D. deltatus*, in which the base of the geniculate coniform M element extends somewhat farther posteriorly than is apparently the case with comparable structures in the apparatus of *D. delicatus*. In collections from an interval in the Parker Spring Formation 31 m to 112 m above its base are single specimens that clearly represent a species of *Diaphorodus* with elements closely related morphologically to those of *D. deltatus* but probably not conspecific. This may be the same species that is represented in the Ibex area of Utah, in the lower part of the Fillmore Formation below the one that yields clear representatives of *D. deltatus*.

Diaphorodus russoi (Serpagli, 1974), p. 35-37, text-figure 5; pl. 8, figs. 1–5; pl. 20, figs. 7, 8 (as *Acodus*?*russoi*). Repetski, 1982, p. 13, pl. 3, figs. 1–5 (as *Acodus*? *russoi*).

Eoconodontus notchpeakensis (Miller, 1969), p. 438, pl. 66, figs. 13–29 (as *Proconodontus notchpeakensis*). Miller, 1980, p. 22, text-figs. 3D, E; pl. 1, figs. 10–12.

Eucharodus parallelus (Branson and Mehl, 1933), p. 59, pl. 4a, figure 17. Ethington and Clark, 1982, p. 38, 39, pl. 3, figure 8 (as "*Drepanodus*" *parallelus*). Kennedy, 1980, p. 58–60, pl. 1, figs. 35–38.

Eucharodus toomeyi (Ethington and Clark, 1964). Ethington and Clark, 1982, p. 39–40, pl. 3, figure 11 (as "*Drepanodus*" *toomeyi*).

Fahraeusodus marathonensis (Bradshaw, 1969). Ethington and Clark, 1982, p. 55–56, pl. 5, figs. 14, 19, 20, 23, 24, 27 (as "*Microzarkodina*" *marathonensis*).

Fryxellodontus inornatus Miller, 1969, p. 426, pl. 65, figs. 1–10, 12, 16, 23–25.

Fryxellodontus lineatus Miller, 1969, p. 429, pl. 65, figs. 17–22, 26–29.

Glyptoconus Kennedy, 1980. See *Colaptoconus* Kennedy, 1994.

Hirsutodontus hirsutus Miller, 1969, p. 431, pl. 64, figs. 25, 26, 29–31.

Hirsutodontus rarus Miller, 1969, p. 431, pl. 64, figs. 36–42.

Hirsutodontus simplex (Druce and Jones, 1971). Miller, 1969, pl. 64, figs. 27, 28, 32–35 (as *Hirsutodontus hirsutus*).

Iapetognathus preaengensis Landing, in Fortey and others, 1982, p. 124, 126, figs. 6B, C, 8B, C, H.

Jumudontus gananda Cooper, 1981, pl. 31, figure 13. Ethington and Clark, 1982, pl. 2, figs. 9, 10. Nicoll, 1992b, figs. 7, 8. This species is represented by its distinctive Pa elements in just 10 Shingle Pass samples, and in a majority of these by just one or two specimens. Nicoll (1992b) has reconstructed the complete septimembrate apparatus of *Jumudontus gananda,* but only a few of the ramiform types he included are represented in our samples from Shingle Pass. Although all of the ramiform elements we refer to *J. gananda* are similar to those Nicoll includes in the species' apparatus, there are also differences that are difficult to evaluate. The latter may indicate considerable variability in various elements of the apparatus, or they may indicate that the Shingle Pass specimens represent an undescribed species or subspecies.

Monocostodus sevierensis (Miller, 1969), p. 418, pl. 63, figs. 25–31; pl. 64, figs. 49–54 (as *Acodus sevierensis*). Miller, 1980, p. 26–27, text-figure 4U; pl. 2, figs. 8,9.

Neomultioistodus compressus Harris and Harris, 1965, p. 43–44, pl. 1, figs. 7a–c. Ethington and Clark, 1982, p. 58–59, pl. 6, figs. 8–11, 16 (as *Multioistodus compressus*).

Oepikodus sp. cf. *O. evae* (Lindström, 1955). Elements typical of the apparatus of *O. evae* are assembled by Lindström and illustrated in Ziegler, ed., 1977, p. 253–255, *Oepikodus*-Plate 1, figs. 6–11. Specimens from Shingle Pass samples are closely comparable, but process sides of P elements lack the ledges characteristic of typical representatives of the species. The significance of this feature is uncertain, hence our identification is tentative.

Oistodus multicorrugatus Harris, 1962. Ethington and Clark, 1982, p. 68–70, text-figure 17; pl. 7, figs. 9, 10, 12–14. Single specimens reported by Ethington and Clark (1982) from samples 250 and 340 ft above the base of Ibex-area section H, but the first full apparatus is in a sample 330 ft above the base of Ibex-area section ST, and we take this as the level of first appearance of the species in the Ibex area.

Oneotodus costatus Ethington and Brand, 1981, p. 242–245, figs. 2B,D,G,H; 2A, D–M. *O. costatus* had evidently not been determined to be distinct from *O. simplex* when Ethington and Clark prepared their report on Ibex-area conodonts. Hence, we initially assumed that the specimens they logged in their tables as aff. *Oneotodus simplex* were like the one they illustrated, which is from a sample 260 ft above the base of Hintze's Square Top section and would now be referred to *Oneotodus costatus*. In their discussion of the *Acodus deltatus/Oneotodus costatus* Zone, however, Ross and others (1993) noted that *O. costatus* appears first 600 ft (183 m) above the base of the Fillmore Formation, whereas Ethington and Clark (1982) identified as "aff. *O. simplex*" specimens from as low as 425 ft (130 m) and 559 ft (or 170 m) above the base of the Fillmore in Hintze's C and M Sections. We have not seen these specimens, but we suspect that they should now be referred to *Oneotodus simplex*, or to an unnamed species intermediate between *O. simplex* and *O. costatus*. In the faunal lists of Appendixes 2 and 3, we log these specimens as *O. simplex*. Ji and Barnes (1994) established *O. costatus* as type species of a new genus, *Stultodontus*, which also includes species with apparatuses composed of elements like those we refer to *Paraserratognathus abruptus*.

Oneotodus simplex (Furnish, 1938). Ethington and Brand, 1981, p. 239–242, text-figure 1A, C, E, F, I; text-figure 2B, C.

Paltodus sp. cf. *P. deltifer* (Lindström, 1955). A few Shingle Pass specimens are similar morphologically to the types of multielement *P. deltifer*. They may represent *P. deltifer* or an unnamed, closely related species. Typical *P. deltifer* is diagnosed and illustrated by Lindström in Ziegler, ed., 1977, p. 421–423, *Paltodus*-Plate 1, figs. 1–4.

Paltodus sp. cf. *P. subaequalis* Pander, 1856. Specimens in three Shingle Pass samples resemble the elements of multielement *P. subaequalis* as reconstructed by Lindström in Ziegler, ed., 1977, p. 427–428, *Paltodus*-Plate 1, figs. 7–9, but cannot be assigned to that species with certainty. The elements may represent an undescribed, unnamed species.

Parapanderodus emarginatus (Barnes and Tuke, 1970). Ethington and Clark, 1982, p. 99, 100, pl. 11, figs. 15,16 (as "*Scolopodus*" *emarginatus*).

Parapanderodus paracornuformis (Ethington and Clark 1982), p. 102, figure 25, pl. 22, figure 21 (as *Scolopodus paracornuformis*).

Parapanderodus striatus (Graves and Ellison, 1941). Ethington and Clark, 1982, p. 100, 101, pl. 11, figs. 27, 28 (as "*Scolopodus*" *gracilis*).

Paraserratognathus abruptus (Repetski, 1982). Repetski (1982 p. 45–46, pl. 21, figs. 1, 3) provided good views of the type specimen of this distinctive species, which he referred to *Scolopodus*. One year later, An (1983) established *Paraserratognathus* for the species *P. obesus* Yang, which was diagnosed for the first time in the same report and is based on elements that are closely similar morphologically to the types of *Scolopodus abruptus*. Elements typical of *Scolopodus* species are hyaline, however, whereas those of *Paraserratognathus* have albid cusps. Thus we have transferred Repetski's *Scolopodus abruptus* to *Paraserratognathus* in the faunal lists of Appendixes 2 and 3. Nomenclature of this taxon was further complicated, however, by Smith (1991) and Ji and Barnes (1994). Smith erected *Wandelia* for species with elements closely related or identical morphologically to those of *Scolopodus abruptus* and regarded *Paraserratognathus* as a probable junior subjective synonym of *Oneotodus*. He did not mention *S. abruptus*, which may be the senior synonym of *Wandelia guyi*, the type species of *Wandelia*. Ji and Barnes established *Stultodontus* for *Oneotodus costatus* Ethington and Brand, 1981 and noted that *Scolopodus abruptus* may be a senior synonym of their species *S. pygmaeus*. They do not mention *Paraserratognathus* in connection with their discussion of *Stultodontus*. In collections from the Shingle Pass section, we have only a few specimens referable to *Paraserratognathus abruptus*, which makes its debut 55 m above the base of the *deltatus /costatus* Zone and ranges upward to a level a few meters above the base of the *andinus* Zone. Specimens in the upper two-thirds of the *deltatus/ costatus* Zone intergrade morphologically with those of *Oneotodus costatus*, which is thus a credible ancestor and should perhaps be included in the same genus. Should that revision ultimately be made, we suggest that the appropriate genus is *Paraserratognathus*, not *Wandelia* or *Stultodontus*.

Paroistodus numarcuatus (Lindström, 1955)? Nine samples from the lower part of the Parker Spring Formation contain a few elements that may represent *P. numarcuatus* but cannot be referred to that species with certainty. Elements of *P. numarcuatus* have most recently been described and illustrated by Stouge and Bagnoli (1988, p. 127–128, pl. 8, figs. 8–11), who included a synonymy.

Paroistodus originalis (Sergeeva, 1963)? Nine samples from late Ibexian and early Whiterockian strata in the upper Shingle Limestone have yielded elements that may represent this species but cannot be assigned to it with confidence. Typical *P. originalis* was described and illustrated by Löfgren (1978, p. 69–71, pl. 1, figs. 22–25; text-fig. 28), who demonstrated in a later report (Löfgren, 1995) that an early population of *P. originalis* was probably ancestral to species like "*Cordylodus*" *horridus* Barnes and Poplawski, 1973, which has been reported by Harris and others (1979) from the Whiterockian Antelope Valley Limestone at two localities in the Toquima Range of central Nevada.

Phakelodus tenuis (Müller, 1959), p. 457–458, pl. 13, figs. 11, 13, 14, 20c (as *Oneotodus tenuis*).

Polonodus corbatoi (Serpagli, 1974), p. a47–48, pl. 10, figs. 1a–6c; pl. 22, figs. 1–5 (as *Fryxellodontus*? *corbatoi*).

Prioniodus sp. Three samples from the lower part of the Shingle Limestone contain very small, inconspicuously denticulated elements that compare favorably in many (but not all) respects with the ones from beds 9 and 11 of the Cow Head Group in Newfoundland identified as *Prioniodus elegans* Pander by Stouge and Bagnoli (1988). Specific assignment of these specimens will require further study.

Proconodontus muelleri Miller, 1969, p. 437, pl. 66, figs. 30–40.

Proconodontus serratus Miller, 1969, p. 438, pl. 66, figs. 41–44.

Prooneotodus gallatini (Müller, 1959), p. 457, pl. 13, figs. 5–10, 18. Müller and Hinz, 1991, p. 37, pl. 24, figs. 1–28.

Prooneotodus rotundatus (Druce and Jones, 1971), p. 62, 63, text-figure 22c, d; pl. 9, figs. 10a–13b.

Prosagittodontus eureka (Müller, 1959), p. 461, pl. 14, figure 6 (as *Sagittodontus eureka*). Miller, 1969, pl. 65, figs. 32, 33 (as *Sagittodontus eureka*).

Protopanderodus elongatus Serpagli, 1974. The few Shingle Pass specimens referred to this species are closely similar to typical forms illustrated and described by Serpagli (1974, pl. 16, figs. 8a–11c; pl. 25, figs. 13–16; pl. 30, figure 4; text-fig. 16) and to the single specimen illustrated by Ethington and Clark (1982, pl. 9, figure l5).

Protopanderodus elongatus Serpagli, 1974 of Repetski, 1982. El Paso specimens included in *P. elongatus* by Repetski (1982, pl. 16, figs. 4, 5, 7, 9, 11, 12) exhibit a similar range of morphologic variation, but differ from the types in being hyaline, rather than albid. Morphologically identical specimens from Shingle Pass samples group with “scandodontiform” elements to form a distinctive multielement assembly, which probably represents a species for which there are currently no appropriate generic or specific names. This species has a range in the Shingle Pass section comparable to that in Repetski’s (1982) El Paso section.

Protopanderodus gradatus Serpagli, 1974, pl. 15, figs. 5a–8b; pl. 26, figs. 11–15; pl. 30, figs. 1a,b; text-fig. 17.

Protopanderodus leonardii Serpagli, 1974, pl. 16, figs. 1a–4c; pl. 27, figs. 12–16; text-fig. 18.

Protoprioniodus nyinti Cooper, 1981, p. 176, 178, pl. 29, figs. 1–8, 11, 12.

Protoprioniodus simplicissimus McTavish, 1973, p. 48–49, pl. 2, figs. 6, 8, 9.

Protoprioniodus? n. sp. One denticulate element from the Shingle Limestone occurs with others that clearly represent a species of *Protoprioniodus*. Characteristically, however, elements of *Protoprioniodus* species are adenticulate and that makes assignment of these forms uncertain. They may indicate transition to *Fahraeusodus*, which is similar morphologically and of which *Protoprioniodus* is a likely ancestor. However, the specimens in question are younger than the earliest *Fahraeusodus*, so they may indicate iterative development of species of that genus from *Protoprioniodus*. Further study is obviously needed.

Rossodus manitouensis Repetski and Ethington, 1983, p. 289–301, figs. 1–4. Ethington and Clark, 1982, p. 118, pl. 13, figs. 21, 23, 25–27 (as New genus 3).

?*Rossodus manitouensis* Repetski and Ethington, 1983. Ethington and Clark, 1982, p. 119, pl. 3, figure 26 (as ?New genus 3).

“*Scolopodus*” *triangularis* Ethington and Clark, 1964, p. 699, pl. 115, figs. 2–4, 8, 9. Ethington and Clark, 1982, included this species in the apparatus on which they based their concept of “*Scolopodus*” *gracilis*. We regard *S. gracilis* as a junior synonym of *Drepanodus striatus* Graves and Ellison, 1941, and have elsewhere included it in *Parapanderodus*. Although “*S.*” *triangularis* has essentially the same range as *P. striatus* in the Shingle Pass section, some elements are albid and thus rather different than the typically hyaline components of the *P. striatus* apparatus. For this reason, we report the range of this species separate from that of *P. striatus*.

Semiacontiodus lavadamensis (Miller, 1969), p. 420, pl. 64, figs. 55–61 (as *Acontiodus lavadamensis*). Miller, 1980, p. 33, pl. 2, figure 4.

Semiacontiodus nogamii (Miller, 1969), p. 421, pl. 63, figs. 11–20, 41–50 (as *Acontiodus* (*Semiacontiodus*) *nogamii*). Miller, 1980, p. 32, figure 4V, W; pl. 2, figs. 10–12.

Teridontus nakamurai (Nogami, 1967). Miller, 1969, p. 435, pl. 63, figs. 1–10 (as *Oneotodus nakamurai*). Miller, 1980, p. 34, figure 40, pl. 2, figs. 15,16.

Toxotodus amphigyus Smith, 1991, p. 64–65, figure 37a–d.

Toxotodus carlae (Repetski, 1982), p. 49–50, pl. 23, figs. 1, 2 (as *Scolopodus carlae*) Smith, 1991, p. 65, figure 37e, f.

“*Trichonodella*”? sp. Mound, 1968, p. 420–421, pl. 6, figure 73. Ethington and Clark, 1971, pl. 1, figure 9 (as *Clavohamulus*? sp.). The albid elements of this taxon are rare, but widespread geographically. They are certainly not referable to *Trichonodella*, a junior synonym of *Plectodina*, and probably not to *Clavohamulus*, whose elements show some similarity but are hyaline.

Tropodus comptus (Branson and Mehl, 1933). Ethington and Clark, 1982, p. 114–116, text-fig. 34; pl. 13, figs. 6, 7, 11–13 (as *Walliserodus comptus*). Kennedy, 1980, p. 65–66, pl. 2, figs. 20–27.

Utahconus tenuis Miller, 1980, p. 36, text-fig. 4T; pl. 2, figs. 5–7.

Utahconus utahensis (Miller, 1969), p. 436, pl. 63, figs. 21–24, 33–40; pl. 64, figs. 46–48 (as *Paltodus utahensis*). Miller, 1980, p. 35, text-figs. 3B, F, G; pl. 2, figs. 1, 2.

Variabiloconus bassleri (Furnish, 1938) p. 33l, pl. 42, figure 1. Ethington and Clark,1982, p. 74, pl. 8, figs. 11, 12 (as "*Paltodus*" *bassleri*). Druce and Jones (1971) regarded *Paltodus bassleri* and *P. variabilis* of Furnish (1938) as components of *Scolopodus bassleri*. Sweet and Bergström (1972) added Furnish's *Acodus oneotensis* and *Oistodus*? *triangularis* to this multielement assembly, for which no generic name was then available. Subsequently, Ethington and Clark (1982) noted that Furnish had not documented the full range of morphologic variation within each of his form species and concluded that neither *A. oneotensis* nor *O.*? *triangularis* were components of the assembly. Their conclusion was followed by Repetski (1982). Landing and others (1986), however, regarded not only *A. oneotensis* and *P. bassleri* (including *P. variabilis*), but also *Scolopodus sulcatus* Furnish, 1938, and several other named form species as apparatus components of a species they named *Variabiloconus bassleri* (Furnish). In the Shingle Pass section, *A. oneotensis*, *S. sulcatus*, and *P. bassleri* (including *P. variabilis*) all appear first within a few meters of one another in the House Formation. However, the three species have different upper range limits and, as noted by Ethington and Clark (1982), typical *A. oneotensis* is part of a symmetry-transition series that suggests it represents a species different from the others grouped by Landing and others in *V. bassleri*. Smith (1991) tentatively accepted the reconstruction of Landing and others but noted that his Greenland collections were too small to serve as an adequate test of that reconstruction. Because much obviously remains to be learned about the architecture and distribution of this species, we refer Shingle Pass specimens conservatively to *V. bassleri*, "*Acodus*" *oneotensis*, and *Scolopodus sulcatus*. "*Oistodus*"? *triangularis* of Furnish (1938), regarded as part of this apparatus by Sweet and Bergström (1972) and several subsequent authors, is quite rare in our Shingle Pass collections and is logged separately.

