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CONTENTS

A New Large Theropod Dinosaur from the Upper Jurassic of Colorado	Peter M. Galton and
	James A. Jensen
Preliminary Zonations of Lower Ordovician of Western Utah by Various Taxa	Lehi F. Hintze
Environmental Significance of Pterosaur Tracks in the Navajo Sandstone (Jurassic), Grand County, Utah	William Lee Stokes and James H. Madsen, Jr.
Stratigraphy and Archaeocyathans of Lower Cambrian Strata of Old Douglas Mountain, Stevens County, Washington	George L. Hampton III
Thermoluminescence Dating of Quaternary Basalts: Continental Basalts from the Eastern Margin of the Basin and Range Province, Utah and Northern Arizona	Richard D. Holmes
Upper Devonian and Lower Mississippian Strata on the Flanks of the Western Uintas	W. Carl Spreng
Sedimentary Environment of the Cretaceous Ferron Sandstone near Caineville, Utah	Jack Uresk
Carbonate Mud Mounds from the Lower Ordovician Wah Wah Limestone of the Ibex Area, Western Millard County, Western Utah	Danny J. Wyatt

Publications and Maps of the Geology Department



Cover: Cretaceous coals near Castle Gate, Utah.

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CONTENTS

A NEW LARGE THEROPOD DINOSAUR FROM		Abstract	21
THE UPPER JURASSIC OF COLORADO	1	Introduction	21
Abstract	1	Navajo Sandstone	21
Introduction	1	Geologic setting of the Sand Flats locality	21
	1 1	Postulated sequence of events	23
Acknowledgments		Modern analogy	23
Systematic section	1 4	Petrology	24
Description and comparisons		Discussion and conclusions	25
Humerus, radius, ulna	4	Acknowledgments	26
Manus	4	References cited	26
Pelvic girdle	6	Figures	
Discussion	8	1. Discovery site of pterosaur tracks	21
	11	2. Near view of remnant on ridge above discovery	
Figures	2	site	22
1. Humerus, radius, and ulna	2	One of two track-marked slabs in place of discov-	
2. Articulated forelimb and pelvic girdle	3	ery	22
3. Forelimbs of saurischian dinosaurs	5	4. Photomicrograph: Hematite-cemented sandstone	23
4. Manus	. 6	5. Photomicrograph: Track-bearing sandstone	24
5. Prosauropod manus-digit I	7	6. Near view of track-marked surface	25
6. Ilium and pubis	8,9		
7. Articulated pelvic girdle	10	STRATIGRAPHY AND ARCHAEOCYATHANS OF	
8. Pelvic girdles of saurischian dinosaurs	11	LOWER CAMBRIAN STRATA OF OLD DOUGLAS	
Tables		MOUNTAIN, STEVENS COUNTY, WASHING-	
1. Measurements of figured forelimb bones	4	TON	27
2. Ratios for forelimb bones of carnosaurian thero-	,	Introduction	27
pods	. 4	Location	27
		Previous work	27
PRELIMINARY ZONATIONS OF LOWER ORDO-		Methods	28
VICIAN OF WESTERN UTAH BY VARIOUS		Stratigraphy	28
TAXA	13	Gypsy Quartzite	29
Abstract	13	Maitlen Formation	29
Introduction	13	Structure	32
Trilobite zones	13	Paleontology of carbonate units	33
Conodont zones	14	Systematic paleontology	33
Graptolite zones	15	Introductory remarks	33
Cephalopod zones	15	Classification	34
Other fossil groups	16	Systematics	34
Summary	17	Conclusions	38
Annotated reference list	18	Acknowledgments	38
Figures		References cited	39
1. Geologic map of Utah	13		22
2. Trilobite zones in western Utah	14	Figures 1. Index map	27
3. Ranges of conodonts form—species	14	1. Index map	28
4. Preliminary conodont zones/geologic forma-	1.4	2. View of Douglas Lake	
	14	3. Geologic map	30
5. Graptolite zones/trilobite zones		4. Correlation chart	31
	15	5. Stratigraphic column of study area	32
6. Ranges of brachiopod species	15	6. Fossil detritus lens	33
7. Brachiopod zones/trilobite zones	15	7. Drag folds	34
8. Inarticulate brachiopod occurrences	16 16	Plates	
9. Cephalopod occurrences	16	1. Trilobites, sponges, echinoderm plates, bryo-	1-
10. Gastropod occurrences	16	zoan(?), archaeocyathans	41
11. Sponge occurrences	16	2. Archaeocyathan fauna	43
12. Ostracod occurrences	17	3. Archaeocyathan fauna	45
13. Echinoderm occurrences	17	4. Archaeocyathan fauna	47
14. Occurrences of bryozoa, pelecypods, and corals	17	5. Archaeocyathan fauna	49
73.77470.03.776747 0103.777643.707 0.7 57776			
ENVIRONMENTAL SIGNIFICANCE OF PTERO-		THERMOLUMINESCENCE DATING OF QUA-	
SAUR TRACKS IN THE NAVAJO SANDSTONE		TERNARY BASALTS: CONTINENTAL BASALTS	
(JURASSIC), GRAND COUNTY, UTAH	21	FROM THE EASTERN MARGIN OF THE BASIN	

