U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

THE IBEXIAN SERIES (LOWER ORDOVICIAN), A REPLACEMENT FOR "CANADIAN SERIES" IN NORTH AMERICAN CHRONOSTRATIGRAPHY

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]

Chapter B

in

PALEOZOIC BIOCHRONOLOGY OF THE GREAT BASIN, WESTERN UNITED STATES

Michael E. Taylor[5], Editor

Open-File Report 93-598

1993

[1]Department of Geology, Colorado School of Mines, Golden Colorado 80401; [2]Department of Geology, Brigham Young University, Provo, Utah 84602-4646; [3]Department of Geological Sciences, University of Missouri, Columbia, Missouri 65211; [4]Department of Geography, Geology and Planning, Southwest Missouri State University, Springfield, Missouri 65904-0089; [5]U.S. Geological Survey, Box 25046 MS 919, Denver Federal Center, Colorado 80225-0046; and [6]U.S. Geological Survey, National Center 970, Reston, VA 22092. [7]Department of Geological Sciences, University of Texas, Austin 78712, and [8]Physical Science Division, Rock Valley College, Rockford, IL 61114.

CONTENTS

CAPTIONS

Plates

Plate I. Observed ranges of trilobites from the Ibexian Series composite stratotype section and adjacent rocks, House-Confusion Range area, west-central Utah. Arrowheads at ends of range bars indicate observed limits of stratigraphic ranges. See Figure 10 for explanation of abbreviations and Plate III for explanation of rock symbols. Oversize.

Plate II. Observed ranges of conodonts from the Ibexian Series composite stratotype section and adjacent rocks, House-Confusion Range area, west-central Utah. Arrowheads at ends of range bars indicate observed limits of stratigraphic ranges. See Figure 10 for explanation of abbreviations and Plate III for explanation of rock symbols. Oversize.

Plate III. Observed ranges of echinoderms, molluscs, and brachiopods from the Ibexian Series composite stratotype section and adjacent rocks, House-Confusion Range area, west-central Utah. Arrowheads at ends of range bars indicate observed limits of stratigraphic ranges. See Figure 10 for explanation of abbreviations. Echinoderm ranges compiled by James Sprinkle and T.E. Guensburg. Oversize.

Figures

Figure 1. Index map of the Ibex area in western Utah showing the locations of the detailed maps in Figures 2-7. Inset map shows the location of this figure, in solid black, in the state of Utah. This map includes parts of the U.S. Geological Survey Tule Valley and Wah Wah Mountains North 1:100,000 scale topographic maps. The small squares on the map are about one square mile in area. Page 10.

Figure 2. Geologic map showing the location of the A section of Hintze (1951, 1973). Symbols: OCnl, Lava Dam Member of the Notch Peak Formation; Oh, House Limestone, the middle sandy zone of which is shown by a dashed line; Of, Fillmore Formation; Qa, surficial deposits. Heavy lines are faults with bar-and-ball on the downthrown side. Line of section indicated by inverted "Vs". Topographic base map is the U.S. Geological Survey 1:24,000 Hell'n Moriah Canyon provisional quadrangle, 1991. Geology from Hintze (1974b). Page 12.

Figure 3. Geologic map showing the location of the Sneakover Pass (SnP) measured section of Hintze and others (1988). Symbols: Cnh, Hellnmaria Member of the Notch Peak Formation; Cnr, Red Tops Member of the Notch Peak Formation; OCnl, Lava Dam Member of the Notch Peak Formation; Oh, House Limestone; Qa, surficial deposits. Heavy lines are faults with bar-and-ball on the downthrown side. Line of section indicated by inverted "Vs". Topographic base map is the U.S. Geological Survey 1:24,000 Skull Rock Pass provisional quadrangle. Geology from Hintze (1974b). Page 12.

Figure 4. Geologic map showing the location of the Square Top measured section of Hintze (1973). Symbols: Of, Fillmore Formation; Ow, Wah Wah Limestone; Oe, Eureka Quartzite; Oes, Ely Springs Dolomite; Qa, surficial deposits; Qs, sand. Heavy lines are faults with bar-and-ball on the downthrown side. Line of section indicated by inverted "Vs". Topographic base map is the U.S. Geological Survey 1:24,000 Burnout Canyon provisional quadrangle, 1991. Geology from Hintze (1974a). Page 13.

Figure 5. Geologic map showing the 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. Symbols: Oh, House Limestone; Of, Fillmore Formation with a key bed indicated by the dashed line; Tsr, Skull Rock Pass Conglomerate; Qa, surficial deposits. Lines of sections indicated by inverted "Vs". Topographic base map is the U.S. Geological Survey 1:24,000 Burnout Canyon provisional quadrangle, 1991. Geology from Hintze (1974a). Page 14.

Figure 6. Geologic Map showing the location of the B section of Hintze (1951), the Lava Dam North (LDN) and Lava Dam Five (LD5) measured sections of Hintze (1973) and Hintze and others (1988). Symbols: Cnr, Red Tops Member of the Notch Peak Formation; OCnl, Lava Dam Member of the Notch Peak Formation; Oh, House Limestone; Of, Fillmore Formation; Tv, Tertiary volcanic rocks; Qa, surficial deposits; Qs, sand. Heavy lines are faults, solid lines in bedrock, dotted lines where fault is concealed by surficial deposits, bar-and-ball on the downthrown side. 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). Topographic base map is the U.S. Geological Survey 1:24,000 Red Tops provisional quadrangle, 1991. Geology from Hintze (1974a) and Hintze and others (1988). Page 15.

Figure 7. Geologic map showing the 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. Symbols: Of, Fillmore Formation, with the dashed lines showing key beds; Ow, Wah Wah Limestone; Oj, Juab Limestone; Ok, Kanosh Shale; Ou, undivided Middle and Upper Ordovician rocks that are considerably faulted; Tv, Tertiary volcanic rocks; Qa, surficial deposits; Qs, sand. Heavy lines are faults, dotted where covered by surficial deposits, with bar-and-ball on the downthrown side. Lines of section are indicated by inverted "Vs". Topographic base map is the U.S. Geological Survey 1:24,000 Warm Point provisional quadrangle, 1991. Geology from Hintze (1974a). Page 16.

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). The 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 semi-quantitative (non-probabilistic) estimate of how well established are lowest and

highest occurrences of a species as suggested by occurrence/non-occurrence in subjacent and superjacent fossil-bearing samples. Abbreviations: **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. Page 18.

Figure 9. Photographs of the Lava Dam Five section (LD5), southern House Range, Utah. **9a**, 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 Plates I, II, and III 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 of 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. View from the north. See Figure 6 for location of traverse. **9b**, Close-up 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 Figure 9a (position 4). Photographs by J.F. Miller. Page 20.

Figure 10. New stages of the Ibexian Series showing the shelly fossil and conodont zones upon 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). Page 23.

Table

Table 1. Universal Transverse Mercator Coordinates of component sections of the Ibexian composite stratotype section. Page 17.

ABSTRACT

The Ibexian Series (mainly Lower Ordovician), first proposed by Hintze (1982), replaces the "Canadian Series" of North American usage. The lower boundary stratotype of the Ibexian Series is defined at 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 section of the Steamboat Pass-Lava Dam composite section of Hintze and others (1988). The lower boundary of the Ibexian Series is coincident with the lowest observed occurrence of *Cordylodus andresi* Viira and Segeeva *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 m (4 in) below the lowest trilobite sample assigned to the *Eurekia apopsis* Zone. The top of the Ibexian Series in its type area coincides with the correlated base of the Whiterockian Series which 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).

The Ibexian Series is characterized by over one-hundred-fifty conodont species and over one-hundred-fifty trilobite and articulate brachiopod species from a composite of 11 measured sections in the type area, located in the southern House Range and southern Confusion Range in the Notch Peak and the 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 m (2,628 ft) 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 accepted for 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 U.S., Appalachian Mountains, eastern and western Canada, Mexico, Greenland, Kazakhstan, Australia, southeastern Asia, China, and elsewhere. In deeper water carbonate facies the Ibexian Series is often underlain by the geographically widespread trilobite *Lotagnostus hedini* (Troedsson).

INTRODUCTION

Here we reiterate Hintze's (1982) proposal that the Ibexian Series should replace the fractionated and confusing Canadian Series as the lowest Ordovician Series for the United States. A lower boundary stratotype is defined and the Series is characterized by shelly fossil and conodont zones which illustrate the remarkable biostratigraphic control available for the Series in the type area. Four new stages (Skullrockian, Stairsian, Tulean, and Blackhillsian) are proposed 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 is to focus attention on the superb lithostratigraphic column in the Ibex area and to demonstrate the biostratigraphic excellence of the consolidated Ibexian stratigraphic succession.

The Ibexian has been used outside the United States more frequently than in some regions of the U.S., seemingly because its first publication (Hintze *in* Ross and others, 1982) was poorly distributed in the United States.

After 30 years of fostering cooperative work on the 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. The fruit of his enthusiastic guidance is the superb biostratigraphic documentation of the Ibexian section, unsurpassed by any other Lower Ordovician section in the

world. 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 Ibexian Series has been and continues to be used as the reference section for the Lower Ordovician in North America with a decreasing number of regional exceptions. Its acceptance 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 Stitt (1977, 1983) and Derby and others (1991) in Oklahoma, and by Westrop (1986) and Loch and others (1993) in Alberta, Canada.

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

Normally, field measurements were taken in feet and converted to meters. Both units are given in the report to help readers coordinate painted footages on the outcrops with 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 (Figures 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 at the south end of Blind Valley.

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 statotype of the Ibexian Series is defined as a point in rock in a measured section. Definition of the top of the Ibexian Series is the correlated base of the overlying Whiterockian Series which was defined in the Monitor Range of central Nevada by Ross and Ethington (1991). 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.

Descriptions of the physical and many of the paleontological attributes of the Ibexian Series presented here graphically (Plate I, part of Plate III) 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. The locations of maps (Figures 2-7) showing measured traverses along which features of lithologic units are most easily observed and from which fossils were collected are shown in Figure 1.

The detailed geology of the area that includes the type sections of the formations constituting the composite section of the type Ibexian Series 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 stratigraphic 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). An expected international agreement failed to materialize in 1982. In 1985, Rolf Ludvigsen and S. R. Westrop, tired at 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
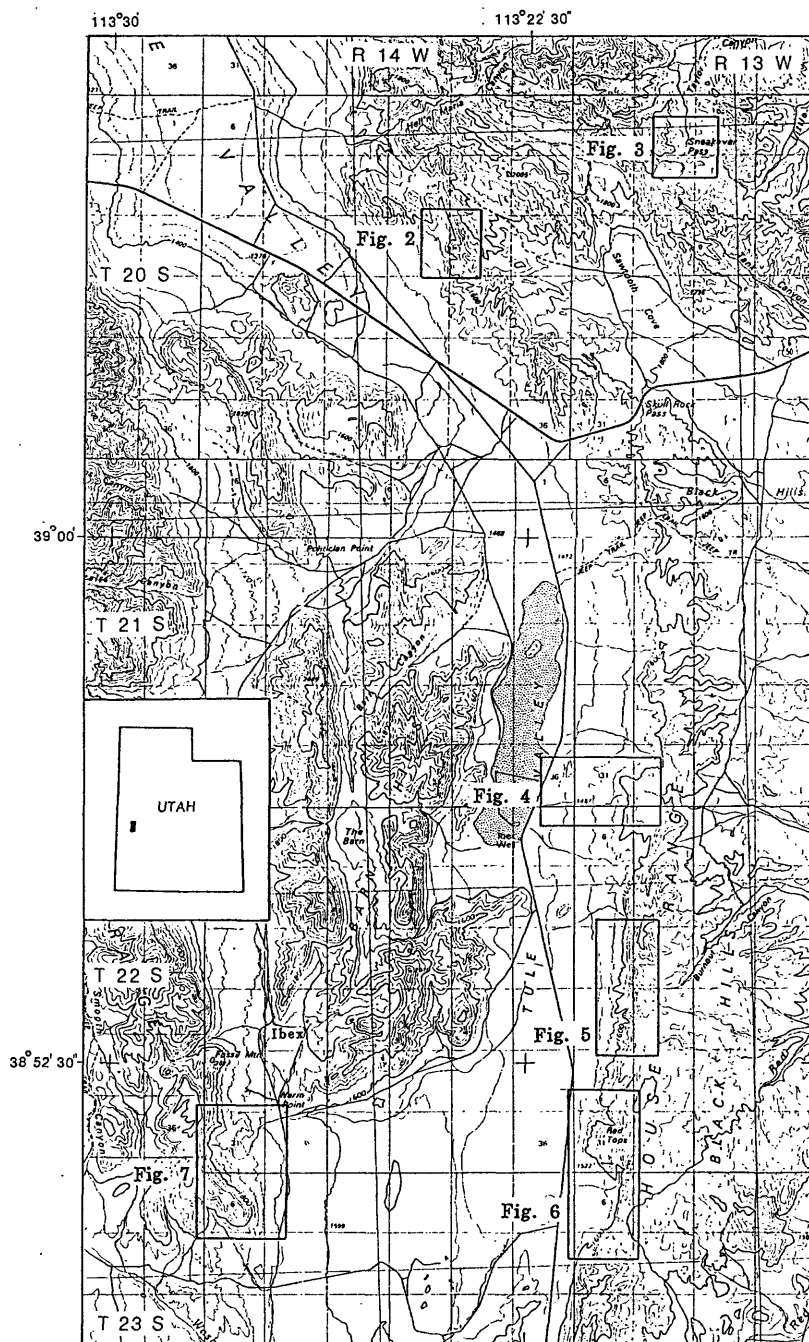
Figure 1. Index map of the Ibex area in western Utah showing the locations of the detailed maps in Figures 2-7. Inset map shows the location of this figure, in solid black, in the state of Utah. This map includes parts of the U.S. Geological Survey Tule Valley and Wah Wah Mountains North 1:100,000 scale topographic maps. The small squares on the map are about one square mile in area.

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 (Figure 9). In the definition of the Ibexian lower-boundary stratotype, we place emphasis on conodonts rather than trilobites because conodonts are more easily extracted from the rock and the conodont taxa tend to be more 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).

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 section of the Steamboat Pass-Lava Dam composite section of Hintze and others (1988, p. 23-24, fig, 9; this report, Figures 6, 8). 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, 1987, which locally defines the base of the *Hirsutodontus hirsutus* Subzone of the *Cordylodus proavus* Zone. This boundary stratotype point is approximately 0.1 m (4 in) below the lowest observed occurrence of trilobites assigned to the *Eurekia apopsis* Zone. 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 correlated base of the Whiterockian Series (Ross and Ethington, 1991) which corresponds to the base of *Tripodus laevis* Zone and coincidentally with the base of the *Paralenorthis-Orthidiella* Zone (= Zone L of Ross, 1951).

Herein, we follow recommendations outlined in the North American Stratigraphic Code (NACSN, 1983) and the International Commission on Stratigraphy (Cowie and 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 (Figures 9a, 9b), in the upper part of the Lava Dam Member of the Notch Peak Formation at the Lava Dam Five section (Figure 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 59.1 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 39.1 m (128.3 ft) is the thickness of part of the Lava Dam Member up to the boundary.

The Ibexian Series is here divided into four new stages which are, in ascending order, the Skullrockian, Stairsian, Tulean, and Blackhillsian Stages. Definitions and faunal characterizations of the new stages are given under appropriate headings below.

We summarize below, 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.