Upper Ordovician–Silurian Macrofossil Biostratigraphy of the Eastern Great Basin, Utah and Nevada

By Peter M. Sheehan *and* Mark T. Harris

EARLY PALEOZOIC BIOCHRONOLOGY OF THE GREAT BASIN, WESTERN UNITED STATES

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Upper Ordovician–Silurian Macrofossil Biostratigraphy of the Eastern Great Basin, Utah and Nevada

By Peter M. Sheehan[1] *and* Mark T. Harris[2]

ABSTRACT

In the eastern Great Basin during the Late Ordovician, a carbonate platform developed on the broad shelf region and received marine deposits. Along its western margin lay a westward-facing carbonate ramp. Near the end of the Ordovician, the carbonate platform was exposed in a regression, and the ramp shallowed to within wave base. In Early Silurian, transgression reflooded the shelf. In late Early Silurian, the continental margin stepped backward toward the craton, and the gently inclined carbonate ramp changed to an abrupt carbonate slope, with an accompanying shift in depositional style. Massive, fine-grained carbonates typify the upper slope deposits; turbidites and slumps (uncommon on the carbonate ramp) appear on the lower slope along with debris flows, gravity flows, and other features consistent with an active slope.

The macrofossil biostratigraphy of the Upper Ordovician and Silurian deposits of the Great Basin has been studied for more than 100 years, and a synthesis of the macrofossil forms and their stratigraphic distribution is appropriate to this volume. The most abundant and well-studied macrofossils are brachiopods, corals, and trilobites, but the level of knowledge of these groups varies widely. On both the carbonate platform and carbonate slope, the biostratigraphic distribution of Silurian brachiopods (a group of low diversity) is well established; that of Upper Ordovician brachiopods, however, is not, though they are abundant, well preserved, and diverse. Upper Ordovician corals on the carbonate platform have been placed into two faunizones and are more clearly understood than those on the carbonate ramp. The biostratigraphy of Silurian corals is well documented for the Middle and Upper Silurian but not for the lower part of the Silurian. Upper Ordovician trilobites are rare on the carbonate platform but common in carbonate ramp deposits; they have been studied primarily on the carbonate ramp.

Sequence stratigraphic study of Silurian rocks on the carbonate platform has revealed strong correlation of sequences with macrofaunal biostratigraphy. Ordovician biostratigraphic intervals are not adequately documented to determine whether sequence boundaries match biostratigraphic boundaries.

INTRODUCTION

The biostratigraphic distribution of Late Ordovician and Silurian fossils in the eastern Great Basin has been studied since Hayden (1872) first reported tabulate corals in northern Utah. An extensive literature on macrofossils has been developed, but this literature is in such a diverse variety of publications that it is difficult to access. This investigation is a synthesis of the current understanding of the biostratigraphic distribution of macrofossils in Utah and Nevada.

The most abundant and well-studied macrofossils are brachiopods, corals, and trilobites, but knowledge of these groups is incomplete. On both the carbonate platform and carbonate slope, the biostratigraphic distribution of Silurian brachiopods is well established; Upper Ordovician brachiopods, however, are virtually unstudied. Upper Ordovician corals have been studied on the carbonate platform but not on the carbonate ramp. The biostratigraphy of Silurian corals is well documented for the Middle and Upper Silurian but not for the lower part of the Silurian. Upper Ordovician trilobites have been studied primarily on the carbonate ramp.

Graptolite and conodont biostratigraphy is not treated in this report, but macrofossil distributions are consistent with graptolite and conodont biostratigraphy. Graptolites have been widely studied in the ramp and slope settings. Conodonts have been studied from both platform and slope environments.

Upper Ordovician and Silurian stratigraphy and lithofacies patterns have been extensively studied. Summaries and an introduction to the literature are available for the Ordovician in Ross (1977) and Sheehan (1989) and for the Silurian in Poole and others (1977), Johnson and Murphy (1984), Sheehan (1989), and Sheehan and Boucot (1991). The primary stratigraphic units are shown in figure 1. Localities referred to in the text are shown in figure 2.

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THE LATE ORDOVICIAN GLACIATION AND MASS EXTINCTION

The most notable biostratigraphic change during this time interval is a clearly defined mass extinction that affected the record of all fossil groups at the end of the Ordovician. The mass extinction was caused by glaciation centered in Africa, which produced glacio-eustatic excursions in sea level and climatic change (Sheehan, 1973, 1975, 1988; Brenchley, 1989). Glaciation probably lasted less than a million years, but the duration is still poorly constrained. Numerous small eustatic sea-level changes probably accompanied an overall decline in sea level. Post-glacial sea-level rise was rapid. (See discussion and additional references in Brenchley, 1989.) This worldwide extinction event decimated virtually all groups of organisms. (See Sheehan, 1973, 1988; Berry and Boucot, 1973; Brenchley, 1989.)

As a result of the extinction event, the endemic epicontinental-sea brachiopod fauna of North America was eliminated (Sheehan and Coorough, 1990). Graptolite (Skevington, 1978; Berry, 1979) and conodont (Barnes and others, 1979; Sweet and Bergström, 1984; Barnes and Bergström, 1988) faunas were devastated.

Two effects of the extinction are important for biostratigraphy. First, because of the extinction, earliest Silurian faunas are of low diversity, and refined correlation in the Early Silurian is difficult compared to the Late Ordovician. Early Silurian conodont zones, for example, are long ranging and have low diversity. Second, Late Ordovician faunas were endemic, and correlation between North America and other tectonic plates is difficult. This pattern is the basis of the need to establish a separate sequence of stages and series for the Late Ordovician in North America. The Cincinnatian Series and the Edenian, Maysvillian, and Richmondian stages are used only in areas containing endemic North American faunas.

The extinction event selectively eliminated endemic taxa (Sheehan and Coorough, 1990). As a result the Silurian fauna was cosmopolitan, and long-distance correlation is relatively easy. The Llandoverian and Wenlockian series and their subdivisions can be recognized worldwide (Berry and Boucot, 1970). Because of the distinct dichotomy of faunas, most biostratigraphers have focused on either the Ordovician or the Silurian-Devonian interval.

DEPOSITIONAL FRAMEWORK

Following late Precambrian rifting (Stewart, 1976, 1980; Bond and others, 1985), a passive continental margin was established in western North America. Thermal subsidence of thinned and stretched continental basement to the east of the rift produced a broad shelf region between the margin and a hingeline in central Utah (Bond and others, 1985). The passive margin evolved normally through the interval of time considered in this report. During the early Paleozoic, the edge of the shelf retreated toward the craton in a series of back steps along probable growth faults. During the Late Ordovician and Silurian, a broad carbonate platform developed on the shelf (fig. 1). In the late Middle Ordovician, regression was accompanied by widespread deposition of quartz sand (Eureka and Swan Peak quartzites). In the Late Ordovician (probably during the latest Edenian, Leatham, 1985), a transgression initiated marine deposition across a broad carbonate platform in eastern Nevada and western Utah. Along the western margin of the carbonate platform, a westward-facing carbonate ramp led to deep water west of the continental margin, which was located in what is now central Nevada (Carpenter and others, 1986). Carbonate ramp facies become progressively finer grained down the ramp. The ramp was stable, and few gravity-emplaced deposits originated on the ramp.

Near the end of the Ordovician, a glacio-eustatic regression of 70 m or more drained epicontinental seas around the world (Sheehan, 1973, 1988; Berry and Boucot, 1973; Brenchley, 1989). In the Great Basin the shallow carbonate platform was exposed (Sheehan and Boucot, 1991). Along the platform margin, proximal ramp facies shallowed to within wave base. Distal ramp environments must have remained below wave base, but direct sedimentologic evidence for this is lacking. The ramp profile was reestablished when the Early Silurian transgression reflooded the shelf.

During the latter part of the Early Silurian, the margin stepped backward toward the craton once more, and the gently inclined carbonate ramp was converted to an abrupt carbonate platform margin (Johnson and Potter, 1975; Hurst and Sheehan, 1985; Hurst and others, 1985; Sheehan, 1986, 1989). The change from a gently inclined carbonate ramp to a steep carbonate slope was accompanied by a shift in depositional style. During the carbonate ramp phase, gradational facies changes reflect gradual change from shallow shelf to distal ramp settings. Turbidites and slumps were uncommon on the carbonate ramp. The depositional pattern on the steep slope was clearly different: Upper slope deposits are massive, fine-grained carbonates. Lower slope deposits are marked by carbonate turbidites, slumps, and debris flows. Stratigraphic sections on the carbonate slope reveal intermittent sedimentation, consistent with an active slope, characterized by sedimentary bypassing, erosion, slumping, and gravity flows.

The abrupt platform margin prograded slowly westward throughout the Silurian and into the Early Devonian until the passive continental margin changed to a compressive margin during the Antler orogeny.

Two distinct basins developed on the platform margin (fig. 2), separated by the east-west-trending Tooele arch (Sheehan and Boucot, 1991). Hintze (1982) named them the Ibex and the North Utah basins. Open-marine sedimentation in the North Utah basin continued through the Llandoverian, but in the early Wenlockian the basin shallowed to near sea level. During the remainder of the Silurian, nondeposition or restricted marine deposition dominated in the North Utah basin.

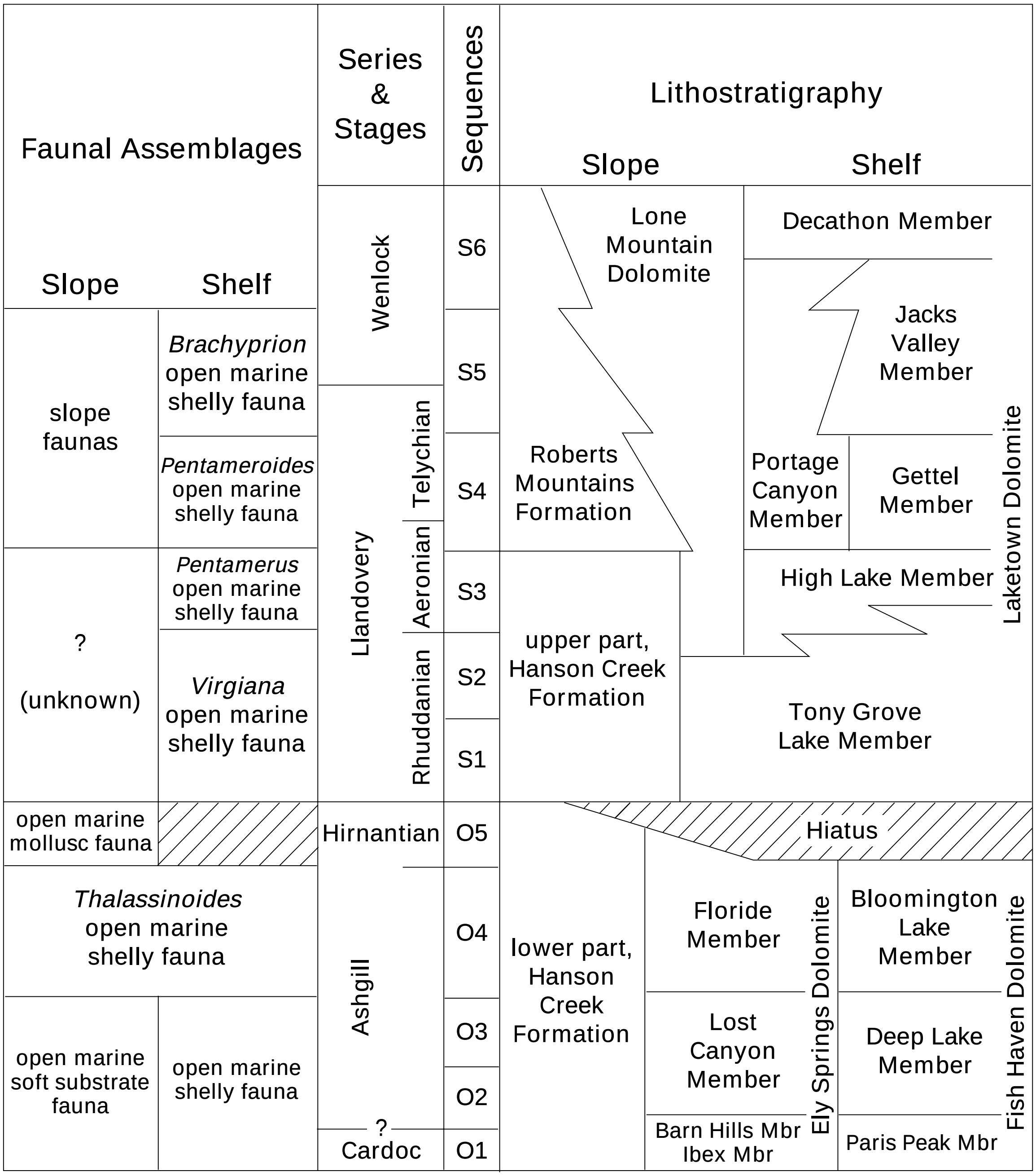

Figure 1. Correlation chart for the principal Upper Ordovician, Llandoverian, and Wenlockian formations and members from the carbonate shelf, carbonate ramp, and carbonate slope in the eastern Great Basin. Faunal assemblages and stages are discussed in the text. Stratigraphic sequences from Harris and Sheehan (1992, 1996).

In the Ibex basin open-marine deposition continued well into the Wenlockian, after which nondeposition or restricted-marine deposition dominated throughout the Silurian. Along the carbonate platform margin to the west and on the southern part of the platform in southern Nevada and adjacent California, shallow, open-marine deposition continued throughout the Silurian (Sheehan and Boucot, 1991).

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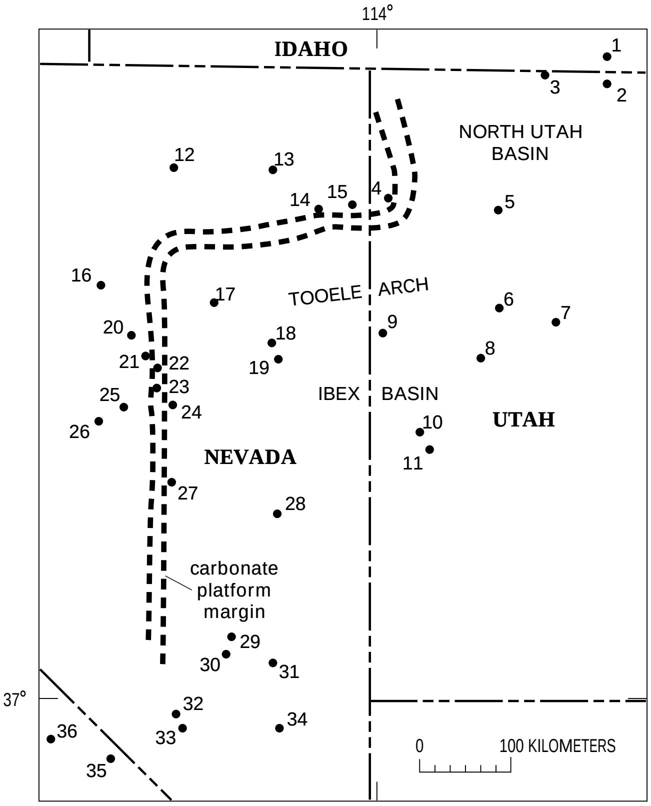


Figure 2. Index map of localities discussed in text.

IDAHO:

1. Paris Peak

UTAH:

2. Tony Grove Lake, Bear River Range
3. Portage Canyon, West Hills
4. Silver Island Mountains
5. Lakeside Mountains
6. Sheeprock Range
7. East Tintic Mountains
8. Thomas Range
9. Deep Creek Mountains
10. Confusion Range
11. Barn Hills

NEVADA:

12. Independence Mountains
13. Antelope Peak
14. Pequop Range
15. Toano Range
16. Shoshone Range
17. Ruby Mountains
18. Cherry Creek Range
19. Northern Egan Range
20. Roberts Creek Mountain
21. Lone Mountain
22. Mountain Boy Range
23. Wood Cone Peak
24. Fish Creek Range
25. Copenhagen Canyon, Monitor Range
26. Ikes Canyon and June Canyon, Toquima Range
27. Pancake Range
28. Southern Egan Range
29. Fossil Mountain
30. Pahranagat Range
31. Delamar Range
32. Ranger Mountain
33. Spotted Range
34. Arrow Canyon Range

CALIFORNIA:

35. Funeral Mountains
36. Panamint Range

UPPER ORDOVICIAN BIOSTRATIGRAPHY

THE CARBONATE PLATFORM

Upper Ordovician platform dolomites are assigned to the Fish Haven Dolomite in northern Utah and to the Ely Springs Dolomite in central and western Utah and eastern Nevada (Budge and Sheehan, 1980a). A wide variety of facies occurs, ranging from restricted-marine laminites (tidal flats) to open-marine sediments deposited within and below storm wave base.

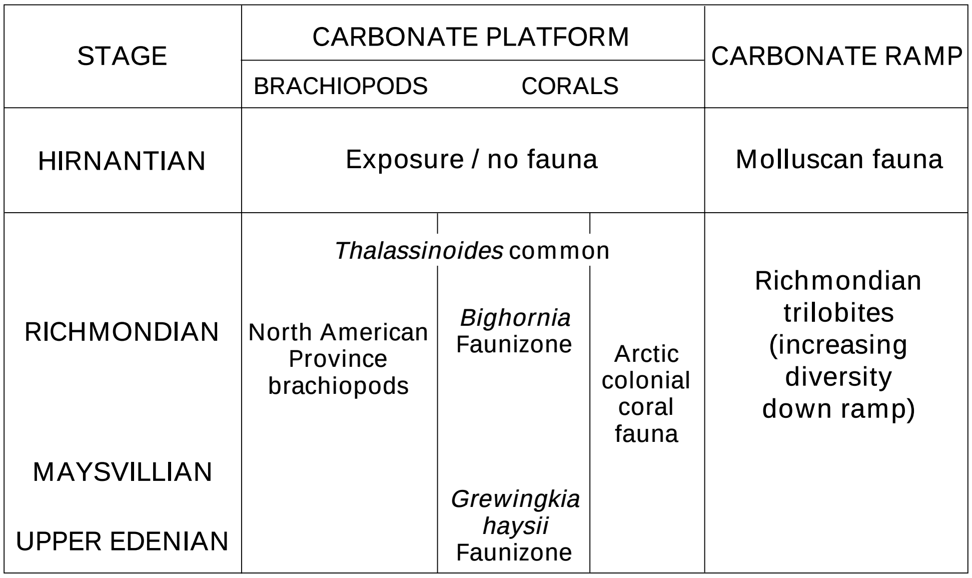
Subtidal dolomites and dolomitic limestones with storm beds mark the upper ramp west of the platform. In more distal ramp settings progressively more argillaceous limestones predominate, and deposition was below storm wave base.