AND RANGE PROVINCE, UTAH AND NORTH-		Figures	
ERN ARIZONA	51	1. Index map	67
Abstract	51	2. Stratigraphic sections: Beaver Creek and South	,_
Introduction	51	Fork	68
TL samples: Collection and preparation	51	3. Composite stratigraphic section: Smith and	
Radioelement determination and dose rate calculations	52	Morehouse Canyon	69
Radioelement determinations	53	4. Stratigraphic sections: Gardner Fork and Du-	
Dose rate calculations	54	chesne River	70
TL measurements	55	5. Lithologic correlation diagram	71
Specific TL calculations and TL age dating	56	6. Unconformable contact	72
Petrochemical variations	56	7. Unconformable contact	72
Specific TL ratio calculations	58	8. Photomicrograph: Dolomitic pelsparite	73
Discussion of the TL results	60	9. Photomicrograph: Dolomicrite	73
Summary and conclusions	61	10. Photomicrograph: Dolomicrite with stylolites	74
Acknowledgments	62	11. Map: Possible extensions of uppermost Devon-	
	62	ian deposition	76
AppendixReferences cited	64	12. Ranges of selected megafauna	77
	04		
Figures	52	SEDIMENTARY ENVIRONMENT OF THE CRE-	
1. Index map, western United States	52 52	TACEOUS FERRON SANDSTONE NEAR CAIN-	
2. Feldspar compositions: Ternary diagrams	52 56	VILLE, UTAH	81
3. Typical glow curves		Abstract	81
4. Alkalies vs. silica variation diagram	58	Introduction	81
5. Alumina vs. silica variation diagram	58 50	Location	81
6. AFM variation diagram	58 50	Previous work	81
7. Type I TL calibration	59 50	Methods	82
8. Type II TL calibration	59	Acknowledgments	82
9. Similar slopes of TL calibrations	61	Geologic setting	82
10. Hypothetical development and saturation of TL.	61	Lithologies	83
Tables		Sandstone	83
Microprobe analysis of feldspars	53	Siltstone	86
2. Interlaboratory comparison of U and Th determi-	7,	•	86
nations: Standard samples	53	Mudstone Coal and carbonaceous shale	86
3. Interlaboratory comparison of U and Th determi-	75	Other rock types	
nations: Basaltic samples	54	Other rock types	87
4. U, Th, and K ₂ O determinations	54	Penalitianal significance of lithologies	87
5. Dose rate calculations	55	Depositional significance of lithologies	87
6. TL measurements	57	Sandstone	87
7. Specific TL ratio calculations		Siltstone	88 88
7. or	00	Gray and green mudstone Purple shale	88
		Coal and carbonaceous shale	89
UPPER DEVONIAN AND LOWER MISSISSIPPIAN			90
STRATA ON THE FLANKS OF THE WESTERN		Ironstone	92
UINTA MOUNTAINS, UTAH	67	Economic possibilities	92
Abstract	67	Uranium	93
Introduction	67	Oil and gas	93
Acknowledgments	67	Titanium	93 93
Stratigraphy	67		93
General lithologic sequences	67	JetGravel	93
Nomenclature	68	Depositional history	93
Unconformities	70	Observations	99
Dolomitization	70	Coal quality and thickness	99
Rhythmic sedimentation	71	Conclusion	99
Method of investigation	73		99
Beaver Creek	73	Appendix 2	100
South Fork	74	Appendix 2 References cited	100
Smith and Morehouse Canyon	74	Figures	100
Gardner Fork	74		01
Duchesne River	74	1. Index map	81
Depositional history	75	2. Measured section location map	83 94
Biostratigraphy	75	3. Fence diagram	84
Summary	78	Geologic map Normal fault related to subsidence	85 86
Addendum	78		86
References cited	78	6. Paraphyllanthoxylon-like log in upper coal seam	87
20002011000 01002	, 5	7. Paleogeologic map of large sandstone	88

0	Sulfur concentration man	90	Total for an energy	106
	Sulfur concentration map	91	Fossil fragments	105
9. 10	Flattened log lacking woodlike structure	-	Pellets	105
		91	Intraclasts	105
	Ironstone concretion with wood core	91	Spar filling	105
	Ironstone concretion	91	Trace occurrences	105
	In situ stump	92	Paleontology	105
	Sandstone-ironstone transition	92	Particle size analysis	106
	Abandoned channel-fill sequence	94	Interpretation	107
16.	Lower coal isopach	94	Surrounding beds	107
17.	Paleogeologic map of large channel above lower		Underlying beds	107
	coal	95	Lateral beds	107
18.	Paleogeologic map of channel-fill and splay		Overlying beds	107
	above lower coal	95	Discussion	109
	"Stray" coal isopach	95	Depositional model and modern analog	109
	Middle coal isopach	95	Conclusions	111
	Small channel-fill sandstone	96	Summary	113
22.	Local structural feature east of measured section		Acknowledgments	113
	40	96	References cited	113
23.	Ironstone over sandstone north of measured sec-		Figures	
	tion 12	96	1. Index map of study area	101
24.	Paleogeologic map of interval between middle		2. Overall view of study area and lens horizon	102
	coal and purple marker unit	97	3. Drillings of lens interiors	102
25.	Paleogeologic map of purple marker unit hori-		4. Lens 14 and measured sections	103
	zon	97	5. Close view of lens 14	103
26.	Paleogeologic map of small channels above		6. Photomicrograph: spar-filled burrows and fossil	
	purple marker horizon	97	debris	104
27.	Paleogeologic map of later sequence of channels		7. Photomicrograph: Trilobites and brachiopods	104
_,.	above purple horizon	98	8. Photomicrograph: Mudstone, lens 14, 114-cm	10
28	Paleogeologic map of upper coal isopach	98		104
29	Paleogeologic map of interval between upper	,0	level	10-
27.	coal and Blue Gate Shale	99		104
	Coal and Dide Gate onale	//	level	104
			10. Photomicrograph: Mudstone showing burrow	105
CARE	ONATE MUD MOUNDS FROM THE		mottling	105
	ER ORDOVICIAN WAH WAH LIMESTONE		11. Photomicrograph: Mottled mudstone, lens 14,	106
OF TE	HE IBEX AREA, WESTERN MILLARD COUN-		50-cm level	105
	VESTERN UTAH	101	12. Photomicrograph: Wackestone-packstone from	106
	·		exterior of lens 14	105
_	ct	101	13. Photomicrograph: Sponge fragment	105
	uction	101	14. Textural classification of constituent elements,	
	cation	101	lens interiors	100
	eologic setting	101	15. Exterior, lens 17	107
M	ethods	102	16. Map of study area lenses	108
Τe	rminology	103	17. Composition of carbonate lenses	108
Pr	evious work	103	18. Measured sections, lens-bearing horizon of study	
Lithol	ogy	103	area	110
Le	ns interior	103	19. Histograms: Percent of skeletal grains by 1-mm	
	Description	103	size intervals	112
	Composition of lenses	104	20. Photomicrograph: Mudstone, unit 3, section	
	Burrows	104	14C	113
	Burrowed matrix	104	21. Photomicrograph: Wackestone of unit 3, section	
	Unburrowed matrix	105	14C	113