Figure 2. Geologic map showing the location of the A section of Hintze (1951, 1973). Symbols: OЄnl, Lava Dam Member of the Notch Peak Formation; Oh, House Limestone, the middle sandy zone of which is shown by a dashed line; Of, Fillmore Formation; Qa, surficial deposits. Heavy lines are faults with bar-and-ball on the downthrown side. Line of section indicated by inverted "Vs". Topographic base map is the U.S. Geological Survey 1:24,000 Hell'n Moriah Canyon provisional quadrangle, 1991. Geology from Hintze (1974b).

Figure 3. Geologic map showing the location of the Sneakover Pass (SnP) measured section of Hintze and others (1988). Symbols: Єnh, Hellnmaria Member of the Notch Peak Formation; Єnr, Red Tops Member of the Notch Peak Formation; OЄnl, Lava Dam Member of the Notch Peak Formation; Oh, House Limestone; Qa, surficial deposits. Heavy lines are faults with bar-and-ball on the downthrown side. Line of section indicated by inverted "Vs". Topographic base map is the U.S. Geological Survey 1:24,000 Skull Rock Pass provisional quadrangle. Geology from Hintze (1974b).

Figure 4. Geologic map showing the location of the Square Top measured section of Hintze (1973). Symbols: Of, Fillmore Formation; Ow, Wah Wah Limestone; Oe, Eureka Quartzite; Oes, Ely Springs Dolomite; Qa, surficial deposits; Qs, sand. Heavy lines are faults with bar-and-ball on the downthrown side. Line of section indicated by inverted "Vs". Topographic base map is the U.S. Geological Survey 1:24,000 Burnout Canyon provisional quadrangle, 1991. Geology from Hintze (1974a).

Figure 5. Geologic map showing the 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. Symbols: Oh, House Limestone; Of, Fillmore Formation with a key bed indicated by the dashed line; Tsr, Skull Rock Pass Conglomerate; Qa, surficial deposits. Lines of sections indicated by inverted "Vs". Topographic base map is the U.S. Geological Survey 1:24,000 Burnout Canyon provisional quadrangle, 1991. Geology from Hintze (1974a).

Figure 6. Geologic Map showing the location of the B section of Hintze (1951), the Lava Dam North (LDN) and Lava Dam Five (LD5) measured sections of Hintze (1973) and Hintze and others (1988). Symbols: Ꞓnr, Red Tops Member of the Notch Peak Formation; OꞒnI, Lava Dam Member of the Notch Peak Formation; Oh, House Limestone; Of, Fillmore Formation; Tv, Tertiary volcanic rocks; Qa, surficial deposits; Qs, sand. Heavy lines are faults, solid lines in bedrock, dotted lines where fault is concealed by surficial deposits, bar-and-ball on the downthrown side. 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). Topographic base map is the U.S. Geological Survey 1:24,000 Red Tops provisional quadrangle, 1991. Geology from Hintze (1974a) and Hintze and others (1988).

Figure 7. Geologic map showing the 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. Symbols: Of, Fillmore Formation, with the dashed lines showing key beds; Ow, Wah Wah Limestone; Oj, Juab Limestone; Ok, Kanosh Shale; Ou, undivided Middle and Upper Ordovician rocks that are considerably faulted; Tv, Tertiary volcanic rocks; Qa, surficial deposits; Qs, sand. Heavy lines are faults, dotted where covered by surficial deposits, with bar-and-ball on the downthrown side. Lines of section are indicated by inverted "Vs". Topographic base map is the U.S. Geological Survey 1:24,000 Warm Point provisional quadrangle, 1991. Geology from Hintze (1974a).

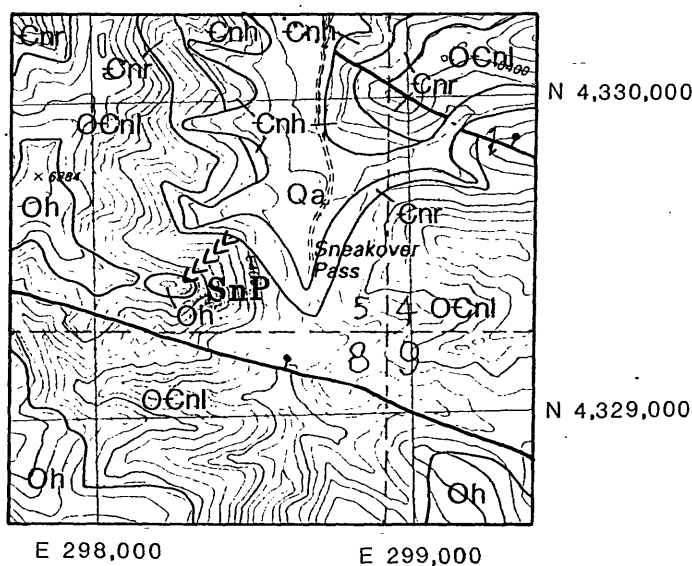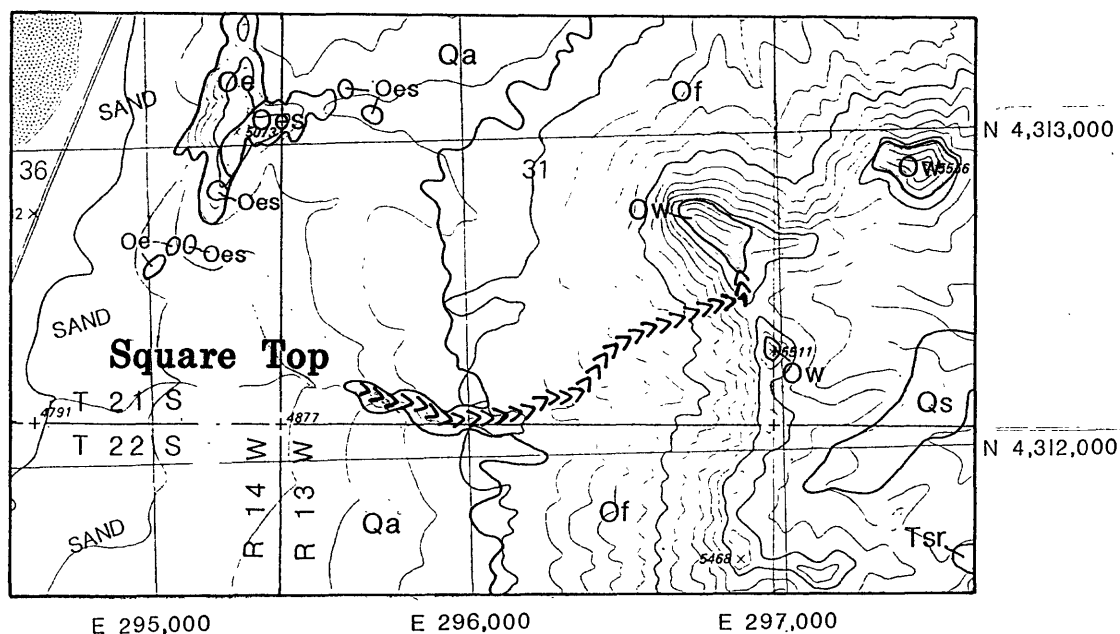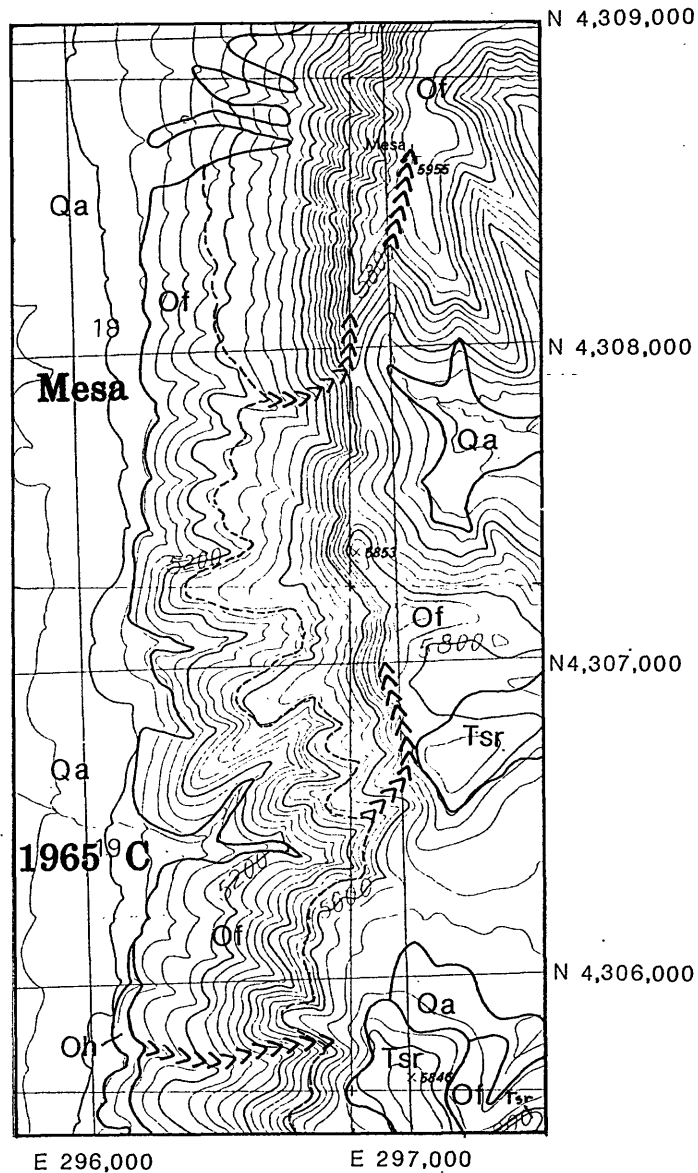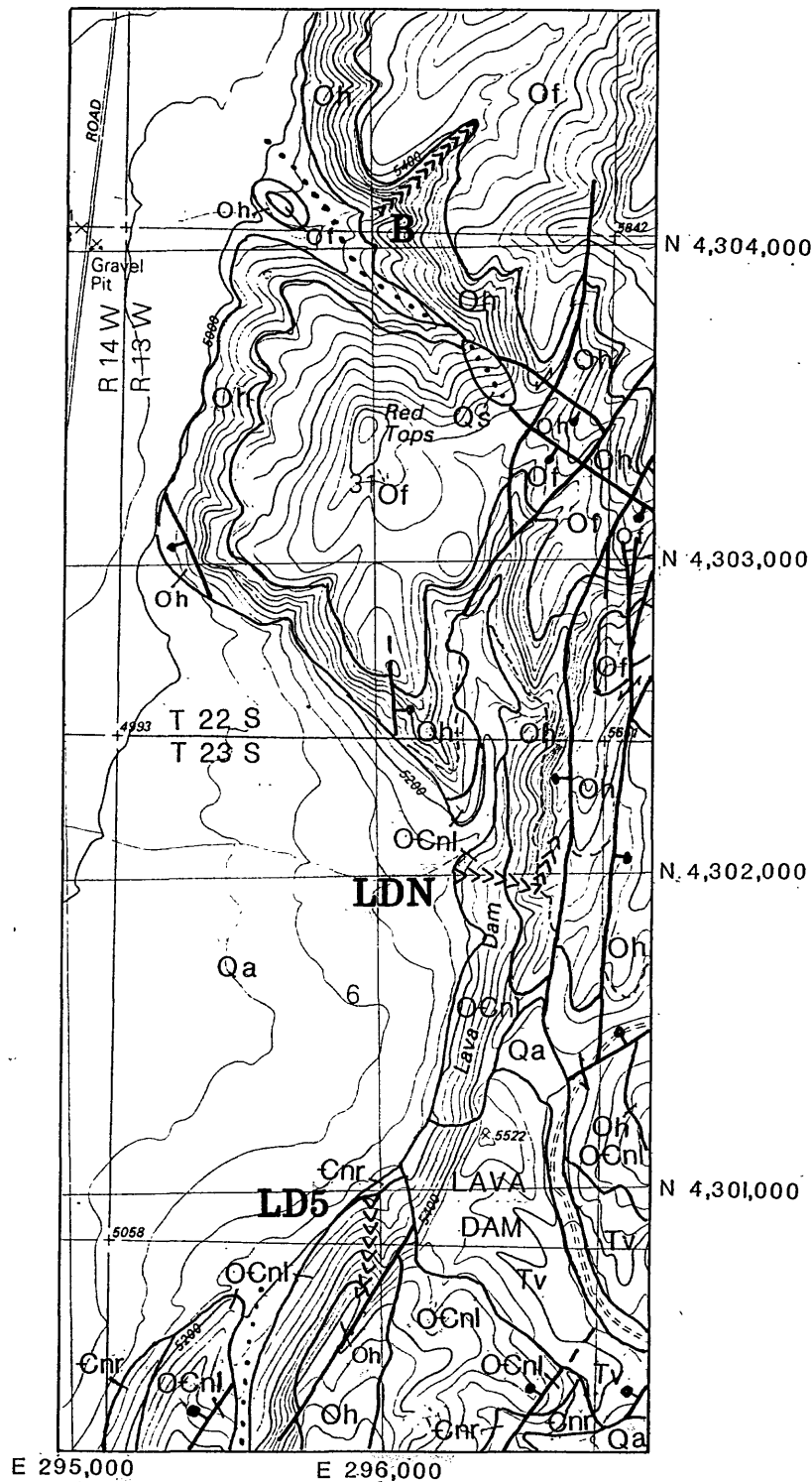## LITHOSTRATIGRAPHY

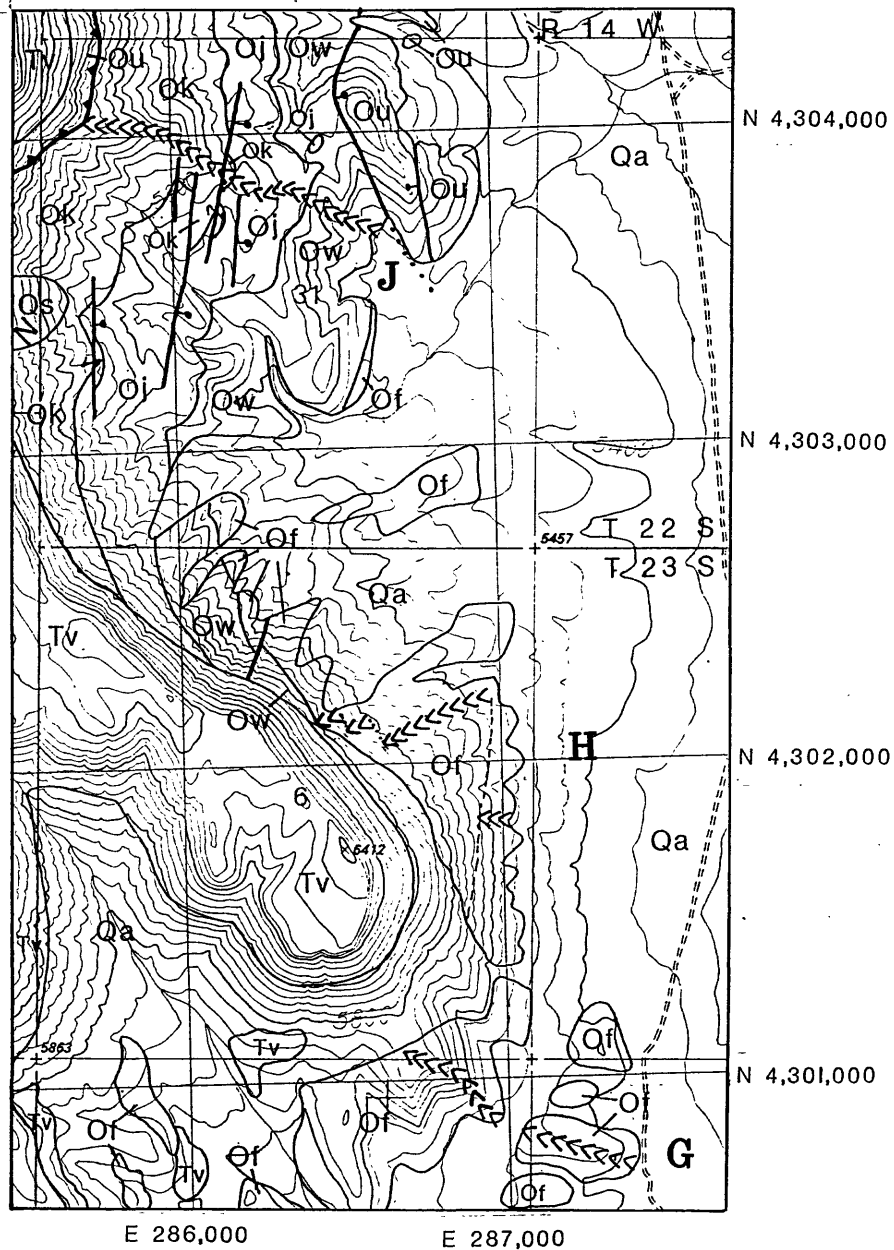The stratotype section of the Ibexian Series is a composite section comprised of part of the Lava Dam Member of the Notch Peak Formation, all of the House Limestone and Fillmore Formation, and part of the Wah Wah Limestone. The House, Fillmore, and Wah Wah, which are the lower part of the Pogonip Group,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