UPPER ORDOVICIAN CORALS

CARBONATE PLATFORM CORALS

Budge (1972, 1977) described Upper Ordovician and Lower Silurian corals from many localities on the carbonate platform. He recognized two faunizones based on corals from the Ely Springs and Fish Haven Dolomites. (Figure 3 outlines Ordovician faunal intervals for macrofossils of this area.)

Budge (1972) recognized a "*Streptelasma*" *haysii* Faunizone (now the *Grewingkia haysii* Faunizone based on reassignment of the species by Elias, 1981) at the base of the Ely Springs Dolomite. This faunizone is present in the Ibex and Barn Hills Members of the Ely Springs Dolomite. Corals restricted to the faunizone include *Lobocorallium goniophylloides*, which is the same as *Grewingkia haysii* according to Elias (1981, p. 17), and *Grewingkia robusta* var. *amplum*, which may include a species of *Deiracorallium* (see Elias,



STAGE	CARBONATE PLATFORM			CARBONATE RAMP
	BRACHIOPODS	CORALS		
HIRNANTIAN	Exposure / no fauna			Molluscan fauna
	Thalassinoides common			
RICHMONDIAN	North American Province brachiopods	*Bighornia* Faunizone	Arctic colonial coral fauna	Richmondian trilobites (increasing diversity down ramp)
MAYSVILLIAN				
UPPER EDENIAN		*Grewingkia haysii* Faunizone		

Figure 3. Ordovician faunal intervals. The *Bighornia* and *Grewingkia haysii* faunizones are from Budge (1972). The Arctic colonial coral fauna was described by Pandolfi (1985). Richmondian trilobites have been described by Ross and others (1979). During the latest Ordovician the carbonate platform was exposed by a glacio-eustatic regression.

1981, p. 22). Corals found in the faunizone but which extend into the overlying faunizone include *Favistina* sp., *Manipora* sp., *Palaeophyllum* sp., *Calapoecia* sp., *Catenipora* sp., and *Paleofavosites* sp.

Above (what is now) the *Grewingkia haysii* Faunizone, Budge (1972) recognized a much more widespread *Bighornia* Faunizone, which he subdivided into three zones. These three zones are not considered further here, because their recognition is dependent on the unpublished systematic descriptions in Budge (1972).

The *Bighornia* Faunizone contains the rugose corals *Bighornia* n. spp., *Bighornia solearis*, *Bodophyllum* n.sp., *Cyathophylloides* n.sp., *Deiracorallium* n.sp., *Favistina* sp., *Grewingkia* sp., *Lobocorallium* sp., *Streptelasma* spp., *Astrocerium* sp., *Tryplasma* n.sp., *Palaeophyllum* sp., *Palaeophyllum cateniforme*?, and the tabulates *Agetolites* spp., aff. *Aulocystis* sp., *Calapoecia* sp., *Catenipora* sp., *Paleofavosites* sp., *Favosites* sp., *Manipora* sp., and *Foerstephyllum* sp. The genera *Tryplasma*, *Palaeophyllum*, *Cyathophylloides*, *Favosites*, *Paleofavosites*, and *Catenipora* range upward into Silurian strata.

The most extensive published study of Upper Ordovician colonial corals is by Pandolfi (1985), who described 20 species of colonial corals from the Ely Springs Dolomite in the northern Egan Range and the Silver Island Mountains (table 1). Greatest diversity was found in the open marine Lost Canyon Member, which contained 18 species. The Ibex Member contained only two species, both of which were also found in the overlying members. The Floride Member had nine species, only one of which was not found in the underlying members.

The fauna found by Pandolfi (1985) in the Lost Canyon and Floride Members is so similar that the members cannot be distinguished on the basis of faunal content. The fauna is part of the “Arctic Ordovician” fauna, which ranges from the upper Middle Ordovician through the Late Ordovician. Associated dasycladacean algae described by Johnson and Sheehan (1985) are *Vermiporella* sp., *Rhabdoporella* sp., and *Cyclocrinites* spp.

Most of the colonial corals in these two members are consistent with the Maysvillian-Richmondian age of the Ely Springs Formation that is indicated by other fossil groups discussed in this report. One exception is ?*Billingsaria parvituba*, which is a species previously known only from Canada in the Middle Ordovician Bad Cache Rapids Formation on the Melville Peninsula and the Blackriverian age Lourdes Formation in western Newfoundland. The species is considerably younger in the Great Basin than in Canada (Pandolfi, 1985).

Duncan (1956) illustrated corals from several localities on the platform. Many of the illustrations and much of the discussion are based on material for which no locality data are available. Illustrated species include *Catenipora gracilis* from the Bluebell Dolomite in the Tintic District, Utah, and *Palaeophyllum* sp., from an unrecorded area in Utah. She also recorded but did not illustrate *Tetradium tubifer* from the Tintic District, Utah. W.A. Oliver in Kleinhampl and Ziony (1985) reported *Palaeophyllum* sp. and *Nyctopora*?

Table 1. Colonial corals from the Ely Springs Dolomite described by Pandolfi (1985).

[x, occurrence; blank, not found]

Coral taxa	Ibex Member	Lost Canyon Member	Floride Member
Calapoecia anticostiensis	x	x	x
Calapoecia sp. cf. *C. coxi*		x	x
Paleofavosites poulseni		x	x
Paleofavosites mccullochae		x	x
Paleofavosites okulitchi		x	x
Paleofavosites sp. cf. *P. transiens*			x
Paleofavosites sp. cf. *P. capax*		x	x
?*Billingsaria parvituba*		x	x
Nyctopora sp.	x		x
Agetolites budgei		x	
Saffordophyllum crenulatum		x	
Catenipora workmanae		x	
Catenipora sheehani		x	
Catenipora sp. cf. *C. foerstei*		x	
Tollina sp.		x	
Palaeophyllum humei		x	
Palaeophyllum gracile		x	
Palaeophyllum sp. cf. *P. raduguini*		x	
Cyathophylloides sp. A		x	
Cyathophylloides sp. B		x	

sp. from the Floride Member of the Ely Springs Dolomite in the Pancake Range. Langenheim and others (1962) reported an 8- to 9-ft-thick[3] *Favistella* biostrome about two-thirds of the way through the Ely Springs Dolomite in the Arrow Canyon Range.

CARBONATE RAMP CORALS

A Richmondian assemblage of corals was reported from the upper carbonate ramp in the Mountain Boy Range in the Hanson Creek Formation by Ross and others (1979; see corresponding discussion of brachiopods). Included were *Bighornia* sp., *Lobocorallium trilobatum major* (which Elias (1981) assigned to *Grewingkia haysii*), *Catenipora* sp., *Paleofavosites* sp., *Saffordophyllum* sp., and *Nictopora*? sp. Duncan (1956) illustrated *Cyathophylloides* sp. from an unnamed location in the Hanson Creek Formation.

C.W. Merriam in Evans (1980) identified *Catenipora* sp., *Palaeofavosites* sp., *Palaeophyllum* sp. cf. *P. thomi*, and *Streptelasma* sp. associated with eight species of brachiopods (listed in “Carbonate Ramp Brachiopods”) from the Hanson Creek Formation in the Tuscarora Mountains. J.M. Berdan in Radtke (1985) reported *Catenipora* sp., *Favosites* sp., *Palaeophyllum* sp., and *Lobocorallium trilobatum* from a nearby locality in the Hanson Creek Formation.

UPPER ORDOVICIAN BRACHIOPODS

Upper Ordovician brachiopods are abundant, well preserved, and diverse in the Ely Springs Dolomite, Fish Haven Dolomite, and Hanson Creek Formation; however, they have received little study. Brachiopods have been reported in numerous studies of regional geology, and a sample of such mention is provided here, to indicate the diversity of brachiopods in the area. However, because the brachiopods have not been systematically studied, biostratigraphic assemblages cannot be identified. The brachiopods are part of the highly endemic Upper Ordovician North American Brachiopod Province (Sheehan and Coorough, 1990; this report, fig. 3).

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[3] Measurements in feet are those of previous workers and are used here to maintain the precision of their studies; 1 ft=0.305 m.

Table 2. Brachiopods reported by Sheehan (1969) from the Ely Springs Dolomite in Nevada and Utah.

[Localities: 1, Pequop Range; 2, Cherry Creek Range; 3, Southern Egan Range; 4, Northern Silver Island Range; 5, Pancake Range; 6, Spotted Range; 7, Ranger Mountain. Queried where uncertain; x, occurrence; blank, not found]

	Lower part of Ely Springs Dolomite			Floride Member			
Localities	1	2	3	4	5	6	7
Hesperorthis sp.			x		?		
Glyptorthis sp.			x			x	x
Plaesiomys (*Plaesiomys*) sp.		x		x			
Platystrophia sp.		x					
Paucicrura? sp.			x				
Diceromyonia tersa		x					
Thaerodonta sp.			x			x	x
Lepidocyclus sp.	x	x	x	x		x	
Rhynchotrema sp.		?					
Zygospira sp.		?					x
Austinella sp.					x	x	x
Diceromyonia sp.				x	x		
Spinorthis sp.					x		
Streptis? sp.					x		
Leptaena sp.							x
Hypsiptycha sp.					x	x	

CARBONATE PLATFORM BRACHIOPODS

The only systematic study of Upper Ordovician brachiopods in Nevada and Utah is by Howe and Reso (1967), who described a collection from near the top of the Floride Member of the Ely Springs Dolomite at Fossil Mountain and in the Pahranagat Range, south-central Nevada. The brachiopods include *Diceromyonia ignota*, *Hypsiptycha* sp. cf. *H. anticostiensis*, and *Hiscobeccus capax*. Associated corals include *Bighornia* sp. and *Catenipora* sp. cf. *C. gracilis*. A Richmondian age is indicated. Reso (1963) reported *Hiscobeccus capax*? and *Zygospira*? sp. from the lower Ely Springs Dolomite in the Pahranagat Range. Sheehan (1969) recorded brachiopods from the Floride Member and from lower Ely Springs Dolomite at several sections on the carbonate platform (table 2).

There are several other reports of brachiopods from the Ibex basin. Staatz and Osterwald (1959) reported *Catazyga*? sp., *Hesperorthis* sp., and *Fardenia* sp. from the Thomas Range, Utah, in strata now considered lower Ely Springs Dolomite. Morris and Lovering (1961) reported *Lepidocyclus perlamellosus* and *Strophomena* sp. from a similar position in the lower Ely Springs Dolomite in the East Tintic Mountains, Utah. Kellogg (1963) reported *Hesperorthis* sp., *Paucicrura* sp. cf. *P. meeki*, and *Paucicrura* sp. cf. *P. multisecta* (the latter two species are assigned to *Onniella*) from the Ely Springs Dolomite in the southern Egan Range, Nevada.

Chamberlain and Langenheim (1971) found *Hypsiptycha anticostiensis*? and *Diceromyonia ignota* in the upper Ely Springs Dolomite in the Arrow Canyon Range. They were associated with rugose and tabulate corals.

On Ranger Mountain Byers and others (1961) recorded *Austinella* sp., *Holtedahlina* sp., *Thaerodonta* sp., *Sowerbyella*? sp., *Leptaena* sp., *Zygospira*? sp., and *Favosites* sp. from between 105 and 185 ft above the base of the Ely Springs Dolomite, and *Dinorthis* sp. from 150 ft below the top of the formation.

North of the Tooele arch in the northwest Silver Island Range, Utah, R.H. Waite (in Schaeffer and Anderson, 1960, p. 52) identified *Hiscobeccus capax*?, *Platystrophia* sp., *Hebertella*? sp., and *Hesperorthis*? sp. in beds now assigned to the Ibex Member of the Ely Springs Dolomite. (See Carpenter, and others, 1986.) In the same publication Waite recorded *Plaesiomys* sp., *Austinella* sp., and *Rhynchotrema* sp. from strata now assigned to the Lost Canyon Member of the Ely Springs Dolomite.

In northern Utah Williams (1948) reported *Strophomena* sp. cf. *S. planumbona* and *Dinorthis* sp. associated with the corals *Halysites* sp., *Calapoecia* sp. cf. *C. canadensis*, *Favistina*? sp. (identified as *Columnaria* sp. cf. *C. alveolata*, but see Flower, 1961, p. 76–79), and *Streptelasma* sp. from the Fish Haven Dolomite. Richardson (1913) reported *Hiscobeccus capax* from the same unit.

CARBONATE RAMP BRACHIOPODS

Ross and others (1979) reported a diverse assemblage of brachiopods, trilobites, bryozoans, corals, and conodonts from the upper part of the carbonate ramp in eastern exposures of the Hanson Creek Formation at Wood Cone Peak and the Mountain Boy Range. Only the trilobites and conodonts were illustrated. The fossils are from nodular limestone, wackestone, and dolomitic limestone in the middle of the formation. The two areas contain distinct assemblages. The Mountain Boy Range assemblage has more diverse corals, bryozoans, and brachiopods than the Wood Cone Peak collections, which have a more diverse trilobite assemblage and lack corals.

Brachiopods from the Mountain Boy locality are *Plaesiomys* (*Dinorthis*) *occidentalis*, *Hesperorthis* sp., *Glyptorthis* sp., *Lepidocyclus gigas*, cf. *Anoptambonites* sp., *Rafinesquina* sp., *Oepikina*? sp., and *Thaerodonta* sp. Associated bryozoans are *Astreptodictya* sp., *Diplotrypa* sp., *Goniotrypa* sp., *Homotrypa* sp., and *Trematopora* sp. Six coral species and three species of trilobites were also associated. (See “Carbonate Ramp Corals” and “Carbonate Ramp Trilobites.”) An indeterminate rhynchonellid, *Thaerodonta* sp., *Thaerodonta* or *Sowerbyella* sp., *Glyptorthis* sp., *Hesperorthis* sp., and *Plaesiomys* (*Dinorthis*) *occidentalis* were found higher in the section with no other associated fauna.

Brachiopods from eight closely spaced collections near Wood Cone Peak include *Plaesiomys* (*Dinorthis*) *occidentalis*, *Lepidocyclus gigas*, *Thaerodonta* sp., and *Thaerodonta* or *Sowerbyella* sp., which were also found in the Mountain Boy Range. In addition, *Lepidocyclus* sp., *Skenidioides* sp., *Strophomena* sp., and *Diceromyonia* sp. A, and a single bryozoan, *Sceptropora* sp., occur near Wood Cone Peak but were not found in the Mountain Boy Range. No corals and 20 species of trilobites were also found (see “Carbonate Ramp Trilobites”). The macrofossils and diverse collections of conodonts from these localities indicate a Richmondian age (Ross and others, 1979).

Although collections from Wood Cone Peak and the Mountain Boy Range are from the Hanson Creek Formation and only 15 km apart, the Mountain Boy collections are from farther east (much farther updip) on the ramp. The nature of the fauna indicates that the Wood Cone Peak assemblage was positioned lower on the ramp because of the much greater diversity of trilobites and the absence of corals and near absence of bryozoans. Among the brachiopods, *Skenidioides*, present only at Wood Cone Peak, is commonly found in relatively deep water settings.

The upper Llandoverian–Early Wenlockian Diana Limestone in Ikes Canyon in the Toquima Range contains Upper Ordovician, brachiopod-bearing carbonate clasts that could be as young as Richmondian. The clasts of older rock were emplaced during the downdropping of the margin in the late Llandoverian (Leatham, 1988). Brachiopods reported by Ross (1970) include (combining two collections) *Paucicrura* sp., *Oxoplecia*? sp., *Leptaena* sp., *Zygospira*? sp., and an indeterminate brachiopod (illustrated on pl. 9, fig. 26). Seven species of ostracodes were reported, and four species of trilobites are listed herein.

Evans (1980) reported *Glyptorthis* sp., *Lepidocyclus*? sp., *Leptellina* sp., *Paucicrura* sp., *Plaesiomys*? sp., *Rhynchotrema* sp., *Thaerodonta* sp., and *Zygospira* sp. cf. *Z. recurvirostrus* in association with four species of corals (listed previously in “Carbonate Ramp Corals”) from 105 m below the top of the Hanson Creek Formation in the Lynn Window in the Tuscarora Mountains, northern Nevada. Associated conodonts are of late Middle or Late Ordovician age. Evans (1980) noted that *Leptellina* was probably no younger than Trentonian age, but the genus is now known to occur in Ashgillian age rocks in Ireland, People’s Republic of China, and Kazakhstan. A small collection from near the top of the formation included *Chaulistomella*? sp. and an unidentified trilobite.

Kerr (1962) reported a diverse fauna from the Hanson Creek Formation in the Independence Mountains. *Hiscobeccus capax* is associated with three species of trilobites, *Streptelasma* sp., *Echinosphaerites* sp., echinoderm columnals, *Michelinoceras beltrami*?, and *Climacograptus* sp. The fossils are from thin-bedded calcisiltites and thin-bedded calcisiltites interbedded with shaly layers. Geographically, the area is well beyond the platform margin (see Sheehan, 1989). The trilobite-dominated fauna, geographic position, and lithofacies are indicative of deposition below normal storm wave base, well down on the carbonate ramp.

CARBONATE RAMP TRILOBITES

Trilobites are rare in carbonate platform strata, but are common in the carbonate ramp deposits of the Hanson Creek Formation, especially in distal settings (fig. 3). Many trilobites have been reported in regional geologic investigations, and only a few of these are mentioned here. The best known assemblage of trilobites was illustrated by Ross and others (1979) from the middle of the Hanson Creek Formation in the Mountain Boy Range and from near Wood Cone Peak, Nevada. The Mountain Boy Range collection contains 20 species dominated by brachiopods, and includes three species of trilobites, *Anataphrus* sp., a calymenid, and *Calyptaulax* sp. In deeper ramp setting from nearby Wood Cone Peak, these three species also occur and are associated with *Isotelus* sp., a proetid, *Stygina*? sp., *Otarion* sp., *Cryptolithoides* sp., *Ceraurinus icarus*, three species of *Ceraurus*, an acanthoparyphinid, *Sphaerocorphe* sp., *Encrinurus* sp., *Cybeloides* sp., a lichid, possibly *Hemiagres* sp., and an odontopleurid, possibly *Ceratocephala* sp.

The increasing abundance of trilobites down the ramp can also be documented in a transect in north-central Nevada. At Lone Mountain, on the upper part of the ramp, where the Hanson Creek Formation grades into the Ely

Springs Dolomite, trilobites are relatively uncommon. To the west, in the type section at Roberts Creek Mountain, trilobites are much more common; and farther west, in the Shoshone Range, Gilluly and Gates (1965, p. 17) described the Hanson Creek Formation as, "***abundantly fossiliferous, with many trilobites and some gastropod fragments."