Preliminary Zonations of Lower Ordovician of Western Utah by Various Taxa

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ABSTRACT.—Lower Ordovician strata of western Utah contain probably the most diverse and best-preserved fossil assemblages for rocks of this age found anywhere in the world. The trilobite zonation, established 25 years ago by Ross and Hintze, has been supplemented by zonations of other groups by various workers in recent years. Brachiopod zones were established by Jensen (1967), graptolite zones by Braithwaite (1976), and conodont zones for the lowest part of the section by Miller (1969), and for the remainder of the section by Ethington and Clark (1971). Other taxa that occur in this sequence have been documented: bryozoa by Hinds (1970), crinoids by Lane (1970), cystoids by Paul (1972), pelecypods by Pojera (1971), some of the cephalopods by Flower (1968a, 1968b, 1976), some of the ostracodes by Berdan (1976a,b), and additional trilobites by Demeter (1973), Taylor (1971), Terrell (1973), and Young (1973). Sponge-algal patch reefs have been described by Roberts (1968) and Church (1974).

Some faunal elements are still in course of study and will be published as completed. These include conodonts by R. L. Ethington, sponges by J. K. Rigby, additional cephalopods by R. H. Flower, additional ostracodes by J. M. Berdan, as well as corals by J. K. Rigby, starfish by J. S. Branstrator, inarticulate brachiopods by A. J. Rowell, edioasteroids by B. M. Bell, and gastropods and additional trilobites. Work by Miller (1969) and Taylor (1971) indicates that this section may be important in resolving worldwide Cambro-Ordovician boundary problems because it contains a sequence of trilobite and conodont faunas that straddle the boundary interval. An annotated bibliography summaizes work published on the Lower Ordovician of western. Utah to date.

INTRODUCTION

Twenty-five years ago Reuben Ross and I, as students at Yale and Columbia universities, established trilobite zones for the Lower Ordovician strata in Utah. He worked in the Garden City Limestone in northeastern Utah (Ross 1951) and I in the Pogonip Group of western Utah and eastern Nevada (Hintze 1952). It ultimately became apparent that one particular area in western Utah, known as the Ibex area (see figure 1 for location), was probably the best place in North America to obtain, not only trilobites, but also a rather complete assemblage of almost all other life forms of Lower Ordovician age. The National Science Foundation funded a three-year cooperative study in 1965 aimed at documenting all the faunal elements, and this paper is a report on the current status of that documentation. It is not intended as a comprehensive comparative discussion of Ordovician zonations from other localities.

A number of papers have been published during the past decade describing aspects of Lower Ordovician strata of western Utah. Stratigraphic units have been redescribed (Hintze 1973) and geologic maps published (Hintze 1974a, 1974b). Various faunal groups have been documented: trilobites by Demeter (1973), Taylor (1971), Terrell (1973), Young (1973); brachiopods by Jensen (1967); graptolites by Braithwaite (1976); bryozoa by Hinds (1970); crinoids by Lane (1970); cystoids by Paul (1972); pelecypods by Pojeta (1971); some of the cephalopods by Flower (1968a, 1968b, 1976); some of the ostracodes by Berdan (1976); and some of the conodonts by Miller (1969). Sponge-algal patch reefs have been described by Roberts (1968) and Church (1974).

In addition to the work already published a number of important papers are in course of preparation. The status of such studies is given in the following pages as far as possible. Most of the fossil collecting upon which this work is based was done during the three-year period funded by the initial NSF grant. Subsequent mapping by Hintze was supported by the Utah Geological and Mineral Survey and the U.S. Geological Survey.

Some contributors, notably Clark, Ethington, Flower, Miller, Rigby, and Taylor, have become involved through their own regional studies of particular faunal groups.

TRILOBITE ZONES

Ross's work in northeastern Utah preceded mine, and he established a series of letter faunal assemblage zones, shown in figure 2 and all subsequent figures, that I followed with slight modifications. He and I shared a fantastic sequence of trilobites which would probably have remained mostly undescribed except for the fortuitous circumstance that the trilobites were silicified throughout most of the Lower Ordovician stratigraphic section, around 1000 m (3000 feet) in thickness. This mode of preservation enabled us to collect trilobites in somewhat the same way one collects conodonts—by obtaining samples at closely spaced intervals throughout the section. Ross and I identified more than 100 trilobite species and about half that many genera. Seventy percent of the Utah trilobites are still known only from western North America. The remaining 30 percent have been recognized elsewhere. The lettered zones in

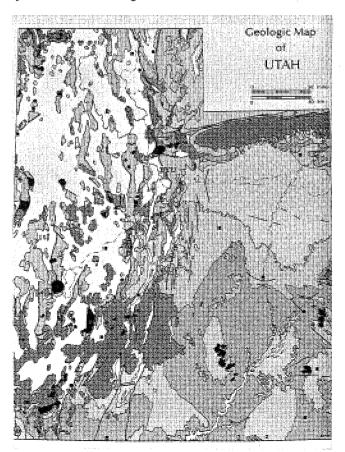


FIGURE 1.—Geologic map of Utah. Ibex area indicated by large black dot in west central part of the state.