SEGMENT	BOTTOM	TOP
Lava Dam Five	E295,950m;N4,300,980m	E295,910m;N4,300,770m
Lava Dam North	E296,230m;N4,302,000m	E296,560m;N4,302,120m
A (1951)	E292,320m;N4,326,980m	E292,570m;N4,326,910m
B (1951)	E296,060m;N4,304,150m	E296,330m;N4,304,400m
Sneakover Pass	E298,440m;N4,329,580m	E298,250m;N4,329,450m
Square Top	E295,600m;N4,312,230m	E295,870m;N4,312,540m
Mesa (lower)	E296,600m;N4,307,850m	E296,860m;N4,308,100m
Mesa (upper)	E297,100m;N4,308,320m	E297,040m;N4,308,600m
1965-C (lower)	E296,160m;N4,305,800m	E296,760m;N4,305,800m
1965-C (upper)	E296,880m;N4,306,500m	E296,950m;N4,307,000m
G	E287,400m;N4,300,720m	E287,680m;N4,301,080m
H (lower)	E287,200m;N4,301,800m	E286,900m;N4,301,070m
H (middle)	E286,960m;N4,302,220m	E286,600m;N4,302,130m
H (upper)	E286,590m;N4,302,130m	E286,400m;N4,302,150m
J	E286,640m;N4,303,670m	E285,700m;N4,304,060m

Table 1. Universal Transverse Mercator 1,000 m grid coordinates, Zone 12, are listed for bottoms and tops of constituent segments of the Ibexian Series composite stratotype section. Map locations are shown in Figures 1-7.

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 was 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, even though 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 section of the Steamboat Pass-Lava Dam composite section (Hintze and others, 1988, p. 23-26).

The Lava Dam Five section of the Steamboat Pass-Lava Dam composite 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; Figure 6, index map). 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

18
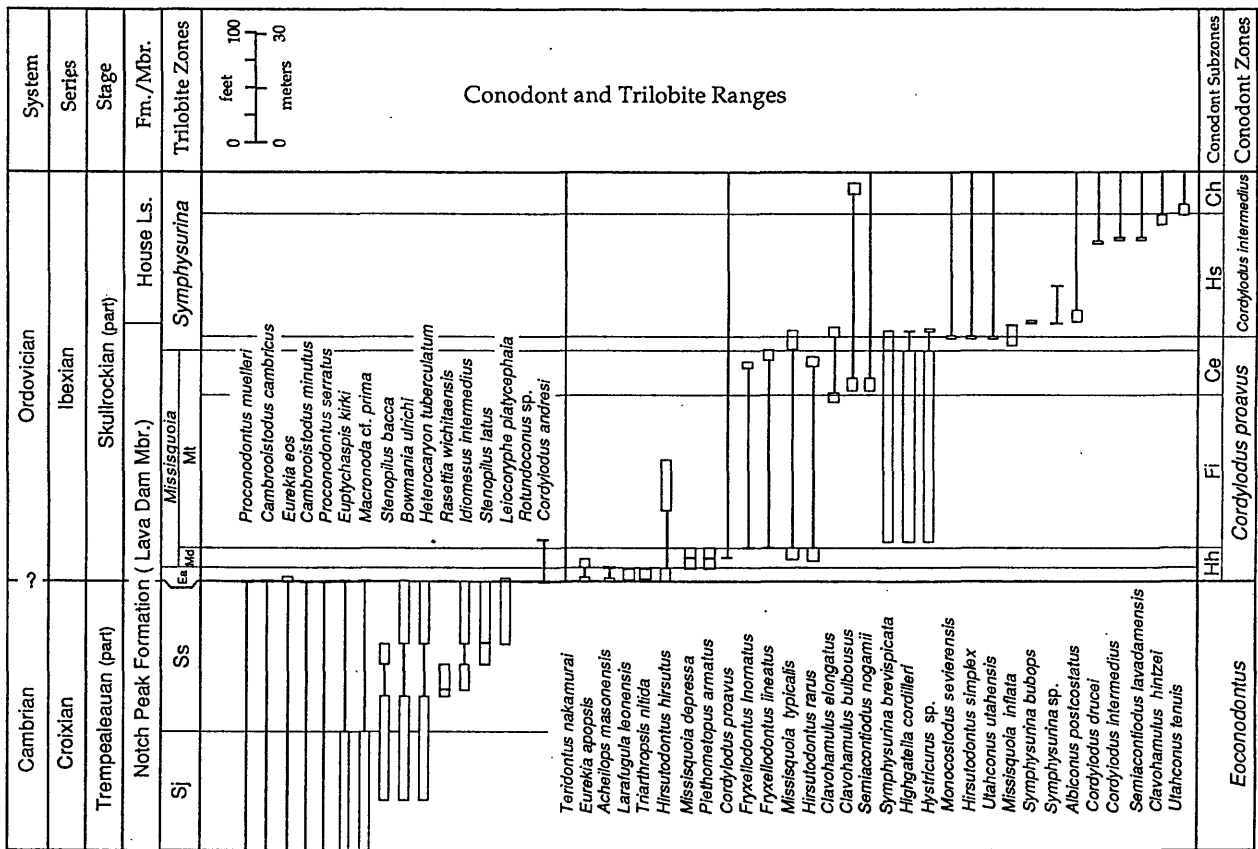
Figure 8. Ranges of selected trilobites and conodonts at the lower boundary stratotype of the Ibexian Series in the Lava Dam Five segment of the Steamboat Pass-Lava Dam section of Hintze and others (1988). The lowest observed occurrence of Cordylodus andresi coincides with the stratigraphic level the 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 semi-quantitative (non-probabilistic) estimate of how well established are lowest and highest occurrences of a species as suggested by occurrence/non-occurrence in subjacent and superjacent fossil-bearing samples. Abbreviations: 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.

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 a trilobite fauna assigned to the *Saukiella junia* Subzone of the *Saukia* Zone (Taylor, 1971; Taylor *in* Hintze and others, 1988, pl. 1).

Lava Dam Member

The type locality of the Lava Dam Member is at Sneakover Pass 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).

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. The member normally 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 is 156.9 m (515 ft) thick. 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 off-set 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 below 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 which 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.

9a

9b

Figure 9. Photographs of the Lava Dam Five section (LD5), southern House Range, Utah. 9a, 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 Plates I, II, and III 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 of 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. View from the north. See Figure 6 for location of traverse. 9b, Close-up 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 Figure 9a (position 4). Photographs by J.F. Miller.

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 member and that the section is offset 0.8 km (0.5 mi) to the north (see Figure 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.

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 (4)

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.

Calathium Calcisiltite Member (5)

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 76.2 m (250 ft) thick, but only the lower 70.1 m (230 ft) is Ibexian in age. The upper 6.1 m (20 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 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 the two points are isochronous. In this practice, emphasis is placed on boundaries rather than content of conodont interval zones. The interval-zone method of correlation alone 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 (Figure 10). The result is a biostratigraphic classification scheme that includes zones which are: 1) defined by the lowest observed occurrence of a particular taxon; and 2) characterized by faunal assemblages with species that lived under different paleoecologic requirements and 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 section of the Steamboat Pass-Lava Dam composite section of Hintze and others (1988, fig. 8; this report Fig. 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. Chronostratigraphic nomenclature of the pre-Ibexian rocks in the Great Basin is discussed in detail by M.E. Taylor (1994, in preparation).

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) (Table II). Conodont species present include *Cambrooistodus cambricus, Cambrooistodus minutus, Eoconodontus notchpeakensis, Phakelodus elongatus, Proconodontus muelleri, Proconodontus serratus,* and *Prosagittodontus eureka*; all of which terminate abruptly at the lower boundary of the Ibexian Series. Other conodonts that range across the lower boundary of the

System Series	Stage	Formation	Shelly Fossil Zones (this report)		Conodont Zones (this report)		Shelly Fossil Zones N. Utah - SE. Idaho Ross (1951, 1968)	W. Utah Hintze (1953)	Conodont Faunas W. Utah Ethington & Clark (1971)
White-rockian Series	Rangerian	Wah Wah Fm.	PO	Paralenorthis-Orthidiella	Tl	Tripodus laevis	L / K	L	
Lower Ordovician Ibexian Series	Blackhillsian	Fillmore Formation	Hm	Hesperonomiella minor	Ra	Reutterodus andinus	J	"K"	E
			Pn	Pseudocybele nasuta				J	
			Pi	Presbynileus ibexensis			I	I	
			Tt	Trigonocerca typica	Oc	Oepikodus communis	H	H	
	Tulean		Pc	Protopliomerella contracta			G-2	G-2	
			Hc	Hintzeia celsaora	AO	Acodus deltatus - Oneotodus costatus	G-1	G-1	D
	Stairsian		Rs	Rossaspis superciliosa	Md	Macerodus dianae	F	F	
			Te	Tesselacauda			E	E	
			LK	Leiostegium-Kainella	LD	"Low diversity interval"	D	D	
	Skullrockian	House Ls.	Pa	Paraplethopeltis	Rm	Rossodus manitouensis	C	C	C
			BX	Bellefontia-Xenostegium	Ca	Cordylodus angulatus	A + B		
					Ia	Iapetognathus n. sp.		B	B
			Sy	Symphysurina	Cl	Cordylodus lindstromi			
		Notch Peak Formation	Mi	Missisquoia	Ci	Cordylodus intermedius			A
			Ea	Eurekia apopsis	Cp	Cordylodus proavus	Not Studied	Not Studied	
Up. Ꞓ Croixian Series	Tremp.		Ss	Saukiella serotina	Eo	Eoconodontus			Not Studied
			Sj	Saukiella junia					

Figure 10. New stages of the Ibexian Series showing the shelly fossil and conodont zones upon 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).

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.

The silicified trilobite fauna of the type Ibexian was 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 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 cephalopod taxa 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 D by James Sprinkle and T. E. Guensburg, and shown in Plate III.

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 below in a section entitled "Historical Perspectives."

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: E297,380m; N4,322,800m), 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, 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 Croxian 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 (Plate I, Figure 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.

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 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).

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 recognized 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.

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 occurrence of *Symphysurina brevispicata* Hintze and *Highgatella cordilleri* (Lochman). The overlying *Symphysurina bulbosa* Subzone is defined by the lowest 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].

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 underlying St. Charles Formations. 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. Possible reasons for this are the sparsity of fossil collections and presence of a massive limestone cliff 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 (Plate I), 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:
> *Hystricuris 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)

Stitt (1983, p. 13-15) named the *Bellefontia-Xenostegium* Zone for 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 lower boundary of the *Bellefontia-Xenostegium* Zone occurs 26.5 m (87 ft) below the top of House Limestone in the B section of Hintze (1951).

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, 29) found a 30-ft-thick interval in the Garden City Formation that lacks distinctive fossils. Hintze (1953, p. 8) discovered forms by which this thin interval might be correlated. However, the range chart in Plate I suggests that this is a transitional zone that includes forms from the top 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 0.9-m- (3-ft-) thick bed located 5.5 to 6.4 m (18 to 21 ft) below the top of the House Limestone in the B section of Hintze (1951, p. 34). This horizon is approximately 228 m (748 ft) above the base of the composite section (pl. I).

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

Trilobites:
      Hystricurus genalatus Ross
      Hystricurus? sp. I of Ross
      Pachycranium? sp. of Ross
      Paraplethopeltis genacurvus Hintze
      Paraplethopeltis genarectus Hintze
      Symphysurina sp. B of Ross (1951)

Brachiopod:
      Syntrophina cf. *S. campbelli* (Walcott)

Stairsian Stage (new)

The lower boundary stratotype for the Stairsian Stage is in a 4.6 m (15 ft) thick, thickly bedded, finely grained ledge-forming limestone 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 coincide 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: E297,000m; N4,322,200m). 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 above, the base of the *Leiostegium-Kainella* Zone is in a 4.6-m- (15-ft-) thick limestone unit 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 0.9 m (3 ft) below the top of the House Limestone. Therefore, the boundary is no higher than 232.6 m (763 ft) above the base of the composite section (Pl. I).

The base of the *Leiostegium-Kainella* Zone is defined above, under "Stairsian Stage." On Plates I-III, the *Leiostegium-Kainella* Zone is indicated by the letters LK. In the typical reference section of the Starsian 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 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 (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 the lower 3.0 m (10 ft) of unit 24 of the informal ledge forming limestone member of the Fillmore Formation in the 1965-C section of Hintze (1973, p. 18). This horizon is 115.8-118.9 m (380-390 ft) above the base of the Fillmore and approximately 349.9 m (1,145 ft) above the base of the composite section (pl. I).

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
  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*.

Stait and others (1984) reported *Rossaspis bunopasi* from the Tarutao Formation of Southern Thailand, 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 of the Fillmore Formation. This horizon is equivalent to 53 m (174 ft) above the lowest exposure of the Fillmore Formation in the G section of Hintze (1973, p. 25). The level is 121 m (398 ft) above the base of the Fillmore Formation in the 1965-C section of Hintze (1973) and approximately 355 m (1,164 ft) above the base of the composite section (pl. I).

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. 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 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 402 m (1,319 ft) above the base of the composite section.

We expect additional studies will require that the base of the stage be moved 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 together 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 Willston 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:
> *Rhabdopora* 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 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. The base of the zone is approximately 480 m (1,574 ft) above the base of the composite section (pl. I).

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 have given 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.
Rhabdopora 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 lower Paleozoic carbonate rocks 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 of the Fillmore Formation. This level is 659.6 m (2,164 ft) above the bottom of the composite section (pl. I).

Trigonocerca typica Zone (= Zone H)

As mentioned above, the *Trigonocerca typica* Zone of Hintze occurs 5.8 m (19 ft) above the base of unit 2 of the informal calcarenite member 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 Hintze (1953, p. 16) the work 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 often be recovered 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 of the Fillmore Formation in the H section of Hintze (1973, p. 25). The level is approximately 719 m (2,360 ft) above the base of the composite section (pl. I).

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 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 772 m (2,534 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 at 65.5 m (215 ft) above the base of unit

20 of the Wah Wah Limestone in the J section of Hintze (1973, p. 29). The level is 844.9 m (2,770 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* 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 (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 a distinct zone in the first place.