Ross (1970) listed *Astroproetus* sp., *Brongniartella* sp., *Whittingtonia*? sp., and *Encrinuroides* sp. from the late Llandovery to early Wenlock Diana Limestone below the Roberts Mountain Formation in Ikes Canyon. Associated brachiopods were listed previously.

In the Tuscarora Mountains, Ross, in Evans (1980), recorded *Anataphrus* or *Bumastoides* sp. associated with the brachiopod *Chaulistomella*? sp. high in the Hanson Creek Formation. Kerr (1962) reported *Cryptolithoides* sp., *Isotelus* sp., and *Ceraurus* sp. associated with brachiopods and other fossils in the Hanson Creek Formation in the Independence Mountains. These areas were well down the carbonate ramp.

UPPER ORDOVICIAN TRACE FOSSILS

Chamberlain (1977, 1979) and Miller (1977) described various trace fossils, primarily from the carbonate platform. However, regional distributions of trace fossils are still little known. The gallery-forming genus *Thalassinoides* is encountered in places throughout the carbonate platform wherever open-marine conditions prevailed during the Late Ordovician and Early Silurian (fig. 3). However, *Thalassinoides* is most abundant in the Floride Member of the Ely Springs Dolomite and the Bloomington Lakes Member of the Fish Haven Dolomite (Sheehan and Schiefelbein, 1984). Galleries composed of 2- to 3-cm diameter burrows of *Thalassinoides* dominate the lithology, forming a burrow-generated fabric that replaces depositional fabrics (Tedesco and Wanless, 1991). *Thalassinoides* galleries are characteristic of members at the top of the Ordovician sequences throughout the carbonate platform and upper ramp.

Bioturbation in the Ely Springs Dolomite is much more intense than on the carbonate platform from the Cambrian to the Middle Ordovician (Droser and Bottjer, 1989). Droser and Bottjer found that bioturbation intensity was comparable to that of post-Ordovician Paleozoic carbonate platform environments.

HIRNANTIAN–LATE ORDOVICIAN EUSTATIC SEA-LEVEL LOWSTAND

During the glacial maximum the carbonate platform was exposed during the glacio-eustatic sea-level lowstand. The most proximal ramp facies (for example, at Lone Mountain) shallowed to exposure as evidenced by soil formation (Ross, 1970; Dunham and Olson, 1980; Carpenter and others, 1986). Slightly downdip, carbonate ramp sedimentation shallowed from below to within normal storm wave base, for example at Roberts Creek Mountain and Antelope Peak, Nevada (Carpenter and others, 1986) and Copenhagen Canyon (Berry, 1986). Distal ramp environments shallowed, but not sufficiently to bring the deep-ramp within storm wave base.

Within-wave-base carbonate grainstones in the Mountain Boy Range contain Zone 13 age conodonts (Harris and others, 1979). This unit caps a glacio-eustatic, shallowing-upward sequence that began well below wave base on the carbonate ramp (Sheehan and Boucot, 1991). Undescribed macrofossils occur, primarily poorly preserved bivalves and gastropods. This shallow-water grainstone unit is present immediately below the Silurian in many proximal ramp sections in Nevada.

SILURIAN BIOSTRATIGRAPHY

The biostratigraphic distribution of macrofossils is well enough known in this region to permit recognition of the major subdivisions of the Silurian System. Silurian brachiopod faunas are more thoroughly described than are those of the Late Ordovician. Coral faunas have been described in the Wenlockian, Ludlovian, and Pridolian, but Llandoverian corals are relatively unstudied. Brachiopods permit recognition of subdivisions of the Llandoverian and Wenlockian series on the carbonate platform. Shallow marine sedimentation continued throughout the Silurian in southern Nevada and along the platform margin in central and northern Nevada, and extensive brachiopod and coral faunas have been described from these areas. Figure 4 outlines Silurian faunal intervals for brachiopod and coral faunas.

Following the Ordovician extinction, brachiopods became cosmopolitan, and the British Silurian series are recognizable over most of the world (Berry and Boucot, 1970). Brachiopod workers use the traditional lower, middle, and upper subdivisions of the Llandoverian Series, which have been designated A, B, and C, respectively. These stage-level subdivisions have been further subdivided in the type areas by a sequence of numbers (A_{1-4}, B_{1-3}, C_{1-6}). Brachiopod workers cannot carry the individual numbered intervals out of the type regions, but they have established ranges of brachiopods that allow recognition of the following stage-level intervals of the Llandoverian (Berry and Boucot, 1970): A_{2-4}, B_{1-3}, C_{1-3}, C_{4-5}, and C_6–Lower Wenlockian. By definition of the Ordovician-Silurian boundary, A_1 is now placed at the top of the Ordovician.

Work in the British Isles has resulted in selection of a sequence of stages based on graptolite zones. The new stages and the original units are Rhuddanian (A_{2-4}), Aeronian (B to mid-C_4), and Telychian (mid-C_4 through C_6). However, these intervals are difficult to recognize with brachiopods, so in this report the subdivisions outlined in Berry and Boucot (1970) are used.

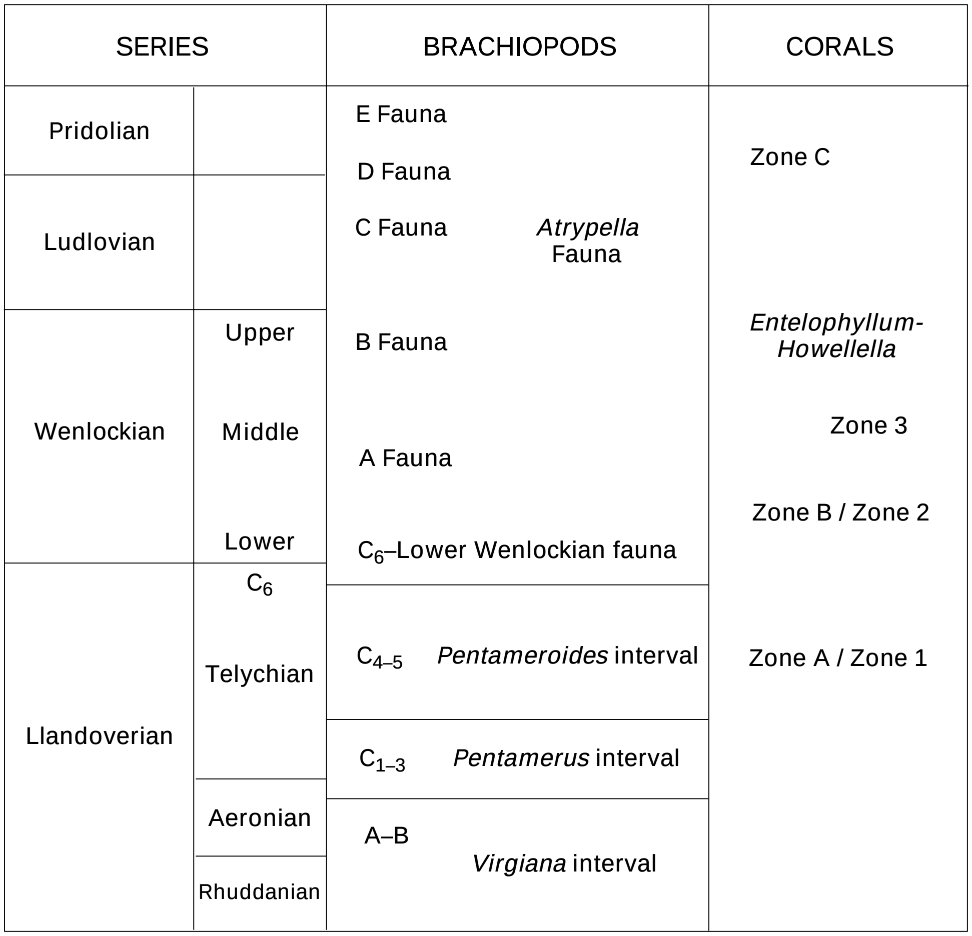

Figure 4. Silurian faunal intervals. The Llandoverian and C_6–lower Wenlockian intervals for brachiopods are from Berry and Boucot (1970) and Sheehan (1980b). The lettered brachiopod faunas A–E are from Johnson and others (1973, 1976). The *Atrypella* fauna is from Johnson and Reso (1964). Coral Zones 1–3 are the *Rhabdocyclus* zones from Budge (1972), and the other coral zones are from Merriam (1973b).

THE CARBONATE PLATFORM

Following the Late Ordovician glaciation, a rapid Early Silurian global sea-level rise flooded the platform. Brachiopods in these early to middle Llandoverian deposits have no relationship with the brachiopods of the underlying Ely Springs and Fish Haven Dolomites. The extinction event had decimated the Late Ordovician North American Province brachiopods. The new Silurian faunas originated from open-marine areas and parts of Siberia, Baltica, and Kazakhstan (Sheehan and Coorough, 1990).

Early and Middle Llandoverian strata on the carbonate platform, the Tony Grove Lake Member of the Laketown Dolomite, are dominated by open-marine sediments with intervals of shallow, restricted cryptalgal-laminites. These facies locally continued into the C_{1-3} interval. The dominant C_{1-3} facies is the coarsely recrystallized, very light colored, massive, poorly bedded, high-energy High Lake Member of the Laketown Dolomite (Sheehan and Boucot, 1991). The *Verticillopora* dasycladacean algal community was common in protected, shallow-water settings.

A broad range of depositional environments developed during the C_{4-5} interval. Water depths at times exceeded storm wave base, especially in the center of the Ibex basin. Stromatolites and cryptalgal communities were common in restricted areas, particularly along the Tooele arch, in the east-central part of Utah, and near the western carbonate platform margin. The *Verticillopora* community was present but much less common than during the preceding interval. Diverse brachiopods and corals dominated open-marine settings. Distinct brachiopod guilds characterize communities from different substrates and water-energy conditions.

Open-marine sedimentation ended in the North Utah basin early in the C_6–Lower Wenlockian. Laketown Dolomite sections are capped by exposure surfaces or cryptalgal laminites of the Water Canyon Formation in the North Utah basin (Williams and Taylor, 1964). The age of the basal part of the Card Member of the Water Canyon Formation cannot be determined because of a lack of fossils, but it could range from Wenlockian to Devonian. The overlying Grassy Flat Member of the Water Canyon Formation has an Early Devonian fish fauna.

Ibex basin deposition continued well into the C_6–Lower Wenlockian interval. The center of the Ibex basin contains sediments deposited near and below storm wave base (Sheehan and Boucot, 1991). Around the margin of the basin, shallower water sediments were deposited within storm wave base. A variety of brachiopod-dominated communities are commonly restricted to particular depositional environments. The most abundant and diverse brachiopod and coral faunas of the Laketown Dolomite flourished during this time interval in the Ibex basin. Deposition of open-marine sediments ended in the Ibex basin in the Wenlockian. The restricted marine Sevy Dolomite overlies the Laketown, but a lack of fossils makes correlation difficult.

Open-marine sedimentation continued throughout the Silurian in southern Nevada and along the carbonate platform margin in central Nevada. The upper Decathon Member of the Laketown thickens to more than 1,000 ft in southern Nevada (Sheehan and Boucot, 1991). In central Nevada this unit is given the name Lone Mountain Dolomite. Tongues of dark dolomite in the Lone Mountain Dolomite resemble the Portage Canyon Formation but are much younger.

THE CARBONATE RAMP

Lower Silurian macrofaunas on the carbonate ramp were scarce, and little can be done with them biostratigraphically. Following conversion of the carbonate ramp to a relatively steep carbonate slope, macrofossils are abundant from the Wenlockian through the Pridolian, during which time they are useful for correlation.

The Llandoverian part of the Hanson Creek Formation is laterally equivalent to the Tony Grove Lake Member and is a ramp deposit that in a few places produces a macrofauna. On the upper carbonate ramp, near the platform margin, scarce brachiopods occur. *Virgiana* sp. has been found by the authors just below the Roberts Mountains Formation in the Toano Range north of Interstate 80.

Above the Ordovician part of the Hanson Creek Formation near the platform margin in the Mountain Boy Range, *Virgiana* sp. occurs in storm-generated coquinas that resemble the Tony Grove Lake Member of the Laketown Dolomite. This area was very close to the ramp-platform margin because it was not downdropped, and late Llandoverian units belong to the Lone Mountain Dolomite of the platform margin rather than being slope deposits of the Roberts Mountains Formation.

Farther down the ramp at Pete Hanson Creek on Roberts Creek Mountain, for example, the upper Hanson Creek Formation has few storm beds such as those that dominate the member on the platform. Macrofossils are very scarce, possibly because the fauna was eliminated by the Late Ordovician extinction event (Sheehan and Boucot, 1991).

CONVERSION OF THE CARBONATE RAMP TO A CARBONATE SLOPE

Timing of the late Llandoverian conversion of the gently inclined carbonate ramp to a more steeply inclined carbonate slope with an abrupt shelf margin (Johnson and Potter, 1975; Hurst and Sheehan, 1985; Hurst and others, 1985) is not well constrained. Tectonic downdropping, which established this new margin, probably is associated with the progressive retreat of the platform margin along the lower Paleozoic passive margin of Cordilleran North America (Sheehan and Boucot, 1991).

The Hanson Creek Formation, underlying the subsidence-event horizon, includes rocks of late Llandoverian age. The base of the overlying Roberts Mountains Formation probably contains a condensed interval. Condensed and even missing graptolite zones are reported, and a cherty interval and local phosphatic lenses indicate slow deposition (Hurst and Sheehan, 1985). The earliest macrofossils on the slope are late Llandovery corals.

Conodont evidence dates the subsidence event as late Llandoverian. Rocks below are from the *Distomodus kentuckyensis* conodont zone, and rocks above belong in the younger *Pterospathodus celloni* conodont zone (Poole and others, 1977; Murphy and others, 1979). The change occurred during or prior to the *Monograptus spiralis* Zone, but not earlier than the *Rastrites maximus* Subzone of the *Monograptus turriculatus* Zone (Berry, 1986). In arctic Canada the *Monograptus spiralis* Zone ranges down to the top of the *Monograptus turriculatus* Zone (Lenz, 1988), a position near the C_3–C_4 boundary in the United Kingdom. At Roberts Creek Mountain and adjacent regions, Berry and Murphy (1975) showed that the first occurrence of *M. spiralis* is in the basal Roberts Mountains Formation, and it is beneath the first occurrence of *Cyrtograptus lapworthi* wherever the two species occur in the same section. Thus, in the biostratigraphic scheme adopted for this study, the downdropping event could have occurred as early as the C_3–C_4 boundary or as late as C_6.

THE CARBONATE SLOPE

The carbonate slope and shelf margin following the downdropping event have been extensively studied (Matti and others, 1975; Matti and McKee, 1977; Nichols and Silberling, 1977; Hurst and Sheehan, 1985; Hurst and others, 1985; Sheehan, 1979, 1986, 1989; Sheehan and Boucot, 1991). The Lone Mountain Dolomite was deposited along the carbonate shelf margin. Most carbonate slope deposits are assigned to the Roberts Mountains Formation. The lateral facies within the Roberts Mountain Formation are complex. Berry and Boucot (1970) recognized a platy-limestone facies low on the carbonate slope and a thick-bedded facies closer to the platform margin.

The platy-limestone facies is thin-bedded, argillaceous, red-tinged to buff dolomitic limestone with alternating light and dark laminae. Silt layers occur as low-amplitude climbing ripples, irregular laminae, and faded ripples. Deposition was probably from distal, dilute turbidity currents on the deep slope. (See summary in Sheehan and Boucot, 1991; and Hurst and Sheehan, 1985.) Macrofossils are rare, possibly because of low oxygen conditions. An abundant graptolite fauna makes accurate correlation possible (Berry and Boucot, 1970; Berry and Murphy, 1975; Berry, 1986). Conodonts have also been extensively studied (Murphy and others, 1979; Klapper and Murphy, 1975).

The thick-bedded facies of Berry and Boucot (1970) is composed of several distinct subfacies with two distinct origins (Hurst and Sheehan, 1985; Sheehan and Boucot, 1991). A coarsening-upward, thick-bedded facies (CUF) found at the top of the formation in eastern sections (Sheehan and Boucot, 1991) is composed of sands and conglomerates associated with the prograding Lone Mountain Dolomite. These beds were gravity emplaced, and some contain a mixed fauna derived from higher on the slope.

A second thick-bedded facies, composed of fine-grained, laminated carbonates (LTBF) illustrated by Sheehan (1989) occurs along the eastern margin of the Roberts Mountains Formation (Hurst and Sheehan, 1985; Sheehan and Boucot, 1991). These upper-slope finely laminated or bioturbated argillaceous limestones may have been derived from shelf sediments placed in suspension by storms and tidal currents and swept over the margin (Hurst and Sheehan, 1985). Slumps are common in the LTBF (Hurst and Sheehan, 1985; Sheehan, 1989). The substrate was soft, and many corals and brachiopods from this facies have “snow-shoe” adaptations to prevent their sinking into the mud (Sheehan, 1989).

SILURIAN BRACHIOPOD BIOSTRATIGRAPHY

LOWER AND MIDDLE LLANDOVERIAN CARBONATE PLATFORM BRACHIOPODS

Lower and middle Llandoverian brachiopods (fig. 4) lived in ecologically widespread, low-diversity communities. The brachiopods occur in a wide variety of facies, permitting correlation with other regions of the world.

The brachiopod *Virgiana* was one of the geographically most widespread genera of brachiopods that ever lived (Boucot, 1975). Sheehan and Coorough (1990) recorded it in Laurentia, the margins of Laurentia, Baltica, Kazakhstan, Siberia, and South China (People’s Republic of China). It was distributed in virtually all shallow carbonate platforms of the world.

Virgiana occurs in great abundance in the Tony Grove Lake Member of the Laketown Dolomite in more than 50 sections from the carbonate platform (Sheehan, 1980a). The most common species is *Virgiana utahensis*, although another species may also be present. Associated brachiopods are low in diversity and are rare. They include *Platystrophia* sp., both coarsely and finely ribbed orthids, a dalmanellid, two rhynchonellids, *Plectatrypa* sp., *Hyattidina*? sp., and an atrypid. Sheehan (1980a) recovered more than 1,500 silicified specimens of *Virgiana* from 33 separate localities. Only two collections had as many as four other species of brachiopods associated with *Virgiana utahensis*. Since 1980 the *Virgiana* Community has been observed at hundreds of horizons, so the relative proportions of species in the community and the environmental distribution of the community are well established.

A second brachiopod-dominated community occurs as monospecific coquina beds of an indeterminate rhynchonellid in the Tony Grove Lake Member of the Laketown Dolomite in the Cherry Creek Range (Sheehan, 1980b). The presence of only two brachiopod-dominated communities (one of them uncommon) on the carbonate platform during the early and middle Llandoverian is remarkable and is part of a worldwide pattern.