14 L. F. HINTZE

the middle of figure 2 represent the stratigraphic interval through which each trilobite assemblage occurs. The zone ranges are shown in figure 2 juxtaposed against lithologic changes as indicated by formation and member boundaries. More than half the zone boundaries coincide with lithologic changes. Thickness of the lithologic units is shown in feet alongside the column.

In addition to the Ross-Hintze trilobite zones I have included below them the *Missisquoia* zone, currently recognized as lowest Ordovician, and three uppermost Cambrian trilobite zones. Trilobites are only occasionally found silicified in these four zones, and additional bed-by-bed collecting will be needed to establish the true extent of the zones here shown separated by some gaps. There are only two gaps between zones in the overlying Ordovician: the first is an unfossiliferous 30 m (100 ft.) beween zones D and E in the lower Fillmore Formation, and the second is in the quartzites above zone N. Zone O has not been identified by trilobites at Ibex. Its fauna consists chiefly of corals (*Eofletcheria*) and brachiopods.

CONODONT ZONES

In terms of continuity of occurrence within the Ibex sequence the conodonts are the only fossil group other than the trilobites that forms a near-continuum. At the same time we were collecting at Ibex, D. L. Clark and R. L. Ethington were undertaking a conodont survey of the Great Basin. Ethington is currently describing the Ibex Ordovician conodonts; the Upper Cambrian conodonts have been described by Miller (1969). The zonation shown on figure 3 is tentative, derived in part from the preliminary zonation presented by Ethington and Clark (1971) and from Miller (1969) and from handout sheets that Miller prepared for a Friends of the Cambrian field trip to the Ibex area in 1975.

The conodont zonation shown in figure 3 is essentially first appearance or "Oppel-zonation" and thus different from the trilobite assemblage-zone. Ranges of about 90 conodont species are shown here, beginning with the oldest first appearance at the lower left in Miller's Proconodontus muelleri Subzone 1 of his Proconodontus Zone I. Miller's Roman-numeral zones and subzones are refinements of Fauna A of Ethington and Clark (1971). Their faunas B through E continue upwards to overlap the 1-2-3-4 system employed by Sweet, Ethington, and Barnes (1971) for Middle and Upper Ordovician conodont faunas.

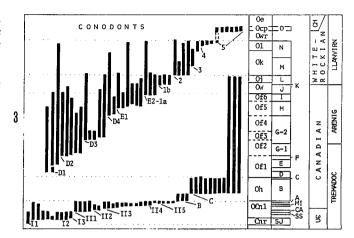


FIGURE 3.-Ranges of conodonts form-species.

Most Ordovician conodont occurrences shown in figure 3 are derived from as yet unpublished conodont ranges supplied to me by R. L. Ethington. I have taken the liberty of designating subzones D1, D2 through E2 for the purpose of comparing the degree of correspondence of conodont zonation at Ibex with that of trilobites. This zonation is preliminary. Ethington will propose a more formal zonation later. Figure 4 compares the lithologic breaks on the left column, including footages, with the trilobite zones in the middle column, and the informal conodont zones in the right column. At the base of the section there are several horizons where the breaks in lithologies, trilobite zones, and conodont zones are the same:

- 1-2. Red Tops-Saukiella junia-Miller's Zone I, subzones 1 +
- 3-4. House Ls-B-C Zones-conodont faunas B + C

In the middle and upper parts of the chart, the breaks correspond at only three other horizons:

- 5. Base Of5-Zone H-Zone D4
- 6. Base Wah Wah-Zone J-Zone 1b
- 7. Base Kanosh-Zone M-Zone 2, almost

One of the most striking conodont first appearances is that marking the base of Fauna El. Note that this occurs within trilobite Zone H.

	Eureka Quartzite Crystal Peak Dolo Watson Ranch Qtzt Lehman Formation Kanosh Shale Juab Limestone	540' 85 250 210 560	Ocp Owr Ol Ok Oj	- О — И М	Pseudoolenoides acicauda - Illaenus Pseudoolenoides dilectus - Bathyurellus Ectenonotus	M M M M M M M M M M M M M M M M M M M	LLANVIRN
	Wah Wah Limestone	250 170	Ow O£6	J	Pseudocybele naeuta Presbynileus ibexensis		
Z 18 s inf	Fillmore Formation 1803' six	310 324 194	Of5 Of4 Of3	Н G-2	Trigonocerca typica Protopliomerella contracta	z «	ARENIG
	informal members	320	Of2	G-1 - F -	Hintzeia celsaora Rossaspis superciliosa	AD I	
		485	Of1	E D	Tesselacauda Leiostegium – Kainella C – Paraplethopeltis	CAN	8
	House Limestone	500	Oh	В	Symphysurina		FREMADOC
	Notch Lava Dam Mbr 3		0€n1	==	A -Missisquoia		۲
	Peak Fm Red Tops Mor		Chr	SJ	-Corbinia apopsis Saukiella serotina Saukiella junia	UPPER CAMBRIAN	

FIGURE Figure 2.—Trilobite zones in western Utah plotted against geologic formations; thickness indicated in feet.

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FIGURE 4.—Preliminary conodont zones plotted against geologic formations in western Utah. Thickness of formations shown in feet.