WHITEROCKIAN SERIES

The Whiterockian, originally proposed as a Stage by Cooper (1956), was redefined as a Series by Ross and Ethington (1991) in the Monitor Range, central Nevada. The correlated 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, 1992, fig. 4A) in the upper Paiute Ridge and Ranger Mountain Members of the Antelope Valley Limestone in the northern Ranger Mountains, Nevada, from which it takes its name. It is succeeded by the Kanoshian Stage represented by faunas of Zones M and N, and by the Chazyan Stage (Zone O). In the Ibex area Zone L is present in the highest 20 feet of the Wah Wah Limestone, throughout the Juab Limestone and in the lowermost limestone beds of the Kanosh Shale.

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).

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

Echinodermata:
    Blastoidocrinus? sp.

Ibexian 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.

A sample of no more than several hundred grams of rock 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 taxa introduced in the Ibex sections. Although this sequence of taxa 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 were characterized by loosely defined faunal associations. Subsequent work in other parts of North America has demonstrated that many taxa 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. Several major studies of Lower Ordovician conodonts are in press or in preparation, and further revisions of nomenclature can be expected. However, the purpose of this paper 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 taxa that are more provincial in their distribution. Strata of the succeeding Stairsian, Tulean, and Blackhillsian stages contain conodont taxa 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 is more difficult. As is

noted below, some species in these younger strata also 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 in Plates I and II, and Figure 10.

Pre-Ibexian Conodont Zones

The conodont biostratigraphy of the 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 all coniform taxa. Uppermost strata of the Trempealeauan Stage (upper part of 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*, taxa 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 a mass extinction 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 II, but the thickness of the *Cambrooistodus minutus* Subzone is 44.8 m (147 ft).

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 coniform taxa 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 (Figure 9b). 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 coniform species, 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 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

coniform taxa, including *Albiconus postcostatus, Hirsutodontus simplex, Monocostodus sevierensis, Semiacontiodus lavadamensis*, and *Utahconus utahensis*. The upper, the *Clavohamulus hintzei* Subzone, 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 cordylodid and coniform taxa 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 coniform species from the underlying *Cordylodus intermedius* Zone continue into this 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 cordylodid 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 coniform species 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 House Limestone north of Skull Rock Pass, central House Range (J.F. Miller and M.E. Taylor, unpubl. data). The same association has been recognized in the Drum Mountains, Utah, in central Texas (Stitt and Miller, 1987; Miller and others, 1990), and in the Rocky Mountains of Canada (Norford, 1969: Westrop and others, 1981). *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). 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 coniform taxa. This zone is characterized by *Cordylodus angulatus* Pander and many taxa from underlying strata that continue into this zone, such as *Cordylodus lindstromi* (see further, pl. I).

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 taxa as conodont 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 *Rossodus manitouensis* Zone fauna, which flourished during deposition of the upper half of the House Limestone, disappears abruptly at the top of that formation. It is replaced in the lower part of the Fillmore 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 North American Cambrian. 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.

The horizon of this event is essentially at the top of the trilobite *Paraplethopeltis* Zone and at the boundary between the House and Fillmore Formations. It marks the top of the Skullrockian Stage defined herein.

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 *Glyptoconus 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 which thus depends upon the trilobites and brachiopods of the *Leiostegium-Kainella* Zone for definition of its lower boundary and characterization of its lowermost zone. The conodont Low Diversity Interval encompasses the *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 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*, 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 Stage, 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, unpubl. data) and in the El Paso Group of West Texas (Repetski, 1982). These widely separated geographic occurrences with consistent biostratigraphic position relative to faunas above and beneath justify recognition of a *Macerodus dianae* Zone.

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. A species similar to, if not conspecific with, *Acodus emanuelensis* McTavish joins it at 167 m (530 ft), and *Oneotodus costatus* Ethington and Brand is introduced to the section at 189 m (600 ft). 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 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 taxon 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 and above a thick interval in the middle and upper Cool Creek Formation with faunas of the *Macerodus dianae* Zone (R.L. Ethington, unpublished 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 conodont paleogeography 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 the 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 part 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 30.5 m (100 ft) below the top of the informal brown slope and ledge member of the Fillmore Formation through the lower 56.4 m (185 ft) of the Wah Wah Limestone, an interval of 271 m (890 ft) of strata. 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 71.6 m (235 ft) below the top of the Fillmore Formation. This interval is approximately 146.3 m (480 ft) thick, encompassing the upper 68.3 m (224 ft) of the informal brown slope and ledge-forming member of the Fillmore and the lower 77.7 m (255 ft) of the informal calcarenite member. The boundary between shelly fossil zones *Protopliomerella contracta* and *Trigonocerca typica* is below the middle of this conodont zone in the type Ibexian, as is the boundary between the Tulean and Blackhillsian Stages.

Reutterodus andinus Zone [new] (= Fauna E, middle part)

Reutterodus andinus was reported by Serpagli (1974) from the San Juan Limestone in Precordilleran Argentina. It is widely distributed in collections of conodonts from the upper Ibexian in the Great Basin, and Repetski (1982) recorded its presence in the El Paso Group. This species 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 correlation using these species. The base of the zone in the type Ibexian is at the lowest occurrence of *Reutterodus andinus* at 71.6 m (235 ft) below the top of the Fillmore Formation. The zone comprises all strata from that horizon through the lower 72 m (237 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 4.4 m (14 ft) above the distinctive brachiopod coquina of the *Hespernomiella minor* Zone of Hintze (1953, p. 19).

As now understood, the *Reutterodus andinus* Zone begins near the top of the *Trigonocerca typica* Zone and includes all of the *Presbynileus ibexensis, Pseudocybele nasuta*, and *Hesperonomiella minor* Zones. It contains all but the lowest part of the Blackhillsian Stage.

Jumudontus and *Protoprioniodus* are abundant in coeval Australian faunas from the Horn Valley Siltstone, and a few specimens representing these genera are known from the Baltic region. *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 hyaline taxa. This association of taxa 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 suggested an assignment of the upper Wah Wah and Juab 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 lower Whiterockian.

In the type area of the Ibexian Series, *Tripodus laevis* Bradshaw is present and abundant in the upper 6.3 m (20 ft) of the Wah Wah Limestone and through the overlying Juab. It is associated through this range with *Protoprionoidus 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 Monitor Range (Ross and Ethington, 1991) and in numerous samples from the Vinini Formation 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, 6.3 m (20 ft) below the top of the Wah Wah Limestone, and 4.4 m (14 ft) above the *Hesperonomiella minor* shell bed.

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 (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 is expanded below.

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, which emphasizes biostratigraphy over pure tradition.

Alternative Viewpoints

From the 1930's into the 1950's the section in the Ozark region of Missouri and Arkansas served as the type of the "Canadian Series". 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 "Canadian Series" in the Ozark region are:

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

The Canadian 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 intra-regional correlation, let alone as an inter-regional standard.

In a paper on ellesmeroceratid cephalopods, Flower (1964) recommended that the Canadian 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 Ft. 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 Demigian. In any case, it was and is impossible to determine where one of those stages left off and the next began 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 communication to RJR, March 7, 1989) sees 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).

GEOGRAPHICAL 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 and others (1981) demonstrated that a hiatus representing the lower part of the *Symphysurina* Zone is present between the Garden City Formation and underlying St. Charles Dolomite. Additionally, they also 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 Dolomite.

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 be more or less continuous. A similar trilobite-conodont succession is present in the Egan Range, east-central Nevada (Taylor and others, 1981, fig. 20; Taylor and others, 1989, p. 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 and Cook, 1976; Cook and Taylor, 1977; Miller, 1992; J.E. Repetski and M.E. Taylor, unpubl. data for Antelope Range, Nevada).

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 where 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, Lane, and Norford, 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* occurred 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 situ strata 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).

Appalachian Province

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 Ibexian Series 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 trilobite *Elkanaspis corrugata* Zone and to be immediately underlain by the 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 China (Lu and Lin, 1980, 1984), and northwestern China (Wang and others, 1985). As noted below, both Apollonov (1991, p. 34-43) and Dubinina (1991, p. 117, 121) support these observations in Kazakhstan.

J.F. Taylor and others (1991) demonstrated 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 a different 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, unpublished 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) 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 identified 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 Dolomite to Garden City Formation in central and northern Utah and southeastern Idaho (M.E. Taylor and others, 1981; M.E. 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.

Southern Midcontinental U.S.

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) named the Jeffersonian Stage of the Canadian Series for dolomitic rocks and chert-mold fossils in the Jefferson City Formation of Missouri. Loch (1993, p. A-53) 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 (1993) are further evidence that the Ibexian Series and its stage divisions are recognizable in different facies of Laurentia and the North American faunal province.

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. But, 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 comprised mainly of 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 U.S. 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 and Wah Wah formations.

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 (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).

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 Formation 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 above as uppermost Ibexian, not necessarily Whiterockian.

Australia

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 (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, of which that of *Hirsutodontus hirsutus* is 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), *Hirsutodontus simplex* Subzone below and the *Clavohamulus hintzei* Subzone above.

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 582-632 m (1,852-2,011 ft) above the base of 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) show 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 peculiar plotting of FAD *Cordylodus proavus* some 40 m (127 ft) higher is 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) repeat and emphasize 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, unpubl. 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 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 (discussed above).

Subsequent collecting at Batyrbai, southern Kazakhstan by J.F. Miller (unpubl. data, 1990), suggests a sight overlap of ranges of *Lotagnostus hedini* and *Cordylodus primitivus* (= *Cordylodus andresi*, this report), as reported by Apollonov and others (1988). However, the interval of overlap is in a 1.5-2.0-m-thick debris-flow bed that occurs immediately above the lowest observed occurrence of *Cordylodus*. The overlap in ranges may be a result of fossil mixing during deposition of the debris-flow bed.

Jilin Province, China

Chen and others (1985, 1988) and Chen (1986) documented ranges of conodonts and other fossils from a section near Dayangcha in northeast China. Their figure 6 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 rejected 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 10.0-28.5 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, unpubl. 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 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, unpubl. 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. Some of the more important products 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, n. 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 by its abundantly fossiliferous and exceptionally well-exposed typical reference section in the southern House and Confusions Ranges of west-central Utah, provides an unrivalled 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 section of the Ibexian Series is a standard reference section for precise biochronologic correlation over the entire span of Early Ordovician time. The standard is a high-resolution biostratigraphy comprised of 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, 1993) 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 most useful lower Paleozoic horizons for global correlation (Miller and others, 1993).

The upper limit of the Ibexian Series is the correlated 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 this Ibexian typical reference section in excellence of exposure, abundance of fossils, quality of fossil preservation, and accessibility.

ACKNOWLEDGMENTS

APPENDIXES A-C: 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 D.

Appendix A: 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 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.

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 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.

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.

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.

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 formosum Hintze, 1953, p. 189-190, pl. VIII, figs. 8-10.

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.

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.

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, figs. 6-. 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.

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.

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.

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.

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 piochensis Hintze, 1953, p. 238, pl. XI, figs. 12-18.

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

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

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 B: Conodonta

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

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

"Acontiodus" propinquus Furnish, 1938, p. 326, pl. 42, figs. 13-15; Ethington and Clark, 1981, p. 24, pl. 1, fig. 26.

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

Acodus? sp. 2 Ethington and Clark, 1981, p. 21, fig. 7, pl. 1, figs. 19, 20.

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

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

aff. *Acodus gladiatus* Lindstrom, 1955. Ethington and Clark, 1981, p. 20, Pl. 1, fig. 14.

aff. *Acodus*? *emanuelensis* McTavish, 1973. Ethington and Clark, 1981, p. 19, 20, fig. 5, pl. 1, figs. 9-13.

Acodus deltatus Lindström, 1955. Ethington and Clark, 1981, p. 18, 19, fig. 4, pl. 1, figs. 1-6.

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

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

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

?*Cordylodus caseyi* Druce and Jones, 1971. Ethington and Clark, 1981, p. 31- 32, pl. 2, fig. 25.

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

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

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. 7-18.

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

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

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

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

Cordylodus intermedius Furnish, 1938. Ethington and Clark, 1981, p. 32, pl. 2, fig. 17(?). Miller, 1980, p. 17, Fig. 4L, pl. 1, fig. 16.

Cordylodus lindstromi Druce and Jones, 1971. Miller, 1980, p. 18, Fig. 4I, J, pl. 1, figs. 18, 19.

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

Cordylodus prion Lindström, 1955. Ethington and Clark, 1981, p. 33, pl. 2, figs. 13, 14.

Cordylodus proavus Müller, 1959. Miller, 1969, p. 424, pl. 65, figs. 37-46. Miller, 1980, p. 19, 20, Fig. 4G, H, pl. 1, figs 14, 15.

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

"*Drepanodus*" *simplex* Branson and Mehl *sensu* Druce and Jones, 1971. Ethington and Clark, 1981, p. 39, pl. 3, fig. 9.

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

aff. *Drepanoistodus forceps* (Lindström, 1955). Ethington and Clark, 1981, p. 43, fig. 13, pl. 3, figs. 22-24.

Drepanodus arcuatus Pander. Ethington and Clark, 1981, p. 36, 37, pl. 3, figs. 4-6, 12.

Drepanodus gracilis (Branson and Mehl) s.f. *sensu* Lindström, 1955. Ethington and Clark, 1981, p. 37, 38, fig. 10, pl. 3, fig. 7.

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

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

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

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

Eucharodus toomeyi (Ethington and Clark, 1964). Ethington and Clark, 1981, p. 39-40, pl. 3, fig. 11.

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. For example, Müller and Hinz, 1991, p. 16-25.

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

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.

Histiodella altifrons Harris, 1962, p. 208, 209, pl. 1, figs. 4a-c. Ethington and Clark, 1981, p. 46, 47, 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.

Iapetognathus Landing, 1982 *in* Fortey and others (1982).

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. 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.

Loxodus bransoni Furnish, 1938. 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, fig. 14, pl. 5, fig. 16.

Milaculum reticulatum Ethington and Clark, 1981, p. 121, pl. 14, figs. 14-17.

Milaculum spinoreticulatum Ethington and Clark, 1981, p. 122, pl. 14, figs. 10, 11.

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

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

New Genus 2 of Ethington and Clark, 1981, p. 117, pl. 13, figs. 18-20, 24.

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

Oepikodus? *minutus* (McTavish, 1973). Ethington and Clark, 1981, p. 62-65, pl. 6, figs. 19, 23, 24, 26-28.

"Oistodus" hunickeni Serpagli, 1974. Ethington and Clark, 1981, p. 67, pl. 7, fig. 8.

"Oistodus" inaequalis Pander, 1856. Ethington and Clark, 1981, p. 67, 68, fig. 15, pl. 7, fig. 7.

"Oistodus" sp. 2 Ethington and Clark, 1981, p. 71, fig. 18, pl. 8, fig. 1.

"Oistodus" sp. 3 Ethington and Clark, 1981, p. 72, pl. 8, fig. 2.

"Oistodus" sp. 5 s.f. Ethington and Clark, 1981, p. 72, pl. 8, fig. 8.

"Oistodus" sp. 6 s.f. Ethington and Clark, 1981, p. 72, 73, pl. 8, fig. 4.

"Oistodus" triangularis Furnish, 1938, p. 330-331, pl. 42, fig. 22. Ethington and Clark, 1981, p. 70-71, pl. 7, figs, 15, 18, 22, 23.

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

Oistodus multicorrugatus Harris, 1962. Ethington and Clark, 1981, p. 68-70, fig. 17, pl. 7, figs. 9, 10, 12-14.

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

Oneotodus costatus Ethington and Brand, 1981, p. 242-245, text-figs. 1B, D, G, H, 2A, D-M.

"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.

aff. *Paltodus? jemtlandicus* Löfgren. Ethington and Clark, 1981, p. 75, fig. 19, pl. 8, fig. 10.

aff. *Protopanderodus arcuatus* (Lindström, 1955). Ethington and Clark, 1981, p. 83, pl. 9, fig. 10.