Sheehan (1975, 1980b, 1992) attributed the broad ecologic distribution and low diversity of the *Virgiana* Community to a recovery of the fauna following the Ordovician extinction event. The extinction had reduced species diversity, and surviving species became widely distributed ecologically in a variety of habitats marked by little competition. Subsequently, communities became progressively more diverse and confined to progressively narrower environmental ranges.

LOWER UPPER LLANDOVERIAN (C_{1-3}) CARBONATE PLATFORM BRACHIOPODS

The pentamerid brachiopod *Virgiana* was replaced at the beginning of the upper Llandoverian by *Pentamerus* sp. in the Great Basin (Sheehan, 1980a, 1980b). The transition was not an evolutionary event, because *Pentamerus* did not evolve from *Virgiana*. *Pentamerus* is a well-established biostratigraphic marker for the beginning of the upper Llandoverian (Berry and Boucot, 1970). *Pentamerus* sp. commonly occurs in shell-lag deposits associated with storm beds and locally as densely packed, in-place shell assemblages. Growth of many specimens is asymmetric because adjacent individuals interfered with each other during growth in the densely packed colonies. Contemporary communities include the *Verticillopora* Community, dominated by dasycladacean algae interpreted to have lived in shallow, relatively protected environments (Rezak, 1959; Sheehan, 1980b). Pelmatozoan columnals are also commonly associated with the *Pentamerus* Community, and pelmatozoan communities were common in the High Lake Member. Restricted conditions are reflected by the presence of stromatolites and cryptalgal laminites, especially as caps to shallowing-upward sequences.

Pentamerus sp. commonly occurs in great abundance and in places is associated with specimens of a fine-ribbed orthid, ?*Brachyprion* sp., *Microcardinalia* sp. A, *Atrypa* sp., *Atrypa* (*Gotatrypa*) sp. cf. *A. gibbosa*, and ?*Pentlandella* sp. Over most of the North Utah and Ibex basins, water depths were not deep enough for deeper water communities such as those dominated by stricklandids in other regions of the world.

UPPER LLANDOVERIAN (C_{4-5}) CARBONATE PLATFORM BRACHIOPODS

The brachiopod *Pentameroides* sp. A of Sheehan (1982) dominated the *Pentameroides* Community, which occupied an ecologic setting similar to that of the earlier *Pentamerus* Community. *Pentameroides* sp. A was derived from *Pentamerus*, and many of the associated species probably had ancestors in the *Pentamerus* Community. *Pentameroides* sp. A, a form transitional between the genera (see Sheehan, 1982), is of late Llandoverian (C_{4-5}) age.

The *Pentameroides* Community is strongly dominated by *Pentameroides*, but associated species are more diverse and more common than they were in the *Pentamerus* Community. Associated species include *Flabellitesia flabellites*, *Dolerorthis*? sp., *Isorthis* sp., fine- and coarse-ribbed orthids, *Microcardinalia* sp., a rhynchonellid, *Atrypa* (*Gotatrypa*) sp. cf. *A. gibbosa*, *Meristina*? sp., *Pentlandella merriami*, and *Cyrtia* sp. (Sheehan, 1982).

The *Microcardinalia* Community also occurs in slightly deeper water platform settings than the *Pentamerus* Community, near or slightly below storm wave base in the Portage Canyon Section, Utah (Sheehan, 1980b, 1982). Tabulate corals of Zone 1 of Budge (1972) dominate this assemblage. Associated brachiopods include *Isorthis* sp., coarse- and fine-ribbed orthids, ?*Spirinella pauciplicata*, and rare *Pentameroides* sp. A.

Muddy platform facies of the lower Gettel Member contain two additional communities, which probably had to make do with very soft substrates. In the southern Egan Range the *Pentlandella* Community occurs stratigraphically between the *Verticillopora* Community and the *Pentameroides* sp. B Community (of C_6–early Wenlockian age). The *Pentlandella* Community is probably of C_{4-5} age, but could be younger. Species include *Pentlandella merriami* (abundant), and much less common *Atrypina erugata*, *Spirigerina* sp., a plectambonitid, a fine-ribbed orthid, an atrypid, and the coral *Asthenophyllum* sp. It is interpreted to be a quiet-water equivalent of the *Pentameroides* Community. Tabulate and solitary rugose corals are present but not common.

The *Cyrtia* Community occupies a similar position stratigraphically above the *Verticillopora* Community in bioturbated, silty dolomites with occasional storm deposits in the Gettel Member in the Barn Hills, Utah. Species include *Flabellitesia flabellites*, *Atrypa* (*Gotatrypa*) *hedei americensis*, *Cyrtia* sp., and *Spirinella pauciplicata*. Corals are uncommon. A similar C_{4-5} age is inferred.

Boucot and Johnson, in Wilden and Kistler (1979, p. 237) identified an upper Llandoverian horizon (from two localities) in the Lone Mountain Dolomite in the Ruby Mountains that contains "*Dolerorthis*" sp., *Dicoelosia* sp., *Salopina* sp. aff. *S. conservatrix*, *Gypidula* sp., *Leptaena* sp., "*Chonetes*" sp., *Hebetoechia*? sp., "*Ancestrorhyncha*" sp., *Atrypa* sp., *Howellella* (*Acanthospirifer*) sp., *Howellella*? sp., and *Spirinella* sp. aff. *S. pauciplicata*. It is underlain by a collection of *Virgiana*? sp. of early to middle Llandoverian age.

C_6–LOWER WENLOCKIAN CARBONATE PLATFORM BRACHIOPODS

A brachiopod biostratigraphic interval encompasses the very latest Llandoverian (C_6) and the early Wenlockian (Berry and Boucot, 1970). In the North Utah basin only a few meters of section at the top of the Laketown Dolomite belong in this interval. In the Tony Grove Lake and Portage Canyon sections, a few meters of strata contain the *Spirinella* Community. It occurs in dark dolomite deposited below storm wave base (Sheehan, 1980b). Brachiopods include abundant *Spirinella pauciplicata*, common *Ancillotoechia* sp., and rare *Brachyprion* (*Eomegastrophia*) *geniculata*. Six species of *Rhabdocyclus* Zone 2 corals of Budge (1972; see section, "Silurian Corals") are associated with these brachiopods.

Restricted cryptalgal laminites were deposited along the margin of the Ibex basin. The *Verticillopora* algal community was also present in more open marine settings (Sheehan, 1980b). *Pentameroides* sp. B of Sheehan (1982) dominates a community from the Gettel Member of the Laketown on the east side of the southern Egan Range. Associated brachiopods include *Atrypa* (*Gotatrypa*) sp. cf. *A. gibbosa*, *Flabellitesia flabellites*, and *Cyrtia* sp. Associated fossils include dasycladacean algae, echinoderm columnals and calyxes, rare tabulate corals, and stromatoporoids. *Pentameroides* sp. B has a more derived morphology than *Pentameroides* sp. A, and is characteristic of C_6–early Wenlockian species of the genus (Sheehan, 1982).

On the west side of the southern Egan Range, five localities from the Gettel Member of the Laketown Dolomite (from Unit 4 of Budge and Sheehan, 1980b, which was assigned to the High Lake Member) contain *Pentameroides* sp. B. Sheehan (1980b) noted that these collections are not dominated by *Pentameroides* as is common in the *Pentameroides* Community and that many associated brachiopods are common in deeper water communities. The Gettel Member was deposited below normal storm wave base, strengthening this conclusion. Associated taxa include *Flabellitesia flabellites*, *Isorthis* sp., *Dicoelosia biloba*, *Eoplectodonta* sp., *Microcardinalia* sp., *Atrypina erugata*, *Cyrtia* sp., and *Spirinella pauciplicata*. Collections from the upper part of the Laketown Dolomite that overlie strata with *Pentameroides* sp. B are also probably of C_6–early Wenlockian age, but could range higher into the Wenlockian.

The *Spirinella* Community is the deepest community in platform sections in the Jack Valley Member of the Laketown Dolomite in the Ibex basin in the Barn Hills, Confusion Range, and Sheeprock Range, Utah. Species include *Brachyprion* (*Eomegastrophia*) *geniculata*, *Hercotrema pahranagatensis*, *Hercotrema perryi*, an athyridacid, and *Spirinella pauciplicata* (Waite, 1956; Sheehan, 1982). A diverse, undescribed tabulate and rugose coral fauna is present, including corals assigned to zones 2 and 3 of Budge (1972), discussed in “Silurian Corals.” Rare bivalves, common trochoid and high-spired gastropods, and a few bryozoans occur.

The *Atrypina* Community, from the Jack Valley Member of the Laketown Dolomite in the southern Egan Range, has the greatest brachiopod diversity and abundance of any community in the Laketown Dolomite. Corals are also very diverse and include many assigned to Zone 2 of Budge. Rare planispiral and trochoid gastropods and bivalves also occur. Brachiopods, which are evenly distributed, include *Flabellitesia flabellites*, *Isorthis* sp., *Dicoelosia biloba*, *Dicoelosia* sp., *Dalejina* sp., *Eoplectodonta* sp., *Leptaena* sp., *Protochonetes elyensis*, *Camerella*? sp., *Pentameroides* sp. B, *Microcardinalia* sp., *Stegerhynchus estonicus* (=*Ferganella borealis* of Sheehan, 1982), *Hercotrema perryi*, *Plectatrypa* sp. cf. *P. imbricata*, *Atrypa* (*Gotatrypa*) sp. cf. *A. gibbosa*, *Atrypina erugata*, *Cyrtia* sp., *Hedeina*? sp., *Howellella* sp., and *Spirinella pauciplicata eganensis*. Corals and brachiopods described by Merriam (1973a) from the Mountain Boy Range probably are part of the *Atrypina* Community.

Boucot and Johnson, in Wilden and Kistler (1979, p. 237) identified a fauna from the Lone Mountain Dolomite in the Ruby Mountains that includes *Skenidioides* sp., *Dicoelosia* sp., *Anastrophia* sp., *Antirhynchonella*? sp., *Leptaena* sp., *Stegerhynchus* sp. aff. *S. estonicus*, *Lingulopugnoides*? sp., *Atrypa* sp., *Zygatrypa* sp. aff. *Z. paupera*, *Hedeina* sp., and the rugose coral *Palaeocyclas* sp. They assigned a C_6–early Wenlockian age. *Skenidioides*, which normally occurs in relatively deep water, is found here in the shallow-water Lone Mountain Dolomite.

MIDDLE WENLOCKIAN AND YOUNGER CARBONATE PLATFORM BRACHIOPODS

Several faunas have been described from the middle Wenlockian and younger platform strata in southern Nevada and from the Lone Mountain Dolomite along the platform margin in central and northern Nevada. In the Pahranagat Range Johnson and Reso (1964) identified probable Wenlockian brachiopods and corals from these dark beds. Similar faunas in similar strata occur in the Delamar and Pancake ranges (Budge and Sheehan, 1980b; Sheehan, 1980b). Johnson and Reso (1964) recorded the brachiopods *Atrypa* spp., *Howellella* sp. cf. *H. nucula*, *Howellella* sp., *Hyatidina hesperalis*, *Hercotrema pahranagatensis*, and indeterminate dalmanellids and rhynchonellids. Waite (1956) also recorded *Howellella smithi* from near this horizon. Associated corals include *Halysites* sp., *Favosites* sp., *Breviphyllum*? sp., *Disphyllum*? sp., *Clavidictyon* sp., and “*Cladopora*” sp.

At the base of the Decathon Member of the Laketown Dolomite in strata originally assigned to the Sevy Dolomite, Johnson and Reso (1964) identified a late Wenlockian or Ludlovian *Atrypella carinata* fauna of brachiopods associated with a single species of high-spired gastropod. Brachiopods include *Gypidula*? *biloba*, *Stegerhynchus*? *lincolnensis*, *Camarotoechia*? *reesidei*, *Atrypa* sp., *Atrypella carinata*, *Atrypella* sp., *Macropleura*? sp., *Spirinella pauciplicata*, *Howellella* sp. cf. *H. nucula*, *Howellella*? sp. cf. *H.*? *arctica*, *Hyattidina hesperalis*, and *Nucleospira hecetensis.*

Merriam (1973a) described an *Entelophyllum-Howellella* assemblage from dark tongues of dolomite in the upper part of the Lone Mountain Dolomite in the Fish Creek Range and the Mountain Boy Range that is very similar to that in the Pahranagat Range. Johnson and Oliver (1977) reviewed these fossils and concluded they were of late Wenlockian or early Ludlovian age. Brachiopods from the Mountain Boy Range include *Camarotoechia* sp.,?*Hyattidina* sp., and *Spirinella pauciplicata*. The latter species resembles the plicate subspecies *Spirinella pauciplicata eganensis* from the Jack Valley Member of the Laketown Dolomite in the Egan Range. Corals are listed in the section, “Silurian Corals.” A different assemblage is recorded by Merriam (1973a) from the upper Lone Mountain Dolomite in the Fish Creek Range. Brachiopods include *Salopina* sp., *Hercotrema pahranagatensis*, *Camarotoechia* sp. b and sp. f, *Atrypa* sp.,?*Hyattidina* sp., a species incorrectly assigned to *Hindella*, and *Howellella smithi*. Three species from the latter assemblage are present in the probable Wenlockian assemblage from the Portage Canyon Member in the Pahranagat Range. None of the species from the Mountain Boy Range occur in the Pahranagat Range assemblage, but the occurrence of *Spirinella pauciplicata eganensis* suggests correlation with the early to middle Wenlockian assemblages in the Jack Valley Member of the Laketown Dolomite.

CARBONATE SLOPE BRACHIOPODS

Brachiopod biostratigraphy of the Roberts Mountains Formation has been intensely studied. Brachiopod biostratigraphy can be integrated with graptolite (Berry and Murphy, 1975), conodont (Klapper and Murphy, 1975), and ostracode (McClellan, 1973; Stone and Berdan, 1984) biostratigraphy in well-studied sections on Roberts Creek Mountain.

Five brachiopod faunas ranging in age from middle Wenlockian through Pridolian have been described by Johnson and others (1973, 1976). The faunas, designated by the letters A to E, are listed in the next section. Many of the faunas are composed of collections made from several different facies; thus they are biostratigraphic units, not communities. Many of the shelly horizons in the Roberts Mountains Formation are from gravity-emplaced sediments, and so the collections may contain individuals that lived in different environments. In addition to the five lettered faunas, several other collections are discussed.

WENLOCKIAN BRACHIOPODS FROM ROBERTS CREEK MOUNTAIN REGION

The A Fauna of Johnson and others (1976) comes from the lower few hundred feet (approximately 100 m) of the Roberts Mountains Formation and is composed of species from several communities. The brachiopods are of middle to late Wenlockian age, which is consistent with associated graptolites of the *Cyrtograptus rigidus* through *Monograptus testus* zones (Berry and Murphy, 1975). One assemblage of very small, thin-shelled brachiopods including *Chonetoidea* sp. cf. *C. andersoni*, *Dicoelosia parvifrons*, and *Epitomyonia clausula*, was recognized as a community representing the outermost shelly-fauna community developed adjacent to platy limestones containing only pelagic fossils.

Species restricted to the A Fauna are *Skenidioides* sp., *Ptychopleurella* sp., *Dolerorthis* sp., *Salopina*? sp., *Isorthis* sp., *Isorthis microscapha*, *Resserella canalis celtica*, *Dalejina*? sp., *Dicoelosia parvifrons*, *Epitomyonia clausula*, *Conchidium brevimura*, *Conchidium* sp., *Vosmiverstum wenlockum*, *Cymbidium* sp., "*Cymbidium*" sp. (smooth), *Spondylostrophia*? sp., *Kirkidium*? sp., *Pentameroides*? sp., *Brooksina*? sp., *Morinorhynchus* sp., *Eoplectodonta* sp. cf. *E. transversalis*, *Chonetoidea* sp. cf. *C. andersoni*, *Stegerhynchus estonicus*, "*Ancillotoechia*" sp. cf. "*A.*" *minerva*, *Rhynchotreta* sp., *Atrypa* sp., *Atrypa* sp. A, *Reticulatrypa* sp. A, *Spirigerina* sp., *Plectatrypa* sp. cf. *P. rugosa*, *Gracianella praecrista*, *Gracianella* sp., *Eospirifer* sp., *Janius* sp., *Cyrtia* sp., *Plicocyrtia* sp., *Howellella* sp., and *Spirinella* sp.

At most five species extend upward into the B Fauna. The A Fauna shares *Gypidula* sp. and *Nucleospira* sp. with the B Fauna. *Atrypella* sp. is found in the A Fauna and has questionably been identified in B Fauna. Two species from the B Fauna, *Kozlowskiellina deltidialis* and *Meristina* sp., have questionably been found in the A Fauna.

B Fauna overlies the A Fauna and is of latest Wenlockian age based on the brachiopods and associated graptolites of *Pristograptus dubius frequens* and *Pristograptus ludensis* zones (Berry and Murphy, 1975). Five species associated with A Fauna are listed previously. Only two species, "*Schuchertella*" sp. and *Nucleospira* sp., extend upward into the C Fauna. Species restricted to B Fauna are *Ptychopleurella micula*, *Salopina* sp. cf. *S. conservatrix*, *Anastrophia* sp., *Leptaena* sp., *Placotriplesia* sp., *Leangella* sp., *Ancillotoechia* sp., *Plagirhyncha* sp., *Rhynchotreta cuneata*, *Spinatrypa* sp., *Cryptatrypa triangularis*, *Atrypina erugata*, *Lissatrypa* sp., *Protozeuga* sp., *Homeospira evax*, and *Spirinella* sp. B.

The B Fauna occurs in a narrow stratigraphic interval of the Roberts Mountains Formation and is characterized by the small size of the species and lack of pentamerids. It is very distinct from both older and younger faunas.

LUDLOVIAN BRACHIOPODS FROM ROBERTS CREEK MOUNTAIN REGION

The C Fauna of Johnson and others (1976) comes from lower but not lowest and middle Ludlovian strata. Associated graptolites include the upper part of the *Colonograptus colonus* and the *Saetograptus chimaera* Zones of Berry and Murphy (1975). Brachiopods were not found in the lower and middle part of the *C. colonus* Zone in the Roberts Creek Mountain area.