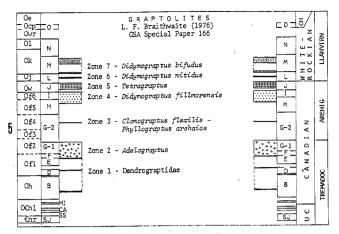


FIGURE 5.-Graptolite zones in western Utah plotted against trilobite zones.

The degree of zonation obtained using conodonts is about the same fineness as that using trilobites. Probably both could not be much further refined at Ibex without a great deal of additional collecting. Ethington (letter dated March 3, 1977) says that conodonts of the Juab Limestone mark the base of the Whiterock Stage as inferred from trilobites and brachiopods, and that conodonts of the Crystal Peak Dolomite are like those of the type Chazy Formation in New York.

GRAPTOLITE ZONES

Braithwaite's graptolite study done 10 years ago has finally been published (1976), and the results are summarized in figure 5. He identified 45 species from 13 genera and made valuable contributions to graptolite ontogenetic knowledge. The graptolites at Ibex occur in light olive shales interbedded within the limestones, and the graptolites are beautifully preserved as translucent, amber, resinous films. Unfortunately, there are many gaps in the graptolite record at Ibex. Braithwaite noted that there seemed to be more provinciality to the Ibex graptolites than he expected. He even noted that the western Utah graptolite assemblages differ somewhat from those of northeastern Utah.

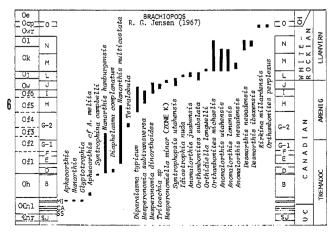


FIGURE 6.-Ranges of brachiopod species in western Utah.

Broadly speaking, Braithwaite's zone 1 corresponds with Berry's Anisograptus zone of the Marathon region of west Texas. Zone 2 corresponds with Berry's Adelograptus-Clonograptus zone. Thereafter the correlation of the Texas-Utah section breaks down except for the useful Didymograptus bifidus zone, common to both regions. The Zone 5 Tetragraptus in Utah is no doubt comparable to some part of Berry's five Tetragraptus zones. The Didymograptus bifidus zone seems to establish the correlation with the British Llanvirnian.

BRACHIOPOD ZONES

Next to trilobites and conodonts, articulate brachiopods are the most continuously distributed fossils in the Ibex section. Figure 6 shows the range distribution of the 27 taxa obtained by Jensen (1967). Except for those at the very top (*Orthoambonites perplexus* in the Crystal Peak Dolomite), none of the brachiopods are silicified.

Figure 7 shows the eight brachiopod zones established by Jensen for western Utah. Most of the zones are characterized by scattered individual shells, but a few zones are coquinas, for example, Syntrophina, Hesperonomiella minor, and some horizons in the Anomalorthis, Desmorthis and Kirkina zones.

The sequence of appearance of brachiopods at Ibex is slightly different from that in the type Whiterock of central Nevada. Whereas *Orthidiella* occurs as the lowest Whiterock fauna in Nevada, it occurs in western Utah somewhat above the appearance of *Anomalorthis*. And whereas in Nevada *Anomalorthis* appears above *Desmorthis*, at Ibex the reverse is true.

Inarticulate brachiopods have not been pursued very vigorously at Ibex. They are not abundant and have yet to be described. A. J. Rowell identified the forms we sent him as shown in figure 8. Inarticulates seem to be more valuable for paleoenvironmental interpretation than for time indicators.

CEPHALOPOD ZONES

Cephalopods constitute an important but not abundant part of the Ibex faunas. Rousseau Flower has been working on these faunas since before the inception of the project and is still in course of publishing his results, having been distracted by other cephalopods elsewhere. The cephalopod identifications shown in figure 9 have been kindly furnished by Dr. Flower.

Flower identifies his "First Endoceroid" zone in the upper

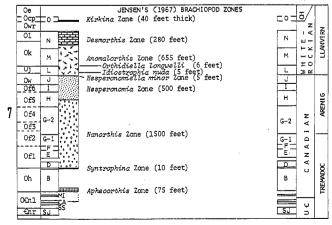


FIGURE 7.-Brachiopod zones in western Utah plotted against trilobite zones.

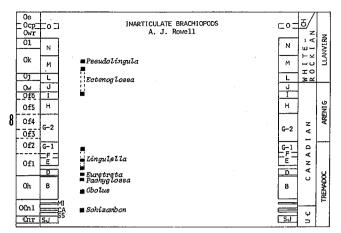


FIGURE 8.-Inarticulate brachiopod occurrences in western Utah.

Zone D at Ibex enabling its correlation with the Cooks Formation of the El Paso Group, the lower Manitou of Colorado, the Goodwin of Nevada, the lower Gorman of central Texas, the Roubidoux of Missouri, the Fort Ann of New York, and the Longview of Virginia.

His "First Pilocerid" zone occurs in Zone E at Ibex. This zone is also recognized in the El Paso, Manitou, and Garden City formations.

Zones F, G, and H at Ibex have yielded a few baltoceratids and protocycloceratids of poor correlation value. Zone I yielded forms which suggest correlation with the Fort Cassin of New York, the Smithville of Arkansas, and the Scenic Drive of El Paso.

Zone J, the Wah Wah Limestone, includes Buttsoceras which indicates latest Canadian and correlation with the Florida Formation of the El Paso Group and the Odenville of Alabama

Zone L, Juab Limestone, contains a rather abundant cephalopod fauna comparable to that of the Oil Creek of Oklahoma.

Zone M of the Kanosh Shale has as its commonest form a Rossoceras similar to those in the Palliseria Zone of the Antelope Valley Limestone of Nevada.

Zone N contains cephalopods similar to those of the sponge beds at Ike's Canyon in central Nevada.