Parapanderodus striatus (Graves and Ellison, 1941). Ethington and Clark, 1981, p. 100, 101, pl. 11, figs. 27, 28.

Paroistodus parallelus (Pander, 1856). Ethington and Clark, 1981, p. 79, pl. 9, fig. 1.

Phakelodus elongatus (An) in An and others, 1983, p. 125, pl. 5, figs. 4, 5. Müller and Hinz, 1991, p. 32, pl. 1, figs. 1-5, 7-9, 12-14, 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, Text-fig. 22c, d, pl. 9, figs. 10a-13b.

Prosagittodontus eureka (Müller, 1959), p. 461, pl. 14, fig. 6. Miller, 1969, pl. 65, figs. 32, 33.

Protopanderodus elongatus Serpagli, 1974, p. 73-76, 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. 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, p. 27, figs. 12-16. Ethington and Clark, 1981, p. 85, pl. 9, figs. 18, 22, 23.

Protopanderodus? *asymmetricus* Barnes and Poplawski, 1973. Ethington and Clark, 1981, p. 83, 83, pl. 9, figs. 11, 12, 14, 19.

Protoprioniodus aranda Cooper, 1981, p. 175, 176, pl. 30, figs. 1, 6, 7, 10, 12. Ethington and Clark, 1981, p. 86, 87, pl. 9. 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. Ethington and Clark, 1981, p. 91, pl. 10, fig. 18.

Reutterodus borealis Repetski, 1982, p. 41, 42, pl. 19, figs. 4-7.

Rossodus manitouensis Repetski and Ethington, 1983, p. 289-301, figs. 1-4.

Rotundoconus An and Zhang in An and others, 1983. For example, Chen and Gong in Chen, 1986, p. 172, pl. 28, fig. 2.

"Scandodus" robustus Serpagli, 1974, p. 69, pl. 18, figs. 3, 4, pl. 28, figs. 12, 13. Ethington and Clark, 1981, p. 94, pl. 10, figs. 25-27.

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

"Scandodus" sp. 2 s.f. Ethington and Clark, 1981, p. 97, fig. 23, pl. 11, figs. 8, 9.

"Scandodus" sp. 3 s.f. Ethington and Clark, 1981, p. 97, 98, fig. 24, pl. 11, fig. 10.

"Scandodus" sp. 5 s.f. Ethington and Clark, 1981, p. 98, pl. 11, fig. 12.

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

"Scolopodus" emarginatus Barnes and Tuke, 1970. Ethington and Clark, 1981, p. 99, 100, pl. 11, figs. 15, 16.

"Scolopodus" filosus Ethington and Clark, 1964, p. 699, pl. 114, figs. 12, 17-19, text-fig. 2E. Ethington and Clark, 1981, p. 100, pl. 11, fig. 22.

aff. *"Scandodus"flexuosus* Barnes and Poplawski. Ethington and Clark, 1981, p. 93, 94, fig. 21, pl. 10, figs. 20-22.

aff. *Scolopodus rex* Lindström, 1955. Ethington and Clark, 1981, p. 104, 105, pl. 12, figs. 1, 2.

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

Scolopodus cornutiformis Branson and Mehl, 1933, p. 62, pl. 4, fig. 23. Ethington and Clark, 1981, p. 99, pl. 11, figs. 13, 14.

Scolopodus floweri Repetski, 1982, p. 47, 48, pl. 24, figs. 7, 9, 10, pl. 25, figs. 1, 4.

Scolopodus paracornuformis Ethington and Clark, 1982, p. 102, fig. 25, pl. 11, fig. 21.

Scolopodus? sulcatus Furnish, 1938, p. 325, 334, pl. 41, figs. 14, 15, pl. 42, figs 26-29. Ethington and Clark, 1981, p. 20, 21, 105, 106, pl. 1, fig. 16, pl. 12, figs. 3, 4, 7, 8. Repetski, 1988, p. 126, fig. 2B-E.

Semiacontiodus lavadamensis (Miller, 1969), p. 420, pl. 64, figs. 55-61; and 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, Fig. 4V, W, pl. 2, figs. 10-12.

Stolodus stola (Lindström, 1955). Ethington and Clark, 1981, p. 108, 109, pl. 12, fig. 21.

Teridontus nakamurai (Nogami, 1967). Miller, 1969, p. 435, pl. 63, figs. 1-10; and Miller, 1980, p. 34, Fig. 4O, pl. 2, figs. 15, 16.

Tripodus laevis Bradshaw, 1969, p. 1164, pl. 135, figs. 9, 10. Ethington and Clark, 1981, p. 110-112, fig. 33, pl. 122, figs. 24, 25, 27-29

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

?*Ulrichodina wisconsinensis* Furnish, 1938. Ethington and Clark, 1981, p. 113, 114, pl. 13, fig. 15.

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

Utahconus tenuis Miller, 1980; p. 36, pl. 2, figs. 5-7. Miller, 1969, pl. 66, 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, Figs. 3B, F, G, pl. 2, figs. 1, 2.

Variabiloconus bassleri (Furnish, 1938), p. 331, pl. 42, fig. 1. Ethington and Clark, 1981, p. 74, pl. 8, figs. 11, 12.

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

Appendix C: 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 D: ECHINODERMATA

ECHINODERM BIOSTRATIGRAPHY

By James Sprinkle[1] and Thomas E. Guensburg[2]

[1]Department of Geological Sciences, University of Texas, Austin, TX 78712.
[2]Physical Science Division, Rock Valley College, Rockford, IL 61114.

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 (Plate III). 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, unpubl. 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 (see Plate III). 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). Crinoids dominate the Fillmore echinoderm fauna with about 78 specimens (Guensburg and Sprinkle, 1990, 1992a). They 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 (Plate III), along with several other distinctive but still unidentified plates, stems, attachment holdfasts, and arm fragments. Another medium-sized echinoderm fauna with 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, in preparation).

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.

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, 1973, p. 144-155; Wilson and others, 1992, p. 26, table 2.

Blastoidocrinus? sp. B of Billings, 1859. See Sprinkle, 1973, 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 III, 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.

REFERENCES CITED

Acenolaza, F.G., 1983, The Tremadocian beds and the Cambrian-Ordovician boundary problem in Latin America: Papers for the Cambrian-Ordovician and Ordovician-Silurian boundaries symposium, Nanjing, China, p. 88-93.

Acenolaza, F.G., and Acenolaza, G.F., 1992, The genus *Jujuyaspis* as a world reference fossil for the Cambrian-Ordovician boundary, p. 115-120, *in* Webby, B.D., and Laurie, J.R., eds., Global perspectives on Ordovician geology: A.A. Balkema, Rotterdam.

An Tai-xiang, Zhang Fang, Xiang Wei-da, Zhang You-qiu, Xu Wen-hao, Zhang Hui-juan, Jiang De-biao, Yang Chang-sheng, Lin Lian-di, Cui Zhan-tang, and Yang Xin-chang, 1983, The Conodonts of North China and the Adjacent Regions: Science Press, Beijing, 223 p. [in Chinese with English abstract]

Apollonov, M.K., 1991, Cambrian-Ordovician boundary beds in the U.S.S.R., p. 33-45, in Barnes, C.R., and Williams, S.H., eds., Advances in Ordovician Geology: Geological Survey of Canada Paper 90-9.

Apollonov, M.K., Chugaeva, M.N., Dubinina, S.V., and Zhemchuzhnikov, V.G., 1988, Batyrbai section, south Kazakhstan, U.S.S.R., potential stratotype for the Cambrian-Ordovician boundary: Geological Magazine, v. 125, no. 4, p. 445-449.

Bagnoli, G., Barnes, C.R., and Stevens, R.K., 1987, Lower Ordovician (Tremadocian) conodonts from Broom Point and Green Point, Western Newfoundland: Estratto dal Bollitino della Societ'a Italiana, v. 25, no. 2, p. 145-158.

Barnes, C.R., 1988, The proposed Cambrian-Ordovician global boundary stratotype and point (GSSP) in western Newfoundland, Canada: Geological Magazine, v. 125, no. 4, p. 381-414.

Barnes, C.R., and Poplawski, M.L.S., 1973, Lower and Middle Ordovician conodonts from the Mystic Formation, Quebec, Canada: Journal of Paleontology, v. 47, p. 760-790.

Barnes, C.R., and Tuke, M.F., 1970, Conodonts from the St. George Formation (Ordovician), northern Newfoundland: Geological Survey of Canada, Bulletin, v. 187, p. 79-97.

Bartolini, Claudio, Steward, J.H., Carter, Claire, Murchey, B.L., and Repetski, J.E., 1989, Stratigraphy of Paleozoic eugeoclinal strata in Sierra el Aliso, central Sonora, Mexico: Boleun del Departamento de Geologia, Universidad de Sonora, v. 6, no. 1/2, p. 11-21.

Bassett, M.G., and Dean, W.T., eds., 1982, The Cambrian-Ordovician boundary: Sections, Fossil Distributions, and Correlations: National Museum of Wales (Cardiff), Geological Series No. 3, 227 p.

Billings, Elkanah, 1857, New species of fossils from Silurian rocks of Canada: Canada Geological Survey, Report of Progress 1853-56. Report for the Year 1856, p. 247-345.

Billings, Elkanah, 1859, Canadian Organic Remains, Decade 4: Geological Survey of Canada, p. 18.

Billings, Elkanah, 1860, On some new species of fossils from the limestone near Point Levis opposite Quebec: Canadian Naturalist, v. 5, p. 301-324.

Billings, Elkanah, 1865, Fossils from various formations in the Silurian and Devonian systems, *in* Palaeozoic Fossils, v. 1: Canada Geological Survey, p. 377-415.

Blake, D.B. and Guensburg, T.E., 1993, New Lower and Middle Ordovician stelleroids (Echinodermata) and their bearing on the origins and early history of the stelleroid echinoderms: Journal of Paleontology, v. 67, no. 1, p. 103-113.

Bockelie, J.F., 1981, The Middle Ordovician of the Oslo Region, Norway, 30. The eocrinoid genera *Cryptocrinites*, *Rhipidocystis* and *Bockia*: Norsk Geologisk Tidsskrift, v. 61, p. 123-147.

Bradshaw, L.E., 1969, Conodonts from the Fort Pena Formation (Middle Ordovician), Marathon basin, Texas: Journal of Paleontology, v. 43, p. 1137-1168.

Braithwaite, L.F., 1969. Graptolites from the Pogonip Group (Lower Ordovician) of western Utah: Brigham Young University, unpublished Ph.D. Dissertation, 152 p.

Braithwaite, L.F., 1976, Graptolites from the lower Ordovician Pogonip Group of western Utah: Geological Society of America, Special Paper 166, 106 p., 21 pls.

Branson, E.B., and Mehl, M.G., 1933, Conodont studies: University of Missouri Studies, v. 8, 349 p.

Bridge, Josiah, 1931 [imprint 1930], Geology of the Eminence and Cardareva Quandrangles: Missouri Bureau of Geology and Mines, v. XXIV, 2nd series, 228 p., 22 pls.

Brower, J.C., and Veinus, Julia, 1974, Middle Ordovician crinoids from southestern Virginia and eastern Tennessee: Bulletins of American Paleontology, v. 66, no. 283, 125 p.

Bruton, D.L., Koch, L., and Repetski, J.E., 1988, The Naersnes section, Oslo region, Norway: trilobite, graptolite and conodont fossils reviewed: Geological Magazine, v. 125, p. 451-455.

Bryant, I.D., and Smith, M.P., 1990, A composite tectonic-eustatic origin for shelf sandstones at the Cambrian-Ordovician boundary in North Greenland: Journal of the Geological Society, London, v. 147, p. 795-809.

Budge, D.R., and Sheehan, P.M., 1980, The Upper Ordovician through Middle Silurian of the eastern Great Basin, Part 1: Milwaukee Public Museum, Contributions in Biology and Geology, p. 1-26.

Chen Jun-yuan and Gong We-li, 1986, Conodonts, p. 93-203, in Chen Jun-yuan, ed., Aspects of Cambrian-Ordovician boundary in Dayangcha, China: Beijing, China Prospect Publishing House. [in English]

Chen Jun-yuan, Qian Yi-yuan, Lin Yao-kun, Zhang Jun-ming, Wang Zhi-hao, Yin Lei-ming, and Erdtmann, B.-D., 1985, Study on Cambrian-Ordovician boundary strata and its biota in Dayangcha, Hunjiang, Jilin, China: Beijing, China Prospect Publishing House, 138 p., 39 pls. [in English]

Chen Jun-yuan, Qian Yi-yuan, Zhang Jun-ming, Lin Yao-kun, Yin Lei-ming, Wang Zhi-hao, Wang Zong-she, Yang Jie-dong, and Wang Ying-xi, 1988, The recommended Cambrian-Ordovician global boundary stratotype of the Xiaoyangqiao section (Dayangcha, Jilin Province), China: Geological Magazine, v. 125, no. 4, p. 415-444.

Chen, Jun-yuan, ed., 1986, Aspects of Cambrian-Ordovician Boundary in Dayangcha, China: Beijing, China Prospect Publishing House, 410 p., 98 pls. [In English]

Cheney, M.G., 1948, Study of Lower Permian and Upper Pennsylvanian stratigraphy in Brazos and Colorado River Valleys, west-central Texas: Abilene Geological Society, Spring Field Trip, June 11-12, 1948 Guidebook.

Church, S.B., 1974, Lower Ordovician patch reefs in western Utah: Brigham Young University Geology Studies, v. 21, no. 3, p. 41-62.

Church, S.B., 1991, A new Lower Ordovician species of Calathium, and skeletal structures of western Utah calathids: Journal of Paleontology, v. 65, p. 602-610.

Clark, T.H., 1935, A new Ordovician graptolite locality in Utah: Journal of Paleontology, v. 9, p. 239-246.

Cook, H.E., and Taylor, M.E., 1977, Comparison of continental slope and shelf environments in the Upper Cambrian and lowest Ordovician of Nevada, p. 51-81, in Cook, H.E. and Enos, Paul, eds., Deep-Water Carbonate Environments: Society of Economic Paleontologists and Mineralogists, Special Publication 25.

Cook, H.E., Taylor, M.E., and Miller, J.F., 1989, Late Cambrian and Early Ordovician stratigraphy, biostratigraphy and depositional environments, Hot Creek Range, Nevada, p. 28-36, in Taylor, M.E., ed., Cambrian and Early Ordovician stratigraphy and paleontology of the Basin and Range Province, western United States: American Geophysical Union, Washington, D.C.

Cooper, B.J., 1981, Early Ordovician conodonts from the Horn Valley Siltstone, central Australia: Palaeontology, v. 24, p. 147-183.

Cooper, G.A., 1956, Chazyan and related brachiopods, Part I, Text; Part II, Plates: Smithsonian Miscellaneous Collections, v. 127, pts. I and II, 1023 p., 269 pls.

Cowie, J.W., Ziegler, W., Boucot, A.J., Bassett, M.G., and Remane, J., 1986, Guidelines and statutes of the International Commission on Stratigraphy (ICS): Courier Forschungsinstitut Senckenberg, v. 83, Frankfurt, 14 p.

Cullison, J.S., 1944, The stratigraphy of some Lower Ordovician formations of the Ozark Uplift: Bulletin University Missouri School Mines and Metallurgy, v. 15, no. 2, p. 1-112.

Dana, J.D., 1874, Reasons for some of the changes in the subdivisions of geologic time in the new edition of Dana's Manual of Geology: American Journal of Science, 3d series, v. 8, p. 214.