C Fauna is characterized by large species, especially pentamerids, and high diversity. It shares 2 species with the underlying B Fauna, and 31 species are confined to it. Eight species are shared with D Fauna, and five other species probably occur in both faunas. Species restricted to C Fauna include *Dolerorthis birchensis trisecta*, *Dolerorthis* sp., *Isorthis* sp., *Dalejina* sp., *Dicoelosia* sp., *Conchidium synclastica*, *Conchidium* sp., *Lamelliconchidium micropleura*, *Cymbidium* sp., "*Cymbidium*" *lissa*, *Vadimia nevadensis*, *Severella spiriferoides*, *Kirkidium vogulicum*, *Brooksina* sp. cf. *B. alaskensis*, *Pentamerifera* sp., *Gypidula* sp. c, *Morinorhynchus* sp., "*Schuchertella*" sp., *Chonetoidea andersoni*, *Reticulatrypa savagei*, *Spirigerina marginalis*, "*Spirigerina*" sp., *Gracianella crista*, *Protathyris* sp., *Nucleospira* sp., *Hedeina*? sp., *Cyrtia* sp., *Howellella*? sp., *Spirinella* spp., *Delthyris*? sp., and *Eoplicoplasia tumeoventer.*

The following species and subspecies occur in both the C and D Faunas: *Ptychopleurella cymbella*, *Dolerorthis birchensis birchensis*, *Severella munda*, *Antirhynchonella minuta*, *Atrypella* spp., *Dubaria* sp., *Gracianella lissumbra lissumbra*, *Chnaurocoelia transversa*. Species found in C fauna but only questionably identified in D Fauna are *Aenigmastrophia cooperi* and *Cryptatrypa* sp. Species found in D Fauna which are questionably identified in C Fauna are *Salopina delta*, *Stegerhynchus*? sp. cf. *S. lincolnensis*, *Gracianella lissumbra costata*, and *Gracianella plicumbra*.

Johnson and others (1976) recognized three communities in the D Fauna. However, because many gravity-emplaced deposits are present in the Roberts Mountains Formation, it will be necessary to reevaluate the facies in which each community was found.

D Fauna comes from middle Ludlovian strata of the *Polygnathoides siluricus* conodont zone. D Fauna is less diverse than C Fauna and has smaller pentamerid species. Species that also occur in the C Fauna are listed previously. The 17 species restricted to D Fauna are *Skenidioides operosa*, *Isorthis microscapha*, *Dicoelosia diversifrons*, *Conchidium microlocularis*, *Cymbidium imitor*, *Spondylopyxis ignotus*, *Pentamerifera* sp. cf. *P. oblongiformis*, *Carygyps plicata*, *Gypidula* sp. cf. *G. orbitatus*, *Leptaena* sp., *Morinorhynchus subcarinatus*, *Areostrophia rara*, *Aesopomum*? sp., *Reticulatrypa variabilis*, *Meristina* sp., *Hedeina ananias*, and *Delthyris fulgens*.

Few brachiopods have been found in upper Ludlovian strata, but one collection from the upper (but not uppermost) Ludlovian *Pedavis latialata* conodont zone was described by Johnson and others (1976). This collection contains *Dolerorthis*? sp., *Skenidioides* sp., *Isorthis* sp., *Dicoelosia* sp., *Kirkidium* sp., *Anastrophia* sp., *Gypidula* sp., *Morinorhynchus*? sp., *Sphaerirhynchia*? sp., *Spirigerina* sp., *Reticulatrypa* sp. cf. *R. savagei*, *Atrypella* sp., *Cryptatrypa triangularis*, *Gracianella plicumbra*, *Coelospira planorostra*, *Nucleospira* sp., *Meristina*? sp., and *Delthyris* sp. cf. *D. elevata*. Johnson and others (1976) also described *Conchidium ultima* and *Kirkidium*? sp. cf. *K.*? *hospes* from Ludlovian collections from Roberts Creek Mountain.

PRIDOLIAN BRACHIOPODS FROM ROBERTS CREEK MOUNTAIN REGION

A single distinctive collection from near the base of the Pridolian was recorded by Johnson and others (1973). Only three species occur in the overlying E Fauna. Species include "*Dolerorthis*" sp., *Ptychopleurella* sp., *Anastrophia* sp., *Gypidula* sp., *Mesopholidostrophia*? sp., *Reticulatrypa neutra*, *Atrypella* sp., *Gracianella cryptumbra*, *Nucleospira* sp., *Meristina*? sp., *Howellella* sp., *Delthyris* sp., and *Alaskospira*? sp.

E Fauna of Johnson and others (1973) is of Pridolian age and is from collections immediately below an occurrence of *Monograptus angustidens* and the *Ozarkodina remschenidensis eosteinhornensis* conodont zone. Species include "*Dolerorthis*" sp., *Salopina* sp., *Gypidula* sp., *Leptaena* sp., *Morinorhynchus punctorostra*, *Aesopomum*? sp., *Mesodouvillina* (*Protocymostrophia*) *costatuloides*, *Lanceomyonia* sp. cf. *L. confinis*, *Eoglossinotoechia*? sp., *Reticulatrypa*? sp., *Atrypella*? sp., *Gracianella reflexa*, *Gracianella* sp. cf. *G. cryptumbra*, *Protathyris* sp., *Delthyris* sp., *Tenellodermis matrix*, and *Cyrtina* sp. which may be present because of contamination during preparation.

Finally, three collections from the uppermost 10 m of the Silurian part of the Roberts Mountains Formation contain a fauna that is transitional to the Devonian fauna. *Dicoelosia nitida*, *Salopina submurifer*, and *Ptychopleurella* sp. F, which are common in overlying Devonian collections, make their first appearance in this fauna. Species with strong Silurian affinity include *Atrypella* sp., *Gracianella* sp. cf. *G. cryptumbra*, *Gracianella* sp. cf. *G. lissumbra*, *Reticulatrypa neutra*, *Tenellodermis matrix*, and *Dubaria megaeroides*. Other species are: *Tyersella*? sp., *Salopina* sp., *Gypidula* sp., *Plectodonta*? sp., *Atrypa* "*reticularis*," *Reticulatrypa* sp. aff. *R. granulifera*, *Meristina*? sp., and *Howellella* sp.

SILURIAN BRACHIOPODS FROM OTHER REGIONS ON THE SLOPE

Outside the Roberts Creek Mountain region, Silurian brachiopod faunas on the carbonate slope are less well known. Virtually all upper slope sections ("Thick-Bedded Facies" of Berry and Boucot, 1970) have abundant brachiopods at some horizons. Sheehan (1976) described an early Wenlockian brachiopod fauna collected from bioturbated, fine-grained upper slope carbonates of the Thick-Bedded Facies of the Roberts Mountains Formation in the Silver Island Mountains, Utah. This assemblage was in a position high on the carbonate slope, close to the platform margin (Sheehan, 1986). The prograding shelf margin facies (Lone Mountain Dolomite) is found about 35 m above these collections. Sheehan (1976) assigned the collection to the *Dicoelosia-Skenidioides* Community, which is commonly found in fine-grained sediments near or below storm wave base in "Benthic Assemblages 4 or 5" of Boucot (1975). Brachiopods recovered are *Skenidioides* sp. cf. *S. pyramidalis*, *Resserella brownsportensis*, *Isorthis* (*Tyersella?*) *amplificata*, *Isorthis* (*Arcualla*) sp., *Dicoelosia johnsoni*, *Salopina boucoti*, *Mesounia* sp., *Eoplectodonta budgei*, *Leptagonia* sp., "*Leptostrophia*" sp., *Conchidium* sp., *Cymbidium*? sp., *Stegerhynchus estonicus*, *Hercotrema berryi*, *Reticulatrypa* sp., *Atrypina disparilis*, *Atrypina erugata*, *Plectatrypa* sp., and *Janius* sp. Rugose corals are common in these beds; tabulate corals are also locally common. Small gastropods and a few bryozoans also occur. A late Wenlockian or possibly earliest Ludlovian age was assigned, based on the brachiopods. More recent work (Boucot and others, 1988) suggests that *Janius* does not occur above the lower Wenlockian. This assemblage and also the B Fauna are characterized by the presence of few pentamerid brachiopods. Of these species only *Atrypina erugata* from the B Fauna of Johnson and others (1976) and *Rhynchotrema estonicus* from the A Fauna have been recorded from collections in the Roberts Creek Mountain. No conodonts or graptolites have been recorded in this section. The recovery of a distinct fauna in the Silver Island Range is an indication that many assemblages remain to be found in the Roberts Mountains Formation.

In the Roberts Mountains Formation in the Hot Creek Range, Boucot in Kleinhampl and Ziony (1985) identified the following brachiopods: *Dolerorthis* sp., *Dicoelosia* sp., *Isorthis* sp., *Conchidium*? sp., *Cymbidium* sp., *Gypidula* sp., *Coolinia*? sp., *Plectodonta* sp., *Atrypa* "*reticularis*," *Spirigerina* sp., *Lissatrypa* sp., *Nucleospira*? sp., and *Spirinella* sp. aff. *S. pauciplicata*. The fauna is Ludlovian because of the presence of *Cymbidium*.

A diverse collection of brachiopods has been described by Boucot and others (1988) from unit h3 of the Hidden Valley Dolomite in southeastern California north of the Death Valley–Furnace Creek fault in the Funeral Mountains. The relationship between the Hidden Valley and Laketown dolomites is poorly understood. Descriptions of the Hidden Valley Dolomite by McAllister (1974) are consistent with the interpretation that this part of the Hidden Valley Dolomite is a carbonate slope deposit. Suggestions by Boucot and others (1988) that the collection might include shallow-water species brought into a deeper water setting are consistent with this suggestion. The brachiopod fauna has similarities with both slope and carbonate platform faunas in central Nevada and northwestern Utah.

Thirty-two species of brachiopods are present in the Hidden Valley locality, which is about 60 m above Coral Zone B locality described by Merriam (1973b; see section, "Silurian Corals"). Species are *Hesperorthis kessei*, *Skenidioides* sp. cf. *S. operosa*, *Resserella canalis erecta*, *Dicoelosia* sp. cf. *Dicoelosia alticavata*, *Eoplectodonta california*, "*Eoplectodonta*" sp., *Aegiria* sp., *Leptaena* sp. cf. *L. depressa*, *Coolinia sulcata*, *Vosmiverstum wenlockum*, *Rhipidium* (*Pararhipidium*) *filicostatum*, *Kirkidium* (*Pinguaella*) *mcallisteri*, *Apopentamerus*? sp., *Gypidula* sp. cf. *G.*? *biloba*, *Stegerhynchus estonicus*, *Rhynchotreta* sp. aff. *R. americana*, *Hercotrema berryi*, *Hercotrema perryi*, *Zygatrypa stenoparva*, *Spirigerina* sp., *Reticulatrypa ryanensis*, *Eospinatrypa sagana*, *Atrypa* (*Gotatrypa*) *altera*, *Dubaria*? sp., *Lissatrypa* sp., *Merista* sp., *Nucleospira* sp., *Janius occidentalis*, *Cyrtia* sp., and *Spirinella* sp. cf. *S. pauciplicata*. Some of the species have been found elsewhere in both slope and platform regions of Nevada and Utah. *Skenidioides operosa* occurs in the D Fauna and *Vosmiverstum wenlockum* and *Stegerhynchus estonicus* occur in the A Fauna at Roberts Creek Mountain. *Hercotrema berryi* and *Stegerhynchus estonicus* occur in the Roberts Mountains Formation in the Silver Island Range. *Gypidula*? *biloba* occurs in the base of the Decathon Member in the Pahranagat Range. *Stegerhynchus estonicus*, *Hercotrema perryi*, and *Spirinella pauciplicata* occur in the Jack Valley Member of the Laketown Dolomite in eastern Nevada and Utah.

SUMMARY OF SILURIAN BRACHIOPOD BIOSTRATIGRAPHY

The biostratigraphy and facies distribution of carbonate platform brachiopods (fig. 4) have been well documented in many sections. Understanding facies distributions of brachiopods is essential if new faunas are to be correlated. Llandoverian brachiopod diversity is higher on the platform than on the carbonate ramp. Conversely, carbonate platform brachiopod diversity was much lower than on the carbonate slope during the Middle and Late Silurian. The carbonate slope environment apparently had more favorable habitats for brachiopods than the carbonate ramp.

The faunas from the Roberts Creek Mountain section provide the best biostratigraphic control for ranges of Wenlockian, Ludlovian, and Pridolian brachiopods in the Great Basin. They occur in sections in which superpositional relationships have been established and the conodont and graptolite zonations have been carefully documented.

Thirty-eight new species were described by Johnson and others (1973, 1976) from the Roberts Creek Mountain area. Most of these species have not been reported elsewhere in the Great Basin. A great potential clearly exists for developing a refined brachiopod biostratigraphy of the slope deposits of the Roberts Mountains Formation. As faunas from other parts of central Nevada are described, the new species will be reencountered. In addition, the facies distribution of slope brachiopod communities needs to be determined. Very distinctive facies are known to occur along the profile of the carbonate slope, but little information is yet available about the faunas present in many of the facies.

Most of the Roberts Mountains Formation brachiopods that have been described were collected in the late 1960's and early 1970's before modern concepts of carbonate facies had been developed. Particularly for slope settings, much of our understanding of depositional facies has been developed since the faunas were collected. Future progress will require the integration of the biostratigraphic and systematic studies with a facies evaluation of faunas. Fortunately, the locations of most collections in the Roberts Creek Mountain region are very accurately known and a return to these sites will be possible. Of particular significance is the potential for tying brachiopod faunas to stratigraphic sequences extending across the platform and slope settings.

SILURIAN CORALS

Corals of the lower and middle Llandoverian Tony Grove Lake Member of the Laketown Dolomite are essentially unstudied. Small solitary rugose corals are commonly associated with the *Virgiana* Community, both in the same beds and interbedded with that community. Tabulate corals including halysitid, favositid, and heliolitid colonies are also common in the Tony Grove Lake Member, though they are less commonly associated with *Virgiana* than are the rugose corals. In addition, large colonial rugose corals commonly occur; they are in need of study. Corals from the early part of the late Llandoverian (C_{3-4}) have also received little or no attention: tabulate corals are common and diverse, and rugose corals are locally abundant. (See fig. 4 for coral zones.)

Merriam (1973a, b) proposed a coral zonation for the Silurian of the Great Basin. The correlation of these zones was revised by Johnson and Oliver (1977), and their revision is accepted here. Merriam's (1973b) "Coral Zone A" is based on collections from the lower Hidden Valley Dolomite in the Panamint Range of southeastern California. Johnson and Oliver (1977) accepted the late Llandoverian date because Miller (1976) had found conodonts at this level belonging to the *Pterospathodus celloni* Zone. Corals include *Arachnophyllum kayi*, *Dalmanophyllum* sp., *Palaeocyclus porpita mcallisteri*, "*Rhegmaphyllum*" sp., and *Tryplasma*? sp. Merriam (1973b) assigned collections from the Confusion Range (probably the Jack Valley Member of the Laketown) to Coral Zone A, but Johnson and Oliver (1977) assigned them a Wenlockian age.

On the carbonate slope in central Nevada, Merriam (1973b) recorded a latest Llandoverian assemblage from the base of the Roberts Mountains Formation at Ikes Canyon in the Toquima Range. Species are *Arachnophyllum kayi*, *Cyathophylloides fergusoni*, and "*Neophyma*" *crawfordi*. Only *Arachnophyllum kayi* occurs in the Hidden Valley Dolomite.

Budge (1972) recognized three carbonate platform coral zones in a *Rhabdocyclus* Faunizone at the top of the Laketown Dolomite. The lower zone, here informally called "Zone 1," is of Late Llandoverian age, based on associated brachiopods. Zone 1 was found only in the North Utah basin in the Portage Canyon Member of the Laketown Dolomite in sections at Portage Canyon in the West Hills, Utah, and at Paris Peak, in the Bear River Range in Idaho. The associated brachiopods *Pentameroides* sp. A and *Microcardinalia* sp. B indicate a C_{4-5} late Llandoverian age, approximately equivalent to Coral Zone A of Merriam (1973b) as revised by Johnson and Oliver (1977). Zone 1 includes the rugose corals *Rhabdocyclus* sp. A, *Aphyllostylus* sp. aff. *gracilis*, *Palaeocyclus* sp., *Ptychophyllum*? sp., *Rhizophyllum* n.sp., *Tryplasma radicula*, *Rhegmaphyllum* sp. aff. *R. conulus*, *Astenophyllum patula*, and the tabulate corals *Astrocerium* sp., *Catenipora* sp., *Cladopora* sp., *Coenites* sp., *Cystihalysites* spp., *Emmonsia* sp., *Favosites* sp., *Planalveolites* sp., *Romingeria* sp., *Striatopora* sp., *Syringopora* sp., *Alveolites* sp., *Aulopora* sp., and *Heliolites* sp.

Collections from the Ruby Mountains, Nevada (*Palaeocyclus* and *Halysites*), and the Confusion Range, Utah (*Palaeocyclus* sp. cf. *P. porpita*, *Brachyelasma* sp., *Tryplasma* sp. cf. *T. hedstromi*, *Alviolites* sp., *Heliolites* sp., and *Halysites* sp.), assigned by Merriam (1973b) to Coral Zone A have been reassigned a Wenlockian age by Johnson and Oliver (1977). The Confusion Range collections are probably from the Jack Valley Member and possibly the Gettel Member of the Laketown. All are part of Coral Zone 2 of Budge (1972).

Corals of Zone 2 of Budge (1972) were found widely in the Ibex basin in rocks of C_{4-5} and C_6-early Wenlockian age in the Jack Valley, Portage Canyon, and Gettel Members of the Laketown (see discussion of brachiopod biostratigraphy and Johnson and Oliver, 1977). The zone was recognized at only one locality in the North Utah basin, from the Jack Valley Member at the very top of the Tony Grove Lake section.

Zone 2 of Budge (1972) includes the rugose corals *Amplexoides* n. sp., *Asthenophyllum* sp. (of Norford), *Palaeocyclus* n. sp., *Ptychophyllum*? sp., *Rhabdocyclus* n.sp. A, *Rhizophyllum* n.sp., *Tryplasma radicula*, *Asthenophyllum* sp. cf. *orthoseptatum*, *Rhegmaphyllum*? sp. aff. *R. conulus*, and the tabulate corals *Cystihalysites* spp., *Halysites* sp., *Romingeria* sp., *Syringopora* sp., *Alveolites* sp., *Aulopora* sp., and *Heliolites* sp. An associated fauna of abundant brachiopods is discussed in the section, "C_6–Lower Wenlockian Carbonate Platform Brachiopods." Rigby (1967) described sponge spicules from this unit.

The uppermost Coral Zone 3 of Budge (1972) was found only at the top of the Jack Valley Member in the Confusion Range. Zone 3 includes the rugose corals *Asthenophyllum* sp. (of Norford), *Rhabdocyclus* n. sp. B, *Asthenophyllum* sp. cf. *A. orthoseptatum*, and the tabulate corals *Syringopora* sp., *Cystihalysites* sp., and *Heliolites* sp.