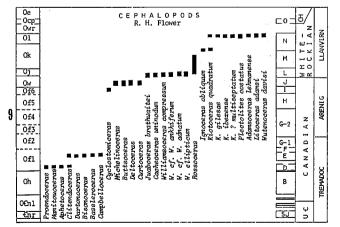


FIGURE 9.-Cephalopod occurrences in western Utah.

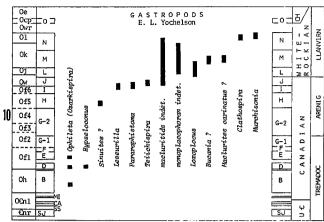


FIGURE 10.-Gastropod occurrences in western Utah.

Zone O of the Crystal Peak Dolomite has not yielded cephalopods well enough preserved to be useful.

In all, although cephalopods are localized in relatively few horizons at Ibex, through Flower's efforts they have proved to be useful in long distance correlations.

OTHER FOSSIL GROUPS

Gastropods

L. F. HINTZE

Gastropods have been rather neglected at Ibex. This is probably because of the way they are preserved. None are silicified. Most are steinkerns. Only occasional specimens show external markings and form of the shell exterior.

Ellis Yochelson has dutifully provided the identifications shown in figure 10. What the gastropods at Ibex really need is a friend who has the interest and skill to coax some shell-bearing specimens out of these reluctant rocks.

Sponges

Sponges occur at only a few stratigraphic horizons at Ibex apparently because favorable conditions were attained only temporarily in the high-energy shallow-water environment represented by the clastic limestones that constitute most of the Ordovician section at Ibex. Sponges seem to enjoy an association with algae and quasialgal organisms, and together they formed patch reefs at certain horizons. The identifications shown in figure 11 were provided by J. K. Rigby, who is describing the

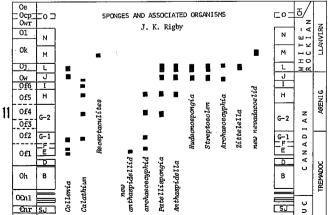


FIGURE 11.-Sponge occurrences in western Utah.

sponge fauna. Rigby (1962, 1965, 1971) has established a preliminary sponge zonation based on his collections from Ibex. He plans a comprehensive treatment of Ordovician sponges in the near future.

Ostracodes

Berdan (1976) has recently described the species whose distribution is charted in figure 12. These ostracodes occur in many Middle Ordovician sections in the Great Basin, and Berdan's formalization of their names will encourage their utility as time indicators elsewhere. Heretofore most published references called almost all Ordovician ostracodes from the west under the catchall "Leperditia bivia". Now that this ostracode sequence from western Utah has been described, an ostracode zonation may prove feasible as other sequential collections are examined.

Echinoderms

Echinoderm fragments are abundant as a component of some of the clastic limestones that constitute much of the Ordovician section at Ibex. Despite their relative abundance throughout the section, only a few specimens complete enough to be nameable have been found. The oldest, a cystoid, is known from several well-preserved specimens found on a bedding surface in the Lower Fillmore Formation and was discovered by Eugene Demeter who was searching for trilobites. This cystoid was described by Paul (1972) who noted that it was the first Ordovician cystoid reported from the western United States, and that it is the oldest pectinirhomb-bearing cystoid known.

Lane (1970) described the ten crinoid specimens found to date, most of them from the Kanosh Shale. Two edrioasteroids have been found, and one is currently being described by Bruce Bell. Jon Branstrator has the starfish under study.

Echinoderms are useful mostly in evolutionary studies. They are too scarce to be used for much else.

Bryozoa

Hinds (1970) documented the bryozoa at Ibex as shown in figure 14. He recognized six species, all new, but because of scarcity and poor preservation he named only two formal species. The bryozoa at Ibex are most like those in the Oil Creek and McLish formations of Oklahoma.

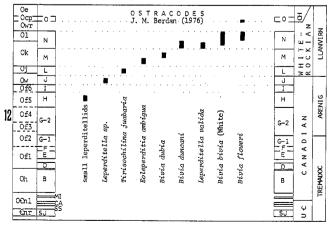


FIGURE 12.-Ostracod occurrences in western Utah.

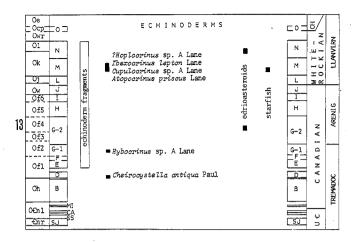


FIGURE 13 - Echinoderm occurrences in western Utah.

Pelecypods

Pelecypods are scarce in the Utah Ordovician, and none have been found well enough preserved for more than generic assignment. *Modiolopsis* is the most common form. It occurs in matter of thin, crushed shells in the upper Kanosh and Lehman formations. Pelecypod identifications shown in figure 14 were provided by John Pojeta.

Coral

Corals make their appearance near the top of the pre-Eureka rocks at Ibex as shown in figure 14. They are some of the oldest corals known. *Lichenaria*, the oldest, occurs as small, thumbnail-size specimens in the Lehman Formation. *Eofletcheria* forms bedded masses up to 1.5m (5 feet) thick in the Crystal Peak Dolomite. These forms have been described by Rigby and Hintze (1977).

SUMMARY

The figures accompanying this paper express the range of fossils known from the Lower Ordovician reference section in western Utah. Most of the forms have now been described, but a few important groups, notably the conodonts, remain to be published. When the task is completed, the documentation of the several taxa from the same stratigraphic sequence will materially assist with correlation problems in other areas.

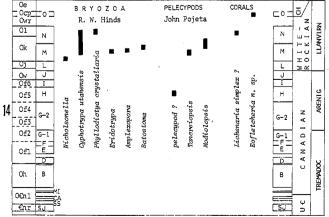


FIGURE 14.-Occurrences of bryozoa, pelecypods, and corals in western Utah.