Dattilo, B.F., 1988, Depositional environments of the Fillmore Formation (Lower Ordovician) of western Utah: Brigham Young University Department of Geology, unpublished M.S. thesis, 94 p.

Dattilo, B.F., 1993, The Lower Ordovician Fillmore Formation of western Utah: storm-dominated sedimentation on a passive margin: Brigham Young University Geology Studies, v. 39, no. 1, p. 71-100.

Dean, W.T., 1978, Preliminary account of the trilobite biostratigraphy of the Survey Peak and Outram Formations (Late Cambrian, Early Ordovician) at Wilcox Pass, southern Canadian Rocky Mountains, Alberta: Geological Survey Canada, Paper 76-34, 10 pgs.

Dean, W.T., 1988, Lower Ordovician trilobites from the uppermost McKay Group at its type section, southeastern British Columbia: Geological Survey Canada, Contributions to Canadian Paleontology, Bulletin 379, p. 1-15.

Dean, W.T., 1989, Trilobites from the Survey Peak, Outram, and Skoki Formations (Upper Cambrian-Lower Ordovician) at Wilcox Pass, Jasper National Park, Alberta: Geological Survey of Canada, Bulletin 389, 56 p., 42 pls.

Demeter, E.J., 1973, Lower Ordovician pliomerid trilobites from western Utah: Brigham Young University Geology Studies, v. 20, pt. 4, p. 35-65.

Derby, J.R., Bauer, J.A., Creath, W.B., Dresbach, R.I., Ethington, R.L., Loch, J.D., Stitt, J.H., McHargue, T.T., Miller, J.F., Miller, M.A., Repetski, J.E., Sweet, W.C., Taylor, J.F., and Williams, M., 1991, Biostratigraphy of the Timbered Hills, Arbuckle, and Simpson Groups, Cambrian and Ordovician, Oklahoma: a review of correlation tools and techniques available to the explorationist: Oklahoma Geological Survey, Circular 92, p. 15-41.

Derby, J.R., Lane, H.R., and Norford, B.S., 1972, Uppermost Cambrian-basal Ordovician faunal succession in Alberta and correlation with similar sequences in western United States: 24th International Geological Congress, Montreal, Proceedings, Section 7, p. 503-512.

Druce, E.C., and Jones, P.J., 1971, Cambro-Ordovician conodonts from the Burke River structural belt, Queensland: Australian Bureau of Mineral Resources, Geology and Geophysics, Bulletin 110, 158 p.

Dubinina, S.V., 1991, Upper Cambrian and Lower Ordovician conodont associations from open ocean paleoenvironments, illustrated by Batyrbai and Sarykum sections in Kazakhstan, p. 107-124, in Barnes, C.R., and Williams, S.H., eds., Advances in Ordovician Geology: Geological Survey of Canada, Paper 90-9, p. 107-124.

Erdtman, B.-D., and Miller, J.F., 1981, Eustatic control of lithofacies and biofacies changes near the base of the Tremadocian, p. 78-81, in Taylor, M.E., ed., Short Papers for the Second International Symposium on the Cambrian System (Denver, Colorado): U.S. Geological Survey Open-File Report 81-743.

Ethington, R.L., 1978, Conodont faunas of the Lower and Middle Ordovician of the House and Confusion Ranges, Utah, p. 35-44, in Miller, J.F., ed., Upper Cambrian to Middle Ordovician conodont faunas of western Utah: Southwest Missouri State University, Science Series, no. 5.

Ethington, R.L., 1979, Conodonts from the pre-Eureka Ordovician of the Great Basin: Brigham Young University Geology Studies, v. 26, pt. 3, p. 16.

Ethington, R.L., and Brand, Uwe, 1981, *Oneotodus simplex* (Furnish) and the genus *Oneototus* (Conodonta): Journal of Palaeontology, v. 55, no. 1, p. 239-247.

Ethington, R.L., and Clark, D.L., 1964, Conodonts from the El Paso Formation (Ordovician) of Texas and Arizona: Journal of Paleontology, v. 38, p. 685-704.

Ethington, R.L., and Clark, D.L., 1971, Lower Ordovician conodonts in North America: Geological Society of America Memoir, v. 127, p. 63-82.

Ethington, R.L., and Clark, D.L., 1981, Lower and Middle Ordovician conodonts from the Ibex area, western Millard County, Utah: Brigham Young University Geology Studies, v. 28, pt. 2, 155 p., 14 pls., 12 tables [range charts of taxa].

Ethington, R.L., Engel, K.M., and Elliott, K.L., 1987, An abrupt change in conodont faunas in the Lower Ordovician of the Midcontinent Province, p. 111-127, in Aldridge, R.J., ed., Palaeobiology of Conodonts: Ellis Horwoood Limited, Chichester, U.K., 155 p.

Fahraeus, L.E., and Nowlan, G.S., 1978, Franconian (Late Cambrian) to early Champlainian (Middle Ordovician) conodonts from the Cow Head Group, western Newfoundland: Journal of Paleontology, v. 52, no. 2, p. 444-471.

Finney, S.C., and Ethington, R.L., 1992, Whiterockian graptolites and conodonts from the Vinini Formation, Nevada: Biostratigraphic implications, p. 153-169, in Webby, B.D., and Laurie, J.R., eds., Global Perspectives on Ordovician Geology: A.A. Balkema, Rotterdam, 513 p.

Fisher, D.W., and Mazzullo, S.J., 1976, Lower Ordovician (Gasconadian) Great Meadows Formation in eastern New York. Geological Society of America Bulletin, v. 87, p. 1443-1448.

Flower, R.F., 1964, The nautiloid order Ellesmeroceratida (Cephalopoda): New Mexico Bureau Mines and Mineral Resources, Memoir 12, p. 17-20, 146-161.

Fortey, R.A., 1979, Early Ordovician trilobites from the Catoche Formation (St. George Group), western Newfoundland: Geological Survey of Canada, Bulletin 321, p. 61-114.

Fortey, R.A., 1988, The international correlation of the lower part of the Ordovician and how it should influence Laurentian chronostratigraphy, p. 43-44, in Landing, Ed, ed., Position Papers on Ordovician Chronostratigraphy. The Canadian Paleontology and Biostratigraphy Seminar, Proceedings: New York State Museum Bulletin, no. 462, 147 p.

Fortey, R.A, Landing, Ed, and Skevington, David, 1982, Cambrian-Ordovician boundary sections in the Cow Head Group, Western Newfoundland, p. 95-129, in Bassett, M.G., and Dean, W.T., eds., The Cambrian-Ordovician Boundary: Sections, fossil distributions, and correlations: National Museum of Wales (Cardiff), Geological Series no. 3.

Fortey, R.A., and Peel, J.S., 1990, Early Ordovician trilobites and molluscs from the Poulsen Cliffs Formation, Washington Land, western North Greenland: Bulletin of the Geological Society of Denmark, v. 38, p. 11-32.

Furnish, W.M., 1938, Conodonts from the Prairie du Chien beds of the upper Mississippi Valley: Journal of Paleontology, v. 12, p. 318-340.

Gastil, R.G., and Miller, R.H., 1983, Pre-batholithic terranes of southern and peninsular California, U.S.A., and Mexico: status report, p. 49-61, in Stevens, C.H., ed., Pre-Jurassic rocks in western North American suspect terranes: Pacific Section, Society of Economic Paleontologists and Mineralogists, Los Angeles.

Graves, R.W., and Ellison, S.P., Jr., 1941, Ordovician conodonts of the Marathon basin, Texas: University of Missouri School of Mining and Metallurgy, Bulletin, Technical Series, v. 14, no. 2, 26 p.

Guensburg, T.E. and Sprinkle, James, 1990, Early Ordovician crinoid-dominated echinoderm fauna from the Fillmore Formation of western Utah: Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A220.

Guensburg, T.E. and Sprinkle, James, 1992a, Rise of echinoderms in the Paleozoic Evolutionary Fauna; significance of paleoenvironmental controls: Geology, v. 20, p. 407-410.

Guensburg, T.E. and Sprinkle, James, 1992b, Environmental controls of rapidly diversifying echinoderms during the Early Paleozoic, p. 114, in Lidgard, S. and Crane, P.R., eds., Fifth North American Paleontological Convention Abstracts and Program: Paleontological Society, Special Publication no. 6.

Harrington, H.J., 1957, Notes on new genera of Pliomeridae (Trilobita): Journal of Paleontology, v. 31, no. 4, p. 811-812.

Harris, R.W., 1962, New conodonts from the Joins (Ordovician) Formation of Oklahoma: Oklahoma Geological Survey Notes, v. 22, p. 199-211.

Hecker, R.F., 1938, New data on Rhipidocystis Jaekel (Order Digitata n.o., Class Carpoidea Jaekel) and on a new genus Bockia (Subclass Eocrinoidea Jaekel, Class Crinoidea Miller) from the Ordovician of Leningrad Province, USSR, and Estonia: Academy of Sciences of USSR, Comptes Rendus, new series, v. 19, no. 2, p. 421-424.

Henningsmoen, Gunnar, 1973, The Cambro-Ordovician boundary: Lethaia, v. 6, p. 423-439.

Hintze, L.F., 1951, Lower Ordovician detailed stratigraphic sections for western Utah: Utah Geological and Mineralogical Survey, Bulletin 39, 99 p.

Hintze, L.F., 1953 [imprint 1952], Lower Ordovician trilobites from western Utah and eastern Nevada: Utah Geological and Mineralogical Survey, Bulletin 48, 249 p., 28 pls.

Hintze, L.F., 1954, Presbynileus and Protopresbynileus, new generic names proposed for Pseudonileus and Paranileus Hintze, preoccupied: Journal of Paleontology, v. 28, p. 119.

Hintze, L.F., 1973, Lower and Middle Ordovician stratigraphic sections in the Ibex area, Millard County, Utah: Brigham Young University Geology Studies, v. 20, pt. 4, p. 3-36.

Hintze, L.F., 1974a, Preliminary geologic map of The Barn Quadrangle, Millard County, Utah: U.S. Geological Survey Miscellaneous Field Studies, Map MF-633, 2 sheets.

Hintze, L.F., 1974b, Preliminary geologic map of the Notch Peak Quadrangle, Millard County, Utah: U.S.Geological Survey Miscellaneous Field Studies, Map MF-636, 2 sheets.

Hintze, L.F., 1979, Preliminary zonations of Lower Ordovician of western Utah by various taxa: Brigham Young University Geology Studies, v. 26, pt. 2, p. 13-19.

Hintze, L.F., 1982, Ibexian Series (Lower Ordovician) type section, western Utah, U.S.A., p. 7-10, in Ross and others, The Ordovician System in the United States of America: International Union of Geological Sciences Publication no. 12.

Hintze, L.F., 1988, Geologic History of Utah: Brigham Young University Geology Studies, Special Publication 7, 204 p.

Hintze, L.F., Braithwaite, L.F., Clark, D.L., Ethington, R.L., and Flower, R.F., 1972 [imprint 1968], A fossiliferous lower Ordovician reference section from western United States: Proceedings, 23rd International Geological Congress (Prague), p. 385-400.

Hintze, L.F., and Jaanusson, Valdar, 1956, Three new genera of asaphid trilobites from the Lower Ordovician of Utah: Bulletin of the Geological Institute of Uppsala, v. 36, p. 51-57.

Hintze, L.F., Taylor, M.E., and Miller, J.F., 1988, Upper Cambrian-Lower Ordovician Notch Peak Formation in western Utah: U.S. Geological Survey Professional Paper 1393, 30 p., 1 pl.

Hook S.C., and Flower, R.H., 1977, Late Canadian (Zones J, K) cephalopod faunas from southwestern United States: New Mexico Bureau of Mines and Mineral Resources, Memoir 32, 102 p., 21 pls.

Ingham, J.K., Curry, G.B., and Williams, A., 1985, Early Ordovician Dounans Limestone fauna, Highland Border Complex, Scotland: Transactions, Royal Society Edinburgh, Earth Sciences, v. 76, p. 481-513.

Jell, P.A., 1985, Tremadoc trilobites of the Digger Island Formation, Waratah Bay, Victoria: Museum of Victoria, Memoirs, v. 46, p. 53-88.

Jensen, R.G., 1967, Ordovician brachiopods from the Pogonip Group of Millard County, western Utah: Brigham Young University Geology Studies, v. 14, p. 67-100.

Kaljo, D., Heinsalu, H., Mens, K., Puura, I., and Viira, V., 1988, Cambrian-Ordovician boundary beds at Tonismagi, Tallin, North Estonia: Geological Magazine, v. 125, no. 4, p. 457-463.

Karklins, O.L., and Repetski, J.E., 1989, Distribution of selected Ordovician conodont faunas in northern New Jersey: U.S. Geological Survey, Miscellaneous Field Studies Map, MF-1066, map., 3 tables.

Kelly, S.M. and Ausich, W.I., 1978, A new Lower Ordovician (Middle Canadian) disparid crinoid from Utah: Journal of Paleontology, v. 52, p. 916-920.

Kelly, S.M. and Ausich, W.I., 1979, A new name for the Lower Ordovician crinoid Pogocrinus Kelly and Ausich: Journal of Paleontology, v. 53, p. 1433.

Kobayashi, T., 1935, The Briscoia fauna of the late Upper Cambrian in Alaska with descriptions of a few Upper Cambrian trilobites from Montana and Nevada: Japanese Journal of Geology and Geography, v. 12, no. 3-4, pt. 8, p. 39-57.

Kurtz, V.E., 1981, The Cambrian-Ordovician boundary in Missouri as determined by conodonts, p. 115-117, in Taylor, M.E., ed., Short Papers for the Second International Symposium on the Cambrian System: U.S. Geological Survey Open File Report 81-743.

Landing, Ed, 1981, Conodont biostratigraphy and thermal color alteration indices of the upper St. Charles and lower Garden City Formation, Bear River Range, northern Utah and southeastern Idaho: U.S.Geological Survey Open File Report 81-740, 22 p., 5 figs.

Landing, Ed, 1983, Highgate Gorge: Upper Cambrian and Lower Ordovician continental slope deposition and biostratigraphy, northwestern Vermont: Journal of Paleontology, v. 57, no. 6, p. 1149-1187.

Landing, Ed, 1993, Cambrian-Ordovician boundary in the Taconic allochthon, eastern New York, and its interregional correlation: Journal of Paleontology, v. 67, no. 1, p. 1-19.

Landing, Ed, Barnes, C.R., and Stevens, R.K., 1986, Tempo of earliest Ordovician graptolite faunal succcession: Conodont-based correlations from the Tremadocian of Quebec: Canadian Journal of Earth Sciences, v. 23, p. 1928-1949.

Landing, Ed, Ludvigsen, Rolf, and von Bitter, P.H., 1980, Upper Cambrian to Lower Ordovician conodont biostratigraphy and biofacies, Rabbittkettle Formation, District of Mackenzie: Royal Ontario Museum, Life Sciences Contributions, no. 126, 42 p.

Landing, Ed, Taylor, M.E., and Erdtmann, B.-D., 1978, Correlation of the Cambrian-Ordovician boundary between the Acado-Baltic and North American faunal provinces: Geology, v. 6, p. 75-78.

Lane, N.G., 1970, Lower and Middle Ordovician crinoids from west-central Utah: Brigham Young University Geology Studies, v. 17, no.1, p.3-17.

Laurie, J.R., 1980, Early Ordovician orthid brachiopods from southern Tasmania: Alcheringa, v. 4, p. 11-23.

Laurie, J.R., 1991, Articulate brachiopods from the Ordovician and Lower Silurian of Tasmania, p. 1-106, in Jell, P.A., ed., Australian Ordovician brachiopod studies: Association of Australasian Paleontologists, Brisbane.