Merriam (1973b) characterized his Coral Zone B by a fauna from 325 ft above the base of the Hidden Valley Dolomite in the Panamint Range and 110 ft above the base of the Hidden Valley Dolomite in the Funeral Mountains. Merriam (1973b) assigned Zone B to the lower to middle Wenlockian. Johnson and Oliver (1977) agreed with this assignment, noting that the horizon in the Funeral Mountains is about 200 ft below beds containing *Rhipidium* sp. cf. *R. tenuistriatum* illustrated by Amsden and others (1967). Thus, at least the lower part of Zone B corresponds to the platform Zones 2 and 3 of Budge (1972).

Zone B corals from the Hidden Valley Dolomite include the rugose corals *Ryderophyllum ubehebensis*, *Brachyelasma* sp., *Pycnactis* sp., *Petrozium mcallisteri*, and the tabulate corals *Cystihalysites* sp. aff. *C. magnitubus*, *Heliolites* sp., and *Syringopora* sp.

An additional assemblage, the *Entelophyllum-Howellella* Assemblage of Merriam (1973b), occurs between Coral zones B and C. Merriam originally included the assemblage in his Coral Zone D, but Johnson and Oliver (1977) pointed out the close similarity of the brachiopods with those in the Decathon Member of the Laketown Dolomite in the Pahranagat Range described by Johnson and Reso (1964). They suggested a late Wenlockian or early Ludlovian age, which is younger than Coral Fauna B but older than Coral Fauna C.

The *Entelophyllum-Howellella* Assemblage was found in the upper part of the Lone Mountain Dolomite in the Mountain Boy Range and the Fish Creek Range, Nevada. In the Mountain Boy Range, corals include ?*Thamnopora* sp. and *Entelophyllum engelmanni*. In the Fish Creek Range, corals include small, massive favositids, thin-walled, ramose favositids, ?*Thamnopora* sp., *Entelophyllum engelmanni* subsp. b, *Entelophyllum eurekaensis*, *Alveolites* sp., and *Tryplasma* sp. Associated brachiopods are discussed in the section on brachiopods. *Entelophyllum engelmanni* was also recognized questionably in association with brachiopods described by Johnson and Reso (1964) in the Pahranagat Range.

Coral Zone C of Merriam (1973b) is known only from the Roberts Mountains Formation at Roberts Creek Mountain. Johnson and Oliver (1977) showed that conodonts, brachiopods, and graptolites described in these sections by Klapper and Murphy (1975), Johnson and others (1976), and Berry and Murphy (1975) establish a Pridolian age for Coral Zone C. Rugose corals include *Denayphyllum denayensis*, *Tryplasma newfarmeri*, and *Entolophylloides* (*Prohexagonaria*) *occidentalis*. Two other species (*Tryplasma* sp. and *Microplasma*? sp.) also occur in this section in beds assigned to this zone by Merriam.

Merriam (1973b) established Coral Zones D and E, which he believed were Late Silurian in age. Johnson and Oliver conclusively demonstrated that brachiopods and conodonts from the sections in which Zones D and E were described are Early Devonian in age.

Several isolated coral collections from the Great Basin have been reported in the literature. Buehler (1955) described and illustrated *Halysites magnitubus* from the Laketown Dolomite near Gold Hill, Utah, but the position within the Laketown is unknown. He noted the occurrence of *Halysites labyrinthica*, but again the position in the Laketown is unknown.

In the lower 200 m of the type section of the Roberts Mountains Formation, Merriam and McKee (1976) found *Cladopora* sp., *Heliolites* sp., *Halysites* sp., *Orthophyllum* sp., and pycnostylid rugosa. These are probably of early to middle Wenlockian age based on their position in the section.

In the June Canyon Sequence in the Toquima Range, Nevada, D.R. Budge and W.A. Oliver (in McKee, 1976, p. 17) identified corals from the basal dolomite unit of the Gatecliff Formation. Included were *Cladopora*? sp., *Favosites* spp., *Halysites* or *Cystihalysites* sp., "*Cystiphyllum*" sp., and an amplexoid coral. An Early Silurian age was proposed by McKee based on nearby graptolites from an overlying chert.

SILURIAN OSTRACODES

Only two studies have been made of ostracodes. Stone and Berdan (1984) described a single well-preserved collection of Pridolian age from the Willow Creek area of Roberts Creek Mountain. Thirty-three species were found at the one horizon in a carbonate gravity-flow bed. The fauna included 3 new genera and 18 new species. The closest similarities were with ostracodes from northwestern Canada and Alaska.

McClellan (1973) identified several poorly preserved ostracodes from the Roberts Mountains Formation. He found 2 Ludlovian species at Ikes Canyon in the Toquima Range, 3 Wenlockian species at Wood Cone Peak, and 14 Ludlovian species at Willow Creek. None of the species recorded by McClellan was found by Stone and Berdan (1984).

SILURIAN ALGAE

The *Verticillopora* Community is present throughout the Silurian in the Great Basin. Species of the community were originally described by Rezak (1959) from Wenlockian strata in the Great Basin. *Verticillopora* occurs widely on the carbonate platform in the early late Llandoverian (Sheehan, 1980b). *Verticillopora* was recorded in Coral Zone B in the Hidden Valley Dolomite in the Panamint Range and Funeral Mountains, California, by Merriam (1973b). He noted that Silurian specimens have thin shafts compared with those from the Devonian, but he illustrated Lower Devonian specimens of *Verticillopora*, which he assigned to the Wenlockian species of Rezak. Devonian specimens of *Verticillopora* have been described and illustrated from the middle part of the Devonian Vaughn Gulch Limestone in the Inyo Mountains, California, and the Roberts Mountains Formation in the Toquima Range and Roberts Creek Mountain by Merriam and McKee (1976). Until they are more carefully documented, dasycladacean algae will have limited biostratigraphic value.

SEQUENCE STRATIGRAPHY AND BIOSTRATIGRAPHIC BOUNDARIES

A sequence stratigraphic study of Silurian rocks on the carbonate platform (Harris and Sheehan, 1992, 1996) has revealed strong correlation of sequences with macrofaunal biostratigraphy. From the early Llandoverian through the C_6–early Wenlockian, five stratigraphic sequences (S1 to S5 in fig. 1) have been identified by Harris and Sheehan (1992, 1996). The sequences are stratigraphic packages that shallow upward and are capped by very shallow water facies or exposure surfaces. Each of the four Llandoverian through middle Wenlockian carbonate platform biostratigraphic intervals based on brachiopods (fig. 1) is bounded above and below by regressions that mark sequence boundaries. During the early and middle Llandoverian (a single biostratigraphic interval), there are two stratigraphic sequences (S1 and S2). The other three biostratigraphic intervals each correspond to a single stratigraphic sequence.

The sequence stratigraphy has been carefully documented in only two sections, but the same intervals and boundaries have been found in a reconnaissance of several other sections. Ordovician biostratigraphic intervals are not adequately documented to determine whether or not sequence boundaries match biostratigraphic boundaries.

The correspondence of regressive sequence boundaries with biostratigraphic boundaries in the Silurian could have a number of causes. Because each of the lower five biostratigraphic boundaries in the Silurian corresponds with a sequence boundary, a spurious correlation seems unlikely, and some direct causal connection is likely. A regression marks each boundary, which raises two obvious possibilities. The first is simply a passive effect: sufficient time elapsed during the regression that when open-marine environments returned to the platform in the next stratigraphic sequence, the faunas had changed through evolution. The second possibility is that the regression caused the faunal change by physically disrupting communities and stimulating enough faunal turnover to allow recognition of a new biostratigraphic interval.

The first possibility seems unlikely, because the faunal change during the intervals of deposition is far less than that found across sequence boundaries. Therefore, some disruption of faunas by the regression seems to be the likely cause of the change.

The biostratigraphic boundaries are of two types. The first type involves nonevolutionary replacement of faunas across the boundary. This occurred at the end of the Ordovician and at the transition between the middle and upper Llandoverian. The Ordovician-Silurian boundary corresponds with a worldwide glacio-eustatic regression and a global mass extinction. The boundary between the middle (B) and upper (C) Llandoverian corresponds to a nonevolutionary replacement of many brachiopod groups on the platform. For example, *Virgiana* was replaced by *Pentamerus*, which was derived from a genus not found in the Great Basin (Sheehan, 1980b). The extinction was followed by invasion of brachiopods from other regions.

The other biostratigraphic boundaries involve evolutionary changes that occurred during the regressive intervals. An example is the evolutionary replacement of *Pentamerus* by *Pentameroides* at the boundary between $C_{1\text{-}3}$ and $C_{4\text{-}5}$.

The preliminary finding that stratigraphic sequences and biostratigraphic intervals correspond could become a powerful new tool for correlation. However, further study is clearly needed. The detailed investigation of sequence stratigraphy needs to be conducted in more sections on the platform. Examination of sequences downdip will be essential, because during the regressive interval between platform sequences, deposition should have been continuous on the ramp and slope. Platform species may have retreated to the ramp and slope environments during regressions.

Understanding the nature of the interaction of regressions and biostratigraphic units must await further study of both platform and ramp-slope environments. Fortunately, as has been shown, macrofossils are both abundant and diverse on the carbonate slope.

CONCLUSIONS

The distribution of macrofossils in the Upper Ordovician and Silurian strata of the Great Basin is well documented for certain intervals, but much work remains to be done. Brachiopods and corals are the most diverse and best preserved macrofossils.

The diverse and locally abundant Upper Ordovician brachiopods have received very little study. There is considerable potential for developing a useful biostratigraphic framework if systematic studies are undertaken.

Silurian brachiopods on the carbonate platform have received considerable study. The Llandoverian and early Wenlockian faunas allow recognition of four biostratigraphic intervals. Upper Wenlockian and Ludlovian brachiopods have also been described. Carbonate slope brachiopods have been extensively studied in the Roberts Creek Mountain region, where five biostratigraphic intervals from Wenlockian to Pridolian have been recognized. However, the presence of many new species in slope settings from other areas of the Great Basin indicates that much descriptive work remains to be done.

The potential for Ordovician and Silurian coral biostratigraphy on the carbonate platform was well demonstrated in Budge's (1972) dissertation. Unfortunately, because the work has not been published elsewhere, the names of new taxa are not widely available. Corals from slope settings have been studied, but, as with the brachiopods, many slope faunas need taxonomic work. Corals are best known from Late Ordovician, Wenlockian, and Ludlovian strata. Llandoverian corals are essentially unstudied.

Late Ordovician trilobites are abundant on the carbonate ramp, but few trilobites are described. Additional studies are needed.

Early Silurian sequence and biostratigraphic boundaries appear to correspond. This pattern needs to be carefully documented in carbonate-platform, shelf-margin, and carbonate-slope settings. The combination of sequence stratigraphy and biostratigraphy may become an important tool for correlation.

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APPENDIX. SPECIES LISTED IN TEXT

ORDOVICIAN CORALS

Agetolites budgei Pandolfi, 1985, p. 30–31, pl. 9, fig. 2; pl. 11, fig. 2; pl. 12, fig. 1; pl. 13, figs. 1, 2; pl. 18, fig. 2.

?Billingsaria parvituba (Troedsson, 1928). Pandolfi, 1985, p. 20–21, pl. 4, figs. 1, 2.

Bighornia solearis (Ladd, 1929), p. 397–399, p. 4, figs. 6–12. Elias, 1981, p. 24.

Calapoecia anticostiesis Billings, 1865. Pandolfi, 1985, p. 18–19, pl. 1, figs. 1, 2; pl. 2, fig. 1; pl. 18, fig. 1

Calapoecia sp. cf. *C. canadensis* Billings, 1865, p. 426, pl. 20, fig. 12. Bassler, 1950, p. 275.

Calapoecia sp. cf. *C. coxi* Bassler, 1950. Pandolfi, 1985, pp. 19–20, pl. 1, fig. 3; pl. 2, fig. 2.

Catenipora sp. cf. *C. foerstei* Nelson, 1963. Pandolfi, 1985, p. 33–34, pl. 7, fig. 4; pl. 10, fig. 2.

Catenipora gracilis Hall, 1852. Duncan, 1956, pl. 27, figs. 1a, 1c.

Catenipora sheehani Pandolfi, 1985, p. 34–35, pl. 20, figs. 1, 2.

Catenipora workmanae Flower, 1961. Pandolfi, 1985, p. 32, pl. 13, fig. 3; pl. 21, figs. 1, 2.

Favistina? sp. (= *Favistella* sp. cf. *F. alveolata* (Goldfuss, 1826). Bassler, 1950, p. 271, pl. 16, fig. 3. Flower, 1961, p. 76–79.)

Grewingkia haysii (Meek, 1865). Elias, 1981, p. 17, pl. 5, figs. 1–15; pl. 6, figs. 1–12.

Grewingkia robusta var. *amplum* (Troedsson), 1928 p. 108, pl. 26, figs. 1–4.

Lobocorallium goniophylloides (Teichert, 1937). Duncan, 1956, pl. 22, figs. 3a, 3b. = *Grewingkia haysii* (Meek, 1865). Elias, 1981, p. 17.

Palaeophyllum cateniforme? Flower, 1961, p.91, pl. 49, figs. 1–6. pl. 5, figs. 1–5.

Palaeophyllum gracile Flower, 1961. Pandolfi, 1985, p. 37, pl. 15, fig. 1; pl. 23, figs. 1, 2.

Palaeophyllum humei Sinclair, 1961. Pandolfi, 1985, p. 35–36, pl. 14, figs. 1, 2; pl. 24, figs. 1, 2.

Palaeophyllum sp. cf. *P. raduguini* Nelson, 1963. Pandolfi, 1985, p. 38, pl. 15, fig. 2; pl. 16, figs. 1, 2.

Palaeophyllum sp. cf. *P. thomi* (Hall, 1857). Flower, 1961, p. 91–92, pl. 47, fig. 9; pl. 51, figs. 1–8; pl. 52, figs. 1–7.

Paleofavosites sp. cf. *P. capax* (Billings, 1865). Bolton, 1980, p. 22–25, pl. 2.7, figs. 1, 4–6.

Paleofavosites mccullochae Flower, 1961. Pandolfi, 1985, p. 25–26, pl. 8, fig. 2; pl. 9, figs. 1, 3; pl. 10, fig.1

Paleofavosites okulitchi Stearn, 1956. Pandolfi, 1985, p. 24–25, pl. 7, fig. 2.

Paleofavosites poulseni Teichert, 1937. Pandolfi, 1985, p. 23–24, pl. 5, figs. 1–3; pl. 6, figs. 1, 2; pl. 7 figs. 1, 3, 5.

Paleofavosites sp. cf. *P. transiens* Stearn, 1956. Pandolfi, 1985, p. 27, pl. 11, fig. 3; pl. 16, fig. 3.

Saffordophyllum crenulatum (Bassler, 1932). Pandolfi, 1985, p. 22, pl. 4, fig. 3.

Tetradium tubifer Troedson, 1928, p. 137–138, pl. 46, figs. 3a, 3b; pl. 47, pl. 1a–1h.

LATE ORDOVICIAN BRACHIOPODS

Diceromyonia ignota (Sardeson, 1897). Howe and Reso, 1967, p. 354–358, pl. 40, figs. 1–16.

Diceromyonia tersa (Sardeson, 1892). Wang, 1949, p. 36, pl. 12B, figs. 1–8; Howe, 1965, pl. 36, figs. 16–25.

Hypsiptycha sp. cf. *H. anticostiensis* (Billings, 1865). Howe and Reso, 1967, p. 358–361, pl. 40, figs. 17–20.

Hiscobeccus capax (Conrad, 1842). Howe and Reso, 1967, p. 362, pl. 40, figs. 21–25.

Lepidocyclus gigas Wang, 1949. Macomber, 1970, p. 447, pl. 80, figs. 1–17.

Lepidocyclus perlamellosus (Whitfield, 1877). Wang, 1949, p. 14, pl. 6A, figs. 1–5.

Onniella sp. cf. *O. meeki* (Miller, 1875). Hall, 1962, p. 145–148, pl. 19, figs. 1–24; pl. 20, figs. 1–10.

Onniella sp. cf. *O. multisecta* (Meek, 1873). Hall, 1962, p. 148–150, pl. 20, figs 11–31.

Plaesiomys (Dinorthis) occidentalis (Okulitch, 1943). Macomber, 1970, p. 430–433, pl. 75, figs. 12–15; pl. 76, figs. 1–27.

Strophomena sp. cf. *S. planumbona* (Hall, 1847). Wang, 1949, p. 23–24, pl. 6D, figs. 1–7.

Zygospira sp. cf. *Z. recurvirostrus* Hall, 1847. Ross, 1959, p, 457, pl. 54, figs. 3, 7, 12, 18.

LATE ORDOVICIAN CEPHALOPODS

Michelinoceras beltrami? (Clarke, 1897). Foerste, 1932, p. 77, pl. 35, fig. 6.

LATE ORDOVICIAN TRILOBITES

Ceraurinus icarus (Billings, 1865). Ross, Nolan, and Harris, 1979, fig. 4, s, z.

SILURIAN BRACHIOPODS

Aenigmastrophia cooperi Boucot, 1971. Johnson, Boucot, and Murphy, 1976, p. 56–57, pl. 21, figs. 1–11.

"*Ancillotoechia*" sp. cf. "*A.*" *minerva* (Barrande, 1847). Johnson, Boucot, and Murphy, 1976, p. 66–67, pl. 5, figs 14–27.

Antirhynchonella minuta Johnson, Boucot, and Murphy, 1976, p. 53, pl. 41, figs. 1–16; pl. 42, figs. 1, 2.

Areostrophia rara Johnson, Boucot, and Murphy, 1976, p. 61–62, pl. 44, figs. 12–19.

Atrypa (Gotatrypa) altera Boucot, Johnson, and Zhang, 1988, p. 118–119, pl. 7, figs. 18–30.

Atrypa (*Gotatrypa*) sp. cf. *A. gibbosa* Hall, 1852. Copper, 1982, p. 698–700, pl. 3, figs. 1–13; =*Atrypa* sp. cf. *A. parva* of Sheehan, 1982, p. 37–39, pl. 10, figs. 1–14.

Atrypa (Gotatrypa) hedei (Struve, 1966) *americensis* Sheehan, 1982, p. 39–40, pl. 10, figs. 15–23.

Atrypella carinata Johnson in Johnson and Reso, 1964, p. 81, pl. 20, figs. 9, 18–26. *Brachyprion (Eomegastrophia) geniculata* (Waite, 1956). Sheehan, 1982, p. 16–21, pl. 4, figs. 24, 25; pl. 5, figs. 1–19; pl. 6, figs. 1–8.

Atrypina disparilis (Hall, 1852). Sheehan, 1976, p. 731, pl. 2, figs. 8–14.

Brooksina sp. cf. *B. alaskensis* Kirk, 1922. Johnson, Boucot, and Murphy, 1976, p. 51–52, pl. 19, figs. 3–15.

Camarotoechia? *reesidei* Kirk and Amsden, 1952. Johnson and Reso, p. 80, pl. 19, figs. 13–19.