L. F. HINTZE 18

ANNOTATED LIST OF PUBLICATIONS

RELATED TO LOWER ORDOVICIAN OF WESTERN UTAH

Berdan, J. M., 1976a, Middle Ordovician Leperditicopid ostracodes from the Ibex area, Millard County, western Utah: Brigham Young University Geology Studies, v. 23, pt. 3, p. 37-65.

Described 8 taxa including 2 new genera, Bivia and Tirisochilina, and 5

Berdan, J. M., 1976b, Middle Ordovician ostracodes from the Great Basin: Geological Society of America Abstracts with Programs, v. 8, no. 6, p. 773.

Braithwaite, L. F., 1976, Graptolites from the Lower Ordovician Pogonip Group of western Utah: Geological Society of America Special Paper 166,

Recognized 45 species from 13 genera; described 15 new species; traced 12 ontogentic and/or early astogentic developmental stages; established 7

graptolite zones for this area.

Church, S. B., 1974, Lower Ordovician patch reefs in western Utah: Brigham Young University Geology Studies, v. 21, pt. 3, p. 41-62.
Stromatolitic algae stabilized the substrate providing a base for anthaspidellid sponge reef framework which harbored trilobites, brachiopods, gas-

tropods, nautiloids, crinoids, and burrowing organisms.

Demeter, E. J., 1973, Lower Ordovician pliomend trilobites from western Utah:

Brigham Young University Geology Studies, v. 20, pt. 4, p. 35-65.

Traced evolution of 7 genera of pliomerid trilobites through 412 m (1,350 feet) of Fillmore Formation. Defined 3 new species and reassigned several species.

Duncan, H., 1956, Ordovician and Silunan coral faunas of western United States: U.S. Geological Survey Bulletin 1021-F. p. 209-36, pls. 21-27.
 Pages 214-16 listed Eofletcheria from Crystal Peak Dolomite.

Ethington, R. L., and Clark, D. L., 1971, Lower Ordovician conodonts in North America: In Sweet, W. C., and Bergström, S. M., Symposium on conodont biostratigraphy: Geological Society of America Memoir 127, p. 63-82.

Identified 5 Cambro-Ordovician conodont assemblages in western Utah

and listed typical representatives.

Flower, R. H., 1968a, The first great expansion of the actinoceroids: New Mexico Bureau of Mines and Mineral Resources Memoir 19, pt. 1, p. 1-16, 13

pls. Described 2 new species from western Utah, Wutinoceres davisi, and

Flower, R. H., 1968b, Some additional Whiterock cephalopods: New Mexico Bureau of Mines and Mineral Resources Memoir 19, pt. 2, p. 19-55, 17

Described 2 new species from western Utah, Juaboceras braithwaitei, and Plectolites costatus. Noted occurrence of Williamsoceras and Rossoceras in the Juab Limestone.

Flower, R. H., 1971, Cephalopods of the Whiterock Stage: Smithsonian Contributions to Paleobiology, v. 3, p. 101-11. Noted occurrence of *Kiotoceras* in Zone N at Ibex, and *Buttsoceras* in

Zones J and K at Ibex.

Flower, R. H., 1976, Some Whiterock and Chazy endoceroids: New Mexico Bureau of Mines and Mineral Resources Memoir 28, pt. 2, p. 13-39, 16

Described 9 new species from western Utah: Kiotoceras gilesae, Kiotoceras ibexense, Kiotoceras multiseptatum, Ignoceras obliquum, Williamsoceras cf. ank-

hiferum, Williamsoceras ellipticum, Cacheoceras uninodum.

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

Described 6 new genera and 19 new species from the Wah Wah Lime-stone of western Utah and the Florida Mountains Formation of Texas-New Mexico. The new genera were Amsleroceras, Rangeroceras, Venefico-New Mexico. The new genera were Amsteroceras, Kangeroceras, Venefico-ceras, Bakeroceras, Wardoceras, and Enigmoceras. The new species were Amsteroceras gracile, Rangeroceras hintzei, Rhabdiferoceras planiseptatum, Vene-ficoceras susanae, Protocycloceras laswelli, P. Rhabdiferum, Catoraphiceras ibexense, C. pearsonae, C. sinuatum, C. staceyae, Kyminoceras kottlowskii, Rudolfoceras keadyi, R. russelli, Bakeroceras wahwahense, Manchuroceras lemmonei, Michelinoceras floridaense, M. melleni, Wardoceras orygoforme, and Eniomoceras diaboli.

Flower, R. H., and Duncan, H. M., 1975, Some problems in coral phylogeny and classification: American Paleontological Bulletin, v. 67, no. 287, p. 175-92.

Page 182 noted occurrence and correlation of Ordovician corals of Utah-Nevada.

 Fortey, R. A., 1974, A new pelagic trilobite from the Ordovician of Spitsbergen, Ireland, and Utah: Palaeontology, v. 17, pt. 1, p. 111-23.
 Lists free check of Opipeuter inconnivus from Fillmore Limestone Zone I of western Utah. Reassigned Utah Remopleuridiella species, for example Young's Remopleuridiella angularis, to Opipeuter.

Hinds, R. W., 1970, Ordovician bryozoa from the Pogonip Group of Millard County, western Utah: Brigham Young University Geology Studies, v. 17, pt, 1, p. 19-40.

Recognized 6 genera of bryozoans from western Utah. Described 2 new species, Dianulites utahensis and Phyllodictya crystalaria.

Hintze, L. F., 1951, Lower Ordovician detailed stratigraphic sections for western Utah and eastern Nevada: Utah Geological and Mineralogical Survey, Bulletin 39, 99p. Established 6 new Ordovician formations and traced their extent in west-

ern Utah and eastern Nevada.