Lehnert, Oliver, 1993, Bioestratigrafia de los conodontes arenigianos de la Formacion San Juan en la localidad de Niquivil (Precordillera Sanjunaina, Argentina) y su correlacion intercontinental: Revista Espanola de Paleontologia, v. 8, no., 2, p. 153-164.

LeMone, D.V., 1975, Correlation aspects of the Ordovician of the southwestern United States, p. 169-190, in Hills, J.M., ed., Exploration from the Mountains to the Basin: El Paso Geological Society, 1975 Guidebook.

Lewis, R.D., 1981, Archaetaxocrinus, new genus, the earliest known flexible crinoid (Whiterockian) and its phylogenetic implications: Journal of Paleontology, v. 55, no. 1, p. 227-238.

Lewis, R.D., Sprinkle, James, Bailey, J.B., Moffit, John, and Parsley, R.L., 1987, Mandalacystis, a new rhipidocystid eocrinoid from the Whiterockian Stage (Ordovician) in Oklahoma and Nevada: Journal of Paleontology, v. 61, no. 6, p. 1222-1235.

Lindström, Maurits, 1955, Conodonts from the lowermost Ordovician strata of south-central Sweden: Geologiska Föreningens i Stockholm, Förhandlingar 76, p. 517-604.

Loch, J.D., Stitt, J.H., and Derby, J.R., 1993, Cambrian-Ordovician boundary interval extinctions: Implications of revised trilobite and brachiopod data from Mount Wilson, Alberta, Canada: Journal of Paleontology, v. 67, no. 4, p. 497-517.

Lochman, Christina, 1964, Upper Cambrian faunas from the subsurface Deadwood Formation, Williston Basin, Montana: Journal of Paleontology, v. 38, no. 1, p. 33-60.

Lochman, Christina, 1966, Lower Ordovician (Arenig) faunas from the Williston Basin, Montana and North Dakota: Journal of Paleontology, v. 40, no. 3, p. 512-548, pls. 61-65.

Löfgren, Anita, 1978, Arenigian and Llanvirnian conodonts from Jämtland, northern Sweden: Fossils and Strata, v. 13, 129 p.

Longacre, S.A., 1970, Trilobites of the Upper Cambrian Ptychaspid Biomere, Wilberns Formation, central Texas: Paleontological Society Memoir 4 (Journal of Paleontology, v. 44, no. 1, suppliment), 70 p.

Lu Yan-hao and Lin Huan-ling, 1980, Cambrian-Ordovician boundary in western Zhejiang, and the trilobites contained therein: Acta Palaeontologia Sinica, v. 19, p. 118-135.

Lu Yan-hao and Lin Huan-ling, 1984, Late Late Cambrian and earliest Ordovician trilobites of Jiangshan-Changshan area, Zhejiang, p. 45-164, in Stratigraphy and Paleontology of Systemic Boundaries in China. Cambrian-Ordovician Boundary: Anhui Science and Technology Publishing House, Anhui, China, 396 p. 18 pls. [In English]

Lu Yan-hao, 1984, Report on Cambrian-Ordovician boundary work in China, p. 1-8, in Stratigraphy and Paleontology of Systemic Boundaries in China. Cambrian-Ordovician Boundary: Anhui Science and Technology Publishing House, Anhui, China, 396 p. 18 pls. [In English]

Ludvigsen, Rolf, 1982, Upper Cambrian and Lower Ordovician trilobite biostratigraphy of the Rabbitkettle Formation, western District of Mackenzie: Life Sciences Contributions, Royal Ontario Museum, no. 134, 187 p.

Ludvigsen, Rolf, and Westrop, S.R., 1985, Three new upper Cambrian stages for North America: Geology, v. 13, p. 139-143.

McTavish, R.A., 1973, Prioniodontacean conodonts from the Emanuel Formation (Lower Ordovician) of western Australia: Geologica et Palaeontologica, v. 7, p. 27-58.

Merriam, C.W., 1963, Paleozoic rocks of Antelope Valley, Eureka and Nye Counties, Nevada: U.S. Geological Survey Professional Paper 423, 67 p.

Miller, J.F., 1969, Conodont fauna of the Notch Peak Limestone (Cambro-Ordovician), House Range, Utah: Journal of Paleontology, v. 43, no. 2, p. 413-439.

Miller, J.F., 1978, Upper Cambrian and lowest Ordovician conodont faunas of the House Range, Utah, p. 1-33, in Miller, J.F., ed., Upper Cambrian to Middle Ordovician conodont faunas of western Utah: Southwest Missouri State University, Science Series, no. 5.

Miller, J.F., 1980, Taxonomic revisions of some Upper Cambrian and Lower Ordovician conodonts with comments on their evolution: University of Kansas (Lawrence), Paleontological Contributions, Paper 99, 39 p.

Miller, J.F., 1984, Cambrian and earliest Ordovician conodont evolution, biofacies, and provincialism: Geological Society of America Special Paper 196, p. 43-68.

Miller, J.F., 1988, Conodonts as biostratigraphic tools for redefinition and correlation of the Cambrian-Ordovician boundary: Geological Magazine, v. 125, no. 4, p. 347-362.

Miller, J.F., 1992, The Lange Ranch Eustatic Event: A regressive-transgressive couplet near the base of the Ordovician System, p. 395-407, in Webby, B.D. and Laurie, J.R., eds., Global Perspectives on Ordovician Geology: A.A. Balkema, Rotterdam.

Miller, J.F., Stitt, J.H., and Taylor, M.E., 1990, New information on the occurrence of the basal Tremadoc olenid trilobite Jujuyaspis from the western United States of America: Subcommission on Cambrian Stratigraphy, International Union of Geological Sciences, Abstracts for the Third International Symposium on the Cambrian System, Novosibirsk, USSR, p. 137.

Miller, J.F., and Taylor, M.E., 1989, Late Cambrian and Early Ordovician strtigraphy and biostratigraphy, southern House Range ("Ibex Area"), Utah, p. 45-58, in Taylor, M.E., ed., Cambrian and Early Ordovician stratigraphy and paleontology of the Basin and Range Province, western United States: American Geophysical Union, Washington, D.C.

Miller, J.F., Taylor, M.E., Cook, H.E., 1989, Global eustatic events near the Cambrian-Ordovician boundary and their influence on depositional processes, redeposition of fossils, and biostratigraphic correlation: Abstracts, 28th International Geological Congress, Washington, D.C., p. 2-436.

Miller, J.F., Taylor, M.E., Stitt, J.H., Ethington, R.L., Hintze, L.F., and Taylor, J.F., 1982, Potential Cambrian-Ordovician boundary stratotype sections in the western United States, p. 155-180, in Bassett, M.G., and Dean, W.T., eds., The Cambrian-Ordovician boundary: sections, fossil distributions, and correlations: National Museum of Wales (Cardiff), Geological Series no. 3.

Miller, J.F., Taylor, M.E., Taylor, J.F., Ripperdan, R.L., Repetski, J.E., Ebneth, S., 1993, Base of the Cordylodus proavus conodont biozone and base of Ibexian Series: An isochronous datum useful for intercontinental correlation near the Cambrian-Ordovician boundary: Program and Abstracts for 1993 Annual Meeting, Geological Society of America, p. A-74.

Mitchell, C.E., 1991, Appendix C. Graptolite correlation of the topmost Ibexian, Whiterock Canyon, Nevada: Palaios, v. 6, p. 171-173.

Müller, K.J., 1959, Kambrische Conodonten: Zeitschrift Deutsche Geologische Gesellschaft, band 111, p. 434-485.

Müller, K.J., and Hinz, I., 1991, Upper Cambrian Conodonts from Sweden: Fossils and Strata, no. 28, 153 p.

Murphy, M.A., 1977, On time-stratigraphic units: Journal of Palaeontology, v. 51, no. 2, p. 213-219.

NACSN (North American Commission on Stratigraphic Nomenclature), 1983, North American stratigraphic code: American Association of Petroleum Geologists Bulletin, v. 67, no. 5, p. 841-875.

Nicoll, R.S., 1990, The genus Cordylodus and a latest Cambrian-earliest Ordovician conodont biostratigraphy: Bureau of Mineral Resources, Journal of Australian Geology and Geophysics, v. 11, p. 529-558.

Nicoll, R.S., 1991, Differentiation of Late Cambrian-Early Ordovician species of *Cordylodus* (Conodonta) with biapical basal cavities: Bureau of Mineral Resources, Journal of Australian Geology & Geophysics, v. 12, no. 3, p. 223-244.

Nicoll, R.S., and Shergold, J.H., 1991, Revised Late Cambrian (pre-Payntonian-Datsonian) conodont biostratigraphy at Black Mountain, Georgina Basin, western Queensland, Australia: Bureau of Mineral Resources, Journal of Australian Geology and Geophysics, v. 12, p. 93-118.

Nogami, Yasuo, 1967, Kambrische Conodonten von China, Teil 2. Conodonten aus den hoch oberkambrischen Yencho-Schichten: Memoirs of the College of Sciences, University of Kyoto, Series B, v. 33, Geology and Mineralogy, p. 211-218.

Norford, B.S., 1969, The early Canadian (Tremadocian) trilobites *Clelandia* and *Jujuyaspis* from the southern Rocky Mountains of Canada: Geological Survey of Canada Bulletin, no. 182, 15 p.

Norford, B.S., 1988, Introduction to papers on the Cambrian-Ordovician boundary: Geological Magazine, v. 125, no. 4, p. 323-326.

Owen, D.D., 1852, Report of a geological survey of Wisconsin, Iowa, and Minnesota: Lippincott, Grambo and Company, Philadelphia, Pennsylvania, 638 p.

Pander, C.H., 1856, Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements: Buchdruckerei der Kaiserlichen Akademie der Wissenschaften, St. Petersburg, 91 p.

Paul, C.R.C., 1972, *Cheirocystella antiqua* gen. et sp. nov., from the Lower Ordovician of western Utah, and its bearing on the evolution of the Cheirocrinidae (Rhombifera, Glyptocystitida): Brigham Young University Geology Studies, v. 19, no. 1, p. 15-63.

Poulsen, C., 1927, The Cambrian, Ozarkian and Canadian faunas of northwest Greenland: Meddelelser om Grönland, v. 70, p. 233-343.

Pratt, B.R., 1988, An Ibexian (early Ordovician) trilobite faunule from the type section of the Rabbitkettle Formation (southern MacKenzie Mountains, Northwest Territories). Canadian Journal of Earth Sciences, v. 25, p. 1595-1607.

Pribyl, A., and Vanek, J., 1980, Ordovician trilobites of Bolivia: Rozpravy Ceskoslovenske Akademie VED, Rada Matematickych a Prirodnich VED, Rocnik 90, Sesit 2, 90 p., 26 pls.

Price, R.D., 1978, Occurrence, quality, and availability of ground water in Jones County, Texas: Texas Department Water Resources, Water Development Board, Report 215, p. 1-224.

Rao, R.I., 1988, Los conodontes ordovicicos del Departmento Tumbaya, en la Cordillera Oriental, Jujuy: Informe final CONICET (inedito).

Rasetti, Franco, 1944, Upper Cambrian trilobites from the Levis Conglomerate: Journal of Paleontology, v. 18, no. 3, p. 229-258.

Rasetti, Franco, 1959, Trempealeauan trilobites from the Conococheague, Frederick, and Grove limestones of the central Appalachians: Journal of Paleontology, v. 33, no. 3, p. 375-398.

Repetski, J.E., 1977, Early Ordovician (Canadian) conodonts from New York: Geological Society of America, North-Central Section, Abstracts with Programs, v. 9, no. 5, p. 647.

Repetski, J.E., 1982, Conodonts from El Paso Group (Lower Ordovician) of westernmost Texas and southern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 40, 121 p.

Repetski, J.E., 1985, Conodont biostratigraphy of the Knox Group at the Thorn Hill and River Ridge sections, northeastern Tennessee, p. 25-31, *in* Walker, K.R., ed., The geologic history of the Thorn Hill Paleozoic section (Cambrian-Mississippian), eastern Tennessee: University of Tennessee, Department of Geological Sciences Studies in Geology, no. 10.

Repetski, J.E., 1988, Ordovician conodonts from the Bliss Sandstone in its type area, west Texas: New Mexico Bureau of Mines and Mineral Resources Memoir 44, p. 123-127.

Repetski, J.E., 1992, Knox Group and basal Stones River Group conodonts from near Graysville, Catoosa County, Georgia, p. 39-46, in Chowns, T.M., and O'Connor, B.J., eds., Cambro-Ordovician strata in Northwest Georgia and Southeast Tennessee; the Knox Group and the Sequatchie Formation: Georgia Geological Society Guidebooks, v. 12, no. 1.

Repetski, J.E., Ethington, R.L., Furnish, W.M., and Kennedy, D.J., 1993, Conodonts from the Oneota and Gasconade Dolomites (Lower Ordovician) of the central midcontinent, U.S.A.: Geological Society of America, North-Central Section, Abstracts with Program, v. 25, p. 74-75.

Repetski, J.E., and Ethington, R.L., 1983, Rossodus manitouensis (Conodonta), a new Early Ordovician index fossil: Journal of Paleontology, v. 57, no. 2, p. 289-301.

Repetski, J.E., and Ethington, R.L., 1984, Paleobiogeographic distribution of Early Ordovician conodonts in central and western United States: Geological Society of America Special Paper, v. 196, p. 89-101.

Repetski, J.E., Harris, A.G., Stewart, J.H., Poole, F.G., and Morales, R., 1985, Early Ordovician conodonts from central Sonora, Mexico, p. 25-26, in Aldridge, R.J., Austin, R.L., and Smith, M.P., eds., Fourth European Conodont Symposium (ECOS IV), Abstracts, Nottingham, U.K.

Repetski, J.E., and Taylor, M.E., 1982, Correlation of Cambrian-Ordovician boundary beds in shelf and basin facies, eastern and central Nevada, western United States, p. 20, in Jeppsson, L., and Löfgren, A., eds., Third European Conodont Symposium (ECOS III), Abstracts: Publications from the Institutes of Mineralogy, Paleontology, and Quaternary Geology, University of Lund, Sweden, no. 238.

Repetski, J.E., and Taylor, M.E., 1983, Correlation of the Cambrian-Ordovician boundary from shelf to basin in eastern and central Nevada: Geological Society of America, Cordilleran and Rocky Mountain combined Sections, Abstracts with Programs 1983, v. 15, no. 5, p. 412.

Ripperdan, R.L., and Kirschvink, J.L., 1992, Paleomagnetic results from the Cambrian-Ordovician boundary section at Black Mountain, Georgina Basin, western Queensland, Australia, p. 93-104, in Webby, B.D., and Laurie, J.R., 1992, Global Perspectives on Ordovician Geology: A.A. Balkema, Rotterdam.

Ripperdan, R.L., Magaritz, M., and Kirschvink, J.L., 1993, Carbon isotope and magnetic polarity evidence for non-depositional events within the Cambrian-Ordovician boundary section near Dayangcha, Jilin Province, China: Geological Magazine, v. 130, no. 4, p. 443-452.

Ripperdan, R.L., Magaritz, M., Nicoll, R.S., and Shergold, J.H., 1992, Simultaneous changes in carbon isotopes, sea level, and conodont biozones within the Cambrian-Ordovician boundary interval at Black Mountain, Australia: Geology, v. 20, p. 1039-1042.

Robison, R.A., and Pantoja-Alor, Jerjes, 1968, Tremadocian trilobites from Nochxtitlan region, Oaxaca, Mexico: Journal of Paleontology, v. 42, no. 3, p. 767-800.