Carygyps plicata Johnson, Boucot, and Murphy, 1976, p. 54–55, pl. 42, figs. 3–15; pl. 43, figs. 1–11.

Chnaurocoelia transversa Johnson, Boucot, and Murphy, 1976, p. 95–96, pl. 55, figs. 1–19.

Chonetoidea sp. cf. *C. andersoni* Johnson, Boucot, and Murphy, 1976, p. 58–59, pl. 20, figs. 3–25.

Coelospira planorostra Johnson, Boucot, and Murphy, 1976, p. 83, pl. 26, figs. 5–16.

Conchidium brevimura Johnson, Boucot, and Murphy, 1976, p. 35–36, pl. 2, figs. 21–28; pl. 3, figs. 1–13.

Conchidium microlocularis Johnson, Boucot, and Murphy, 1976, p. 37–38, pl. 35, figs. 1–26; pl. 36, figs. 1–3.

Conchidium synclastica Johnson, Boucot, and Murphy, 1976, p. 36–37, pl. 15, figs. 11–24; pl. 16, figs. 1–7.

Conchidium ultima Johnson, Boucot, and Murphy, 1976, p. 38–39, pl. 27, figs. 1–20.

Coolinia sulcata Boucot, Johnson, and Zhang, 1988, p. 111–112, pl. 2, figs. 44–45; pl. 3, figs. 1–5.

Cryptatrypa triangularis Johnson, Boucot, and Murphy, 1976, p. 75–76, pl. 25, figs. 22–30; pl. 26, figs. 1–4.

Cymbidium imitor Johnson, Boucot, and Murphy, 1976, p. 42–43, pl. 36, figs. 4–23; pl. 37, figs. 1–11.

"*Cymbidium*" *lissa* Johnson, Boucot, and Murphy, 1976, p. 43, pl. 16, figs. 8–14.

Delthyris sp. cf. *D. elevata* Dalman, 1828. Johnson, Boucot, and Murphy, 1976, p. 89, pl. 26, figs. 17–24.

Delthyris fulgens Johnson, Boucot, and Murphy, 1976, p. 89–90, pl. 53, figs. 11–16.

Dicoelosia sp. cf. *Dicoelosia alticavata* (Whittard & Barker, 1950). Boucot, Johnson, and Zhang, 1988, p. 109–110, pl. 1, figs. 25–43.

Dicoelosia biloba (Linnaeus, 1758). Sheehan, 1982, p. 9–10, pl. 3, figs. 18–26; pl. 4, figs. 1–3.

Dicoelosia diversifrons Johnson, Boucot, and Murphy, 1976, p. 27–28, pl. 33, figs. 3–20.

Dicoelosia johnsoni Sheehan, 1976, p. 720–721, pl. 4, figs. 1–11.

Dicoelosia nitida Johnson, Boucot and Murphy, 1973, p. 22–24, pl. 16, figs. 16–24; pl. 17, figs. 1–7.

Dicoelosia parvifrons Johnson, Boucot, and Murphy, 1976, p. 27, pl. 1, figs. 15–28.

Dolerorthis birchensis birchensis Boucot, Johnson, and Murphy, 1976, p. 22–23, pl. 29, figs. 16–18; pl. 30, figs. 1–31.

Dolerorthis birchensis trisecta Boucot, Johnson, and Murphy, 1976, pl. 31, figs. 1–19.

Dubaria megaeroides Johnson and Boucot, 1970, p. 267, pl. 54, figs. 10–25. Johnson, Boucot and Murphy, 1973, p. 51, pl. 27, figs. 13–15.

Eoplectodonta budgei Sheehan, 1976, p. 726–727, pl. 4, figs. 12–17.

Eoplectodonta california Boucot, Johnson, and Zhang, 1988, p. 110, pl. 3, figs. 6–13.

Eoplectodonta sp. cf. *E. transversalis* (Dalman, 1828). Johnson, Boucot, and Murphy, 1976, p. 58, pl. 4, figs. 17–20.

Eoplicoplasia tumeoventer Johnson and Lenz, 1992. Johnson, Boucot, and Murphy, 1976, p. 94–95, pl. 25, figs. 1–12.

Eospinatrypa sagana Boucot, Johnson, and Zhang, 1988, p. 118, pl. 7, figs. 31–47.

Epitomyonia clausula Johnson, Boucot, and Murphy, 1976, p. 29, pl. 1, figs. 29–36; pl. 2, figs. 1–20.

Flabellitesia flabellites (Foerste, 1889). Sheehan, 1982, p. 3, pl. 1, figs. 13, 14, 17–20; pl. 2, figs. 1–14. Zhang, 1989, p. 56.

Gracianella crista Johnson and Boucot, 1967. Johnson, Boucot, and Murphy, 1976, p. 81, pl. 24, figs. 11–28.

Gracianella cryptumbra Johnson, Boucot and Murphy, 1973, p. 56–57, pl. 3, figs. 1–20.

Gracianella lissumbra costata Johnson, Boucot, and Murphy, 1976, p. 81, pl. 48, figs. 19–25.

Gracianella lissumbra lissumbra Johnson and Boucot, 1967. Johnson, Boucot, and Murphy, 1976, p. 80, pl. 50, figs. 1–19.

Gracianella plicumbra Johnson and Boucot, 1967. Johnson, Boucot, and Murphy, 1976, p. 81, pl. 49, figs. 1–24.

Gracianella praecrista Johnson, Boucot, and Murphy, 1976, p. 79–80, pl. 7, figs. 1–15.

Gracianella reflexa Johnson, Boucot and Murphy, 1973, p. 54–56, pl. 7, figs. 1–18; pl. 8, figs. 1–10.

Gypidula sp. cf. *G. orbitatus* (Barrande, 1879). Johnson, Boucot, and Murphy, 1976, p. 56, pl. 43, figs. 12–18.

Gypidula? *biloba* Johnson in Johnson and Reso, 1964, p. 79–80, pl. 19, figs. 1–4.

Hedeina ananias Johnson, Boucot, and Murphy, 1976, p. 86–87, pl. 51, figs. 11–20; pl. 52, figs. 1–14.

Hercotrema berryi (Sheehan, 1976), pl. 5, figs. 6–14. Boucot, Johnson, and Zhang, 1988, p. 116, pl. 6, figs. 34–40. Jin, 1989, p. 88.

Hercotrema pahranagatensis (Waite, 1956), pl. 3, figs. 1–5. Sheehan, 1982, p. 33–34, pl. 8, figs. 11–19. Jin, 1989, p. 88.

Hercotrema perryi (Sheehan, 1982), p. 32–33, pl. 9, figs. 1–15. Boucot, Johnson, and Zhang, 1988, p. 116, pl. 6, figs. 1–8. Jin, 1989, p. 88.

Hesperorthis kessei Boucot, Johnson, and Zhang, 1988, p. 107–108, pl. 1, figs. 1–16.

Homeospira evax (Hall, 1863). Johnson, Boucot, and Murphy, 1976, p. 85, pl. 11, figs. 28–31; pl. 12, figs. 1–7.

Howellella sp. cf. *H. nucula* (Barrande, 1879). Johnson and Reso, p. 83, pl. 20, figs. 14–17.

Howellella smithi Waite, 1956, pl. 3, figs. 16–19.

Howellella? sp. cf. *H.*? *arctica* (Poulsen, 1943), pl. 6, figs. 9–12. Johnson and Reso, 1964, p. 83.

Hyatidina hesperalis (Waite, 1956), pl. 4, figs. 11–15. Johnson and Reso, 1964, p. 83, pl. 19, figs. 22, 23, 25–28.

Isorthis (Tyersella?) sp. cf. *I. (T.) amplificata* Walmsley, 1965. Sheehan, 1976, p. 716–718, pl. 3, figs. 9–16.

Isorthis microscapha Johnson, Boucot, and Murphy, 1976, p. 25–26, pl. 1, figs 13, 14; pl. 32, figs. 13–23; pl. 33, figs. 1, 2.

Janius occidentalis Boucot, Johnson, and Zhang, 1988, p. 120–121, pl. 9, figs. 1–22.

Kirkidium (Pinguaella) mcallisteri Boucot, Johnson, and Zhang, 1988, p. 113–114, pl. 4, figs. 17–32.

Kirkidium vogulicum (Verneuil, 1845), Johnson, Boucot, and Murphy, 1976, p. 50–51, pl. 18, figs. 2–14; pl. 19, figs. 1, 2.

Kirkidium? sp. cf. *K.*? *hospes* (Barrande, 1879). Johnson, Boucot, and Murphy, 1976, p. 51, pl. 17, figs. 11, 12; pl. 18, fig. 1.

Kozlowskiellina deltidialis (Hedstroem, 1923). Johnson, Boucot, and Murphy, 1976, p. 90–91, pl. 12, figs. 8–21.

Lamelliconchidium micropleura Johnson, Boucot, and Murphy, 1976, p. 40–41, pl. 13, figs. 23–30; pl. 14, figs. 1–19; pl. 15, figs. 1–10.

Lanceomyonia sp. cf. *L. confinis* (Barrande, 1848). Havlicek, 1961, p. 116, pl. 13, figs. 4, 5.

Leptaena sp. cf. *L. depressa* (J. de C. Sowerby 1824). Boucot, Johnson, and Zhang, 1988, p. 111, pl. 2, figs. 42, 43.

Mesodouvillina (Protocymostrophia) costatuloides Johnson, Boucot and Murphy, 1973, p. 41, pl. 6, figs. 1–18.

Morinorhynchus punctorostra Johnson, Boucot and Murphy, 1973, p. 36–38, pl. 4, figs. 1–20; pl. 5, figs. 1–17.

Morinorhynchus subcarinatus Johnson, Boucot, and Murphy, 1976, p. 60–61, pl. 45, figs. 1–16; pl. 46, figs. 1–8.

Nucleospira hecetensis Kirk and Amsden, 1952. Johnson and Reso, 1964, p. 83–84, pl. 19, figs. 24, 29.

Pentamerifera sp. cf. *P. oblongiformis* (Nikiforova, 1937). Johnson, Boucot, and Murphy, 1976, p. 49–50, pl. 40, figs. 1–17.

Pentlandella merriami Sheehan, 1982, p. 35–37, pl. 9, figs. 16–30. *Atrypina erugata* Amsden, 1968. Johnson, Boucot, and Murphy, 1976, p. 78–79, pl. 11, 8–20; Sheehan, 1982, p. 42, pl. 13, figs. 1–13.

Plectatrypa sp. cf. *P. imbricata* (J. de C. Sowerby, 1839). Sheehan, 1982, p. 41, pl. 10, figs. 26, 27.

Plectatrypa sp. cf. *P. rugosa* (Hall, 1852). Johnson, Boucot, and Murphy, 1976, p. 68–69, pl. 6, figs. 20–27.

Protochonetes elyensis Sheehan, 1982, p. 22–24, pl. 6, figs. 5–9.

Ptychopleurella cymbella Johnson, Boucot, and Murphy, 1976, p. 20–21, pl.31, figs. 20–25; pl. 32, figs. 1–12.

Ptychopleurella micula Johnson, Boucot, and Murphy, 1976, p. 19–20, pl. 8, figs. 1–24.

Resserella brownsportensis (Amsden, 1949). Sheehan, 1976, p. 715–716, pl. 3, figs. 1–8.

Resserella canalis celtica Bassett, 1972. Johnson, Boucot, and Murphy, 1976, p. 26, pl. 1, figs. 1–12.

Resserella canalis erecta Boucot, Johnson, and Zhang, 1988, p. 108–109, pl. 2, figs. 21–41.

Reticulatrypa sp. aff. *R. granulifera* (Barrande). Johnson, Boucot and Murphy, 1973, p. 49–50, pl. 2, figs. 19–24.

Reticulatrypa neutra Johnson, Boucot and Murphy, 1973, p. 49, pl. 2, figs. 1–18.

Reticulatrypa ryanensis Boucot, Johnson, and Zhang, 1988, p. 117–118, pl. 7, figs. 1–17.

Reticulatrypa savagei Johnson, Boucot, and Murphy, 1976, p. 72–73, pl. 21, figs. 14–25; pl. 22, figs. 1–13.

Reticulatrypa variabilis Johnson, Boucot, and Murphy, 1976, p. 73–74, pl. 47, figs. 13–26.

Rhipidium sp. cf. *R. tenuistriatum* (Lindstrom, 1880). Amsden, Boucot, and Johnson, 1967, p. 866, pl. 108, figs. 1–11.

Rhipidium (Pararhipidium) filicostatum Boucot, Johnson, and Zhang, 1988, p. 113, pl. 5, figs. 1–19.

Rhynchotreta sp. aff. *R. americana* (Hall, 1879). Boucot, Johnson, and Zhang, 1988, p. 115–116, pl. 6, figs. 41–49.

Rhynchotreta cuneata (Dalman, 1828). Johnson, Boucot, and Murphy, 1976, p. 65–66, pl. 9, figs. 17–32.

Salopina boucoti Sheehan, 1976, p. 721–722, pl. 1, figs. 13–23; pl. 2, figs. 1–6.

Salopina sp. cf. *S. conservatrix* (McLearn, 1924). Johnson, Boucot, and Murphy, 1976, p. 30–31, pl. 8, figs. 25–32.

Salopina delta Johnson, Boucot, and Murphy, 1976, p. 31–32, pl. 34, figs. 1–16.

Salopina submurifer Johnson, Boucot and Murphy, 1973, p. 26–28, pl. 11, figs. 15–23; pl. 12, figs. 1–19.

Severella munda Johnson, Boucot, and Murphy, 1976, p. 46–47, pl. 38, figs. 1–30; pl. 39, figs. 1–23.

Severella spiriferoides Johnson, Boucot, and Murphy, 1976, p. 45–46, pl. 16, figs. 15–28.

Skenidioides operosa Boucot, Johnson, and Murphy, 1976, p. 23–24, pl. 29, figs. 1–15.

Skenidioides sp. cf. *S. pyramidalis* (Hall, 1852). Sheehan, 1976, p. 714–715, pl. 1, figs. 1–12.

Spirigerina marginalis (Dalman, 1828). Johnson, Boucot, and Murphy, 1976, p. 69–70, pl. 22, figs. 14–28; pl. 23, figs. 1, 2.

Spirinella pauciplicata (Waite, 1956), p. 17, pl. 3, figs. 6–10. Sheehan, 1982, p. 50, pl. 11, figs. 29–31; pl. 12, figs. 1–18.

Spirinella pauciplicata (Waite, 1956) *eganensis* Sheehan, 1982, p. 50, pl. 12, figs. 15–18.

Spondylopyxis ignotus Johnson, Boucot, and Murphy, 1976, p. 48, pl. 37, figs. 12–24.

Stegerhynchus estonicus Rubel, 1977. =*Ferganella borealis* of Sheehan, 1982, pl. 8, figs. 1–10. Boucot, Johnson, and Zhang, 1988, p. 115, pl. 6, figs. 9–33.

Stegerhynchus? *lincolnensis* (Johnson, in Johnson and Reso, 1964), pl. 19, figs. 5–12. Jin, 1989, p. 55. Johnson, Boucot, and Murphy, 1976, p. 64–65, p. 47, figs. 1–12.

Tenellodermis matrix Johnson, Boucot and Murphy, 1973, p. 65–66, pl. 9, figs. 1–19.

Vadimia nevadensis Boucot and Rong, 1994, p. 407; Johnson, Boucot, and Murphy, 1976, p. 44, pl. 17, figs. 1–10.

Virgiana utahensis Sheehan, 1980, p. 3–7, pl. 1, figs. 15–17; pl. 2, figs. 1–10.

Vosmiverstum wenlockum Boucot, Johnson, and Zhang, 1988, p. 112–113, pl. 4, figs. 1–16. Johnson, Boucot, and Murphy, 1976, p. 41, pl. 3, figs. 14–18.

Zygatrypa paupera (Billings, 1866). Copper, 1977, p. 310–311, pl. 37, figs. 21–19.

Zygatrypa stenoparva Boucot, Johnson, and Zhang, 1988, p. 117, pl. 8, figs. 11–28.

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Aphyllostylus gracilis Whiteaves, 1904. Stearn, 1956 p. 91, pl. 6, figs. 1, 8.

Arachnophyllum kayi Merriam, 1974, p. 43, pl. 5, figs. 7, 8.

Astenophyllum patula (Rominger, 1876). Ehlers, 1973, p. 44, pl. 1, figs. 9–12; pl. 19, fig. 11.

Asthenophyllum sp. cf. *A. orthoseptatum* Grubbs, 1939, p. 546–547, pl. 61, figs. 14–18.

Cyathophylloides fergusoni Merriam, 1974, p. 33, pl. 5, figs. 9, 10.

Cystihalysites magnitubus (Buehler, 1955), 68, pl. 11, figs. 1–3. Merriam, 1974, p. 15.

Denayphyllum denayensis Merriam, 1974, p. 57, pl. 7, figs. 15–18.

Entelophyllum engelmanni Merriam, 1973, p. 38–39, pl. 10, figs. 5–11; Merriam, 1974, p. 49, pl. 10, figs. 5–13.

Entelophyllum engelmanni subsp. b Merriam, 1973, p. 39, pl. 10, figs. 12–13; pl. 11, figs. 26–17.

Entelophyllum eurekaensis Merriam, 1973, p. 39–40, pl. 10, figs. 1–4. Merriam, 1974, p. 49, pl. 10, figs. 1, 2, 14, 15.

Entolophylloides (Prohexagonaria) occidentalis Merriam, 1974, p. 50–51, pl. 9, figs. 1–4.

Halysites labyrinthica (Goldfuss, 1826). Buehler, 1955, p. 29–30, pl. 3, figs. 1–5. Ehlers, 1974, p. 50, pl. 3, fig. 7.

Neophyma crawfordi Merriam, 1974, p. 51, pl. 13, figs. 5–8.

Palaeocyclus porpita mcallisteri Merriam, 1974, p. 39–40, pl. 1, figs. 12–15, 17.

Petrozium mcallisteri Merriam, 1974, p. 48, pl. 9, figs. 6–10.

Rhegmaphyllum sp. aff. *R. conulus* (Lindstrom, 1868, p. 428, pl. 6, fig. 8). Ehlers, 1973, p. 53, pl. 4, figs. 3–5, Merriam, 1974, p. 31.

Ryderophyllum ubehebensis Merriam, 1974, p. 44–45, pl. 6, figs. 1–7.

Tryplasma sp. cf. *T. hedstromi* Wedekind, 1927, pl. 29, figs. 1, 2.

Tryplasma newfarmeri Merriam, 1974, p. 37–38, pl. 2, figs. 1–4.

Tryplasma radicula (Rominger, 1876). Ehlers, 1973, p. 53, pl. 4, figs. 13–14.

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PLATE 1 →