Ross, R.J., Jr., 1949, Stratigraphy and trilobite faunal zones of the Garden City Formation, northeastern Utah: American Journal of Science, v. 247, p. 472-491.

Ross, R.J., Jr., 1951, Stratigraphy of the Garden City Formation in northeastern Utah, and its trilobite faunas: Peabody Museum Natural History, Bulletin 6, 161 p., 36 pls.

Ross, R.J., Jr., 1953, Additional Garden City (Early Ordovician) trilobites: Journal of Paleontology, v. 27, no. 5, p. 633-646.

Ross, R.J., Jr., 1958, Trilobites in a pillow lava of the Valmy Formation, Nevada: Journal of Paleontology, v. 32, p. 559-570.

Ross, R.J., Jr., 1968, Brachiopods from the upper part of the Garden City Formation (Ordovician), north-central Utah: U.S. Geological Survey Professional Paper 593-H, 13 p., 4 pls.

Ross, R.J., Jr., 1970, Ordovician brachiopods, trilobites, and stratigraphy in eastern and central Nevada: U. S. Geological Survey Professional Paper 639, 103 p.

Ross, R.J., Jr., and Ethington, R.L., 1991, Stratotype of Ordovician Whiterock Series, with an appendix on Graptolite Correlation by C.E.Mitchell, Palaios, v. 6, p. 156-173.

Ross, R.J., Jr., and Ethington, R.L., 1992, North American Whiterock Series suited for global correlation, p.135-152, in Webby, B.D. & Laurie, J.R., 1992, Global Perspectives on Ordovician Geology: A.A. Balkema, Rotterdam.

Ross, R.J., Jr., and others, 1982, Ordovician System in the United States of America: International Union of Geological Sciences Publication 12, 73 p., with correlation chart.

Ross, R.J., Jr., James, N.P., Hintze, L.F., and Poole, F.G., 1989, Architecture and evolution of a Whiterockian (early Middle Ordovician) carbonate platform, Basin Ranges of western U.S.A., p. 167-185, in Cravello, P.D., Wilson, J.L., Sarg, J.F., and Read, J.F., eds., Controls on Carbonate Platform and Basin Development: Society of Paleontologists and Mineraligists Special Publication no. 44.

Rushton, A.W.A., 1982, The biostratigraphy and correlation of the Merioneth-Tremadoc Series boundary in North Wales, p. 41-59, *in* Bassett, M.G., and Dean, W.T., eds., The Cambrian-Ordovician Boundary: Sections, Fossil Distributions, and Correlations: National Museum of Wales (Cardiff), Geological Series no. 3.

Sarmiento, Graciela, and Garcia-Lopez, Susana, 1993, Sintesis sobre las faunas de conodontos del Paleozoico inferioir de Ibero-America y de la Pennsula Iberica (1958-1992): Revista Espanola de Paleontologia, v. 8, no. 2, p. 191-205.

Serpagli, Enrico, 1974, Lower Ordovician condonts from Precordilleran Argentina (Province of San Juan): Bolletino della Societa Paleontolotgica Italiana, v. 13, p. 17-98.

Shaw, A.B., 1951, The paleontology of northwestern Vermont. Part 1, New Late Cambrian trilobites: Journal of Paleontology, v. 25, no. 1, p. 97-114.

Shergold, J.H., and Nicoll, R.S., 1992, Revised Cambrian-Ordovician boundary biostratigraphy, Black Mountain, western Queensland, p. 81-92, *in* Webby, B.D. and Laurie, J.R., 1992, Global Perspectives on Ordovician Geology: A.A. Balkema, Rotterdam.

Sour, T.F., and Buitron, B.E., 1987, Los graptolites del Tremadociano de Ixtaltepec, Oaxaca: Consideraciones sobre el limite Cambrico-Ordovicico de la region: Revista de la Sociedad Mexicana de Paleontologia, v. 1, no. 1, p. 380-395.

Sprinkle, James, 1971, Stratigraphic distribution of echinoderm plates in the Antelope Valley Limestone of Nevada and California: U.S. Geological Survey Professional Paper 750D, p. D89-D98.

Sprinkle, James, 1973a, Morphology and Evolution of Blastozoan Echinoderms: Museum of Comparative Zoology, Harvard University, Special Publication, 283 p.

Sprinkle, James, 1973b, *Tripatocrinus*, a new hybocrinid crinoid based on disarticulated plates from the Antelope Valley Limestone of Nevada and California: Journal of Paleontology, v. 47, p. 861-882.

Sprinkle, James, 1974, New rhombiferan cystoids from the Middle Ordovician of Nevada: Journal of Paleontology, v. 48, p. 1174-1201.

Sprinkle, James, 1989, Origin of the echinoderm Class Rhombifera based on new Early Ordovician discoveries from the Rocky Mountains: Geological Society of America, Abstracts with Programs, v. 21, no. 6, p. A114.

Sprinkle, James, 1990, New echinoderm fauna from the Ninemile Shale (Lower Ordovician) of central and southern Nevada: Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A219.

Sprinkle, James, and Guensburg, T. E., 1991, Origin of echinoderms in the Paleozoic Evolutionary Fauna: new data from the Early Ordovician of Utah and Nevada: Geological Society of America, Abstracts with Programs, v. 23, no. 5, p. A278.

Stait, J.H., Burrett, C., and Wongwanich, T., 1984, Ordovician trilobites from the Tarutao formation, southern Thailand: Neues Jahrbuch für Geologie und Paläontologie Monatshefte (Stuttgart), Heft 1, p. 53-64.

Stitt, J.H., 1971, Late Cambrian and earliest Ordovician trilobites, Timbered Hills and lower Arbuckle Groups, western Arbuckle Mountains, Murray County, Oklahoma: Oklahoma Geological Survey Bulletin 110, 83 p., 12 pls.

Stitt, J.H., 1977, Late Cambrian and earliest Ordovician trilobites, Wichita Mountains area, Oklahoma: Oklahoma Geological Survey Bulletin 124, 79 p., 7 pls.

Stitt, J.H., 1983, Trilobites, biostratigraphy, and lithostratigraphy of the McKenzie Hill Limestone (Lower Ordovician), Wichita and Arbuckle Mountains, Oklahoma: Oklahoma Geological Survey Bulletin 134, 54 p., 7 pls.

Stitt, J.H., and Miller, J.F., 1987, *Jujuyaspis borealis* and associated trilobites and conodonts from the Lower Ordovician of Texas and Utah: Journal of Paleontology, v. 61, p. 112-121.

Stouge, S., 1982, Preliminary conodont biostratigraphy and correlation of Lower to Middle Ordovician carbonates of the St. George Group, Great Northern Peninsula, Newfoundland: Newfoundland and Labrador Department of Mines and Energy, Mineral Development Division, Report 82-3, 59 p.

Stouge, S., and Boyce, W.D., 1983, Fossils of northwestern Newfoundland and southeastern Labrador: conodonts and trilobites: Newfoundland and Labrador Department of Mines and Energy, Mineral Development Division, Report 83-3, 55 p.

Taylor, J.F., Kennedy, D.J., Miller, J.F., and Repetski, J.E., 1991, Uppermost Cambrian slope deposits at Highgate Gorge, Vermont: a minor miscorrelation with major consequences for conodont- and trilobite-based chronocorrelation: Journal of Paleontology, v. 65, p. 855-863.

Taylor, J.F., Repetski, J.E., and Orndorff, R.C., 1992, The Stonehenge transgression: a rapid submergence of the central Appalachian platform in the early Ordovician, p. 409-418, in Webby, B.D., and Laurie, J.R., eds., Global perspectives on Ordovician geology: A.A. Balkema, Rotterdam.

Taylor, M.E., 1971, Biostratigraphy of the upper Cambrian (Upper Franconian-Trempeleauan Stages) in the central Great Basin, Nevada and Utah: University of California, Berkeley, unpublished Ph.D. dissertation, 427 p., 19 pls.

Taylor, M.E., 1987, Biostratigraphy and Paleobiogeography, p. 52-66, in Boardman, R.S., Cheetham, A.H., and Rowell, A.J., eds., Fossil Invertebrates: Blackwell Scientific Publications, Palo Alto, California.

Taylor, M.E., 1994, Upper Cambrian and lowermost Ordovician trilobite faunas from the Basin and Range Province, Nevada and Utah: U.S. Geological Survey Professional Paper, in preparation.

Taylor, M.E., and Cook, H.E., 1976, Continental shelf and slope facies in the Upper Cambrian and lowest Ordovician of Nevada: Brigham Young University, Geology Studies, v. 23, pt. 2, p. 181-214.

Taylor, M.E., and Halley, R.B., 1974, Systematics, environment, and biogeography of some Late Cambrian and Early Ordovician trilobites from eastern New York State: U.S. Geological Survey Professional Paper 834, 38 p., 4 pls.

Taylor, M.E., and Landing, Ed, 1982, Biostratigraphy of the Cambrian-Ordovician transition in the Bear River Range, Utah and Idaho, western United States, p. 181-191, in Bassett, M.G., and Dean, W.T., eds., The Cambrian-Ordovician Boundary: Sections, Fossil Distributions, and Correlations: National Museum of Wales (Cardiff), Geological Series no. 3.

Taylor, M.E., and Repetski, J.E., 1985, Early Ordovician eustatic sea-level changes in northern Utah and southeastern Idaho, p. 237-247, in Kerns, G.J. and Kerns, R.L., Jr., eds., Orogenic patterns and stratigraphy of north-central Utah and southeastern Idaho: Utah Geological Association Publication 14.

Taylor, M.E., Cook, H.E., and Miller, J.F., 1989, Late Cambrian and Early Ordovician biostratigraphy and depositional environments of the Whipple Cave Formation and House Limestone, central Egan Range, Nevada, p. 37-44, in Taylor, M.E., ed., Cambrian and Early Ordovician stratigraphy and paleontology of the basin and range province, western United States: American Geophysical Union, Washington, D.C.

Taylor, M.E., Landing, Ed, and Gillette, S.L., 1981, The Cambrian-Ordovician transition in the Bear River Range, Utah-Idaho: a preliminary evaluation, p. 222-227, in Taylor, M.E., ed., Short Papers for the Second International Symposium on the Cambrian System: U.S. Geological Survey Open-File Report 81-743.

Taylor, M.E., Repetski, J.E., and Sprinkle, James, 1981, Paleontology and biostratigraphy of the Whipple Cave Formation and lower House Limestone, Sawmill Canyon, Egan Range, Nevada, p. 73-77, in Taylor, M.E., and Palmer, A.R., eds., Guidebook for Field Trip 1, Cambrian stratigraphy and paleontology of the Great Basin and vicinity, western United States: Second International Symposium on the Cambrian System, Denver, Colorado.

Teichert, Curt, and Flower, R.H., 1983, Preservation of the name Canadian (Lower Ordovician): Newsletters on Stratigraphy, v. 12, no. 3, p. 162-165.

Terrel, F.M., 1973, Silicified trilobite zonation in the lower Fillmore Formation in western Utah: Brigham Young University Geology Studies, v. 20, pt.4, p. 67-90.

Thompson, T.L., 1991, Paleozoic Succession in Missouri, Part 2, Ordovician System: Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigation no. 70, 282 p.

Tipnis, R.S., and Goodwin, P.W., 1972, Lower Ordovician conodonts from the Stonehenge Formation of Pennsylvania and Maryland: Geological Society of America, North-Central Section, Abstracts with Programs, v. 4, no. 5, p. 352.

Tipnis, R.S., Chatterton, B.D.E., and Ludvigsen, Rolf, 1979, Ordovician conodont biostratigraphy of the southern District of Mackenzie, Canada, p. 39-91, *in* Stelck, C.R., and Chatterton, B.D.E., eds., Western and Arctic Canadian biostratigraphy: Geological Association of Canada, Special Paper 18.

Ulrich, E.O., and Cooper, G.A., 1938, Ozarkian and Canadian brachiopoda: Geological Society of America Special Paper 13, 323 p.

van Wamel, W.A., 1974, Conodont biostratigraphy of the Upper Cambrian and Lower Ordovician of northwestern Öland, southeastern Sweden: Utrecht Micropaleontological Bulletins, v. 10, 126 p.

Viira, Viive, Sergeeva, S., and Popov, Leonid, 1987, Earliest representatives of the genus *Cordylodus* (Conodonta) from Cambro-Ordovician boundary beds of North Estonia and Leningrad region: Proceedings of the Academy of Science of the Estonian SSR, Geology, v. 36, no. 4, p. 145-153.

Walcott, C.D., 1908a, Nomenclature of some Cambrian Cordilleran formations: Smithsonian Miscellaneous Collections, v. 53, no. 1, p. 1-12.

Walcott, D.C., 1908b, Cambrian sections of the Cordilleran area: Smithsonian Miscellaneous Collections, v. 53, no. 4, p. 167-230.

Walcott, C.D., 1925, Cambrian geology and paleontology 5. No. 3, Cambrian and Ozarkian trilobites: Smithsonian Miscellaneous Collections, v. 75, no. 3, p. 61-146.

Wang, Jin-bin, Cheng Sho-ude, Xian Li-wen, and Zhang Tai-rong, 1985, Stratigraphy and trilobite faunas of the Cambrian in the western part of northern Tian Shan, Xinjiang: Peoples Republic of China, Ministry of Geology and Mineral Resources, Geological Memoirs, Series Z, v. 4, 243 p.

Webby, B.D., and Nicoll, R.S., 1989, Australian Phanerozoic time scales. 2, Ordovician correlation chart: Bureau of Mineral Resources, Geology, and Geophysics, 47 p.

Westrop, S.R., 1986, Trilobites of the Upper Cambrian Sunwaptan Stage, southern Canadian Rocky Mountains, Alberta: Palaeontographica Canadiana, no. 3, 176 p., 40 pls.

Westrop, S.R., Landing, Ed, and Ludvigsen, Rolf, 1981, Upper Cambrian and Lower Ordovician trilobite and conodont biostratigraphy, Wilcox Peak, Jasper National Park, Alberta, p. 45-53, *in* Aitken, J.D., compiler, Taylor, M.E., Guidebook for Field Trip 2, The Cambrian System in the southern Canadian Rocky Mountains, Alberta and British Columbia: Second International Symposium on the Cambrian System, Denver, Colorado.

Westrop, S.R., and Ludvigsen, Rolf, 1986, Type species of the basal Ibexian trilobite *Corbinia* Walcott, 1924: Journal Paleontology, v. 60, no. 1, p. 68-75.

Whittington, H.B., 1948, A new Lower Ordovician trilobite: Journal of Paleontology, v. 22, p. 567-572.

Whittington, H.B., 1953, North American Bathyuridae and Leiostegiidae (Trilobita): Journal of Paleontology, v. 27, no. 5, p. 647-678.

Wilson, M.A., Palmer, T.J., Guensburg, T.E., Finton, C.D., and Kaufman, L.E., 1992, The development of an Early Ordovician hardground community in response to rapid sea-floor calcite precipitation: Lethaia, v. 25, p. 19-34.

Winston, Don, and Nicholls, Harry, 1967, Late Cambrian and Early Ordovician faunas from the Wilberns Formation of central Texas: Journal of Paleontology, v. 41, no. 1, p. 66-96.

Wright, J.W., Miller, J.F., and Holser, W.T., 1987, Conodont chemostratigraphy across the Cambrian-Ordovician boundary: western U.S.A. and southeast China, p. 256-283, *in* Austin, R.L., ed., Conodonts: Investigative Techniques and Applications: Ellis Horwood Limited, Chichester, U.K., 422 p.

Young, G.E., 1973, An Ordovician (Arenigian) trilobite fauna of great diversity from the Ibex area, western Utah: Brigham Young University Geology Studies, v. 20, pt. 4, p. 91-115.

--END--