Hintze, L. F., 1952, Lower Ordovician trilobites from western Utah and eastern Nevada: Utah Geological and Mineralogical Survey Bulletin 48, 249p. Established 15 faunal zones in Ordovician Pogonip Group; named 50 new trilobite species belonging to 42 genera; named 5 new genera.

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. Redescribed and redefined in greater detail some of the stratigraphic sec-

tions and formations originally treated in Hintze 1951.

Hintze, L. F., 1974a, Preliminary geologic map of The Barn Quadrangle, Millard County, Utah: U.S. Geological Survey Miscellaneous Field Studies, MF 633, scale 1: 48,000. Differentiated 38 map units of Cambrian through Devonian, Tertiary, and Quaternary ages. Accompanying stratigraphic column listed thick-

ness, lithologies, and common fossils.

Hintze, L. F., 1974b, Preliminary geologic map of the Notch Peak Quadrangle,
House Range, Millard County, Utah: U.S. Geological Survey Miscellaneous Field Studies, MF 636, scale 1: 48,000. Differentiated 40 map units of Cambrian through Devonian, Jurassic,

Tertiary, and Quaternary age. Accompanying stratigraphic column listed

thicknesses, lithologies, and common fossils. Hintze, L. F., Braithwaite, L. F., Clark, D. L., and Ethington, R. L., 1968, A fossiliferous Lower Ordovician reference section from western United States (abs.): International Geological Congress, 23rd, Prague 1968, Report, Sec. 9, p. 256.

Summary of results of Lower Ordovician Project to 1966. Hintze, L. F., Braithwaite, L. F., Clark, D. L., Ethington, R. L., and Flower, R. H., 1972, A fossiliferous Lower Ordovician reference section from western United States: International Paleontological Union Proceedings for 23rd International Geological Congress, Prague, 1968, p. 385-99, Warszawa, Instytut Geologiczny.

Exrended summary of results of Lower Ordovician Project to 1966.

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

Defined Aulacoparia, Aulacoparina, and Stenorhachis.

Hook, S. C., and Flower, R. H., 1976, Tajaroceras and the origin of the Troedssonellidae: Journal of Paleontology, v. 50, p. 293-300. Described Tajaroceras, n. gen. of orthoconic nautiloid from the Wah Wah Limestone, correlating it with the Florida Mountains Formation of Texas.

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.

Recognized 25 brachiopod species in western Utah and assigned them to 9 zones listed in descending order: Kirkina, Desmorthis, Anomalorthis, Orthidiella, Hesperonomiella, Hesperonomia, Nanorthis, Synthrophina, and Apheoorthis. Described three new species, Desmorthis ibexensis, Anomalorthis juabensis, and Finkelnburgia fillmorensis.

Lane, N. G., 1970, Lower and Middle Ordovician crinoids from west-central Utah: Brigham Young University Geology Studies, v. 17, pt. 1, p. 3-17. Described 10 specimens assigned to 5 genera; named 2 new genera and

species: *Ibexocrinus lepton* and *Atopocrinus priscus*.

Miller, J. F., 1969, Conodont fauna of the Notch Peak Limestone (Cambro-Ordovician), House Range, Utah: Journal of Paleontology, v. 43, p.

Primarily concerned with Upper Cambrian conondonts but included conodonts from the Missisquoia and lower Symphysurina trilobite zones.

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: Glyptocystitada): Brigham Young University

Geology Studies v. 19, pt. 1, p. 15-63.

Described the first Ordovician cystoid reported from western United States and identified it as the oldest pectinirhomb-bearing cystoid known.

Established 2 new cystoid genera. Discussed cystoid group relationships.

Pojeta, John, Jr., 1971, Review of Ordovician pelecypods: U.S. Geological Survey Professional Paper 695, 46p. 20 pls.
Figured Modiolopsis cf. M. pogonipensis Walcott from Lehman Formation

of Ibex area.

Rigby, J. K., 1958, Lower Ordovician graptolite faunas of western Utah: Journal of Paleontology, v. 32, p. 907-17.
Figured Dictyonema, Tetragraptus Phyllograptus, and Didymograptus from

western Utah. Established correlation of graptolites with Hintze trilobite

Rigby, J. K., 1962, Canadian and Chazyan receptaculitids from Utah and Nevada (abs.): Geological Society of America Special Paper 68, p. 51-52. Noted occurrence of elongate conico-cylindrical types in lower Pogonip Group and platter-shaped types in higher Pogonip.

Rigby, J. K., 1965, Evolution of Lower and Middle Ordovician sponge reefs in western Utah (abs.): Geological Society of America Special Paper 87, p.

Noted 4 lithistid sponge reef horizons in the lower Fillmore Foundation, Calathium reefs in the upper Fillmore. Lithistid bioherms noted at 4 horizons in the Wah Wah Limestone, and sponge bioherms noted in upper Juab Limestone.

Rigby, J. K., 1971, Sponges and reefs and related facies through time: North American Paleontological Convention, Chicago 1969, pt. J., p. 1374-88, 9

Summarized occurrence of sponge genera in western Utah Ordovician strata and correlated them with occurrences at other North American lo-

Rigby, J. K., and Hintze, L. F., 1977, Early Middle Ordovician corals from western Utah: Utah Geology, v. 4, no. 2, p. 105-11.
 Described *Lichenaria* and *Eofletcheria* species, noting the transitional char-

acteristics of the Eofletcheria species.
Roberts, H. H., 1968, Survey of reef-like structures in the Pogonip Group (Ordovician) of southwestern Utah (abs.): Geological Society of America Special Paper 115, p. 442.

Summarized progressive upward change from algal head to sponge-algal

associations.

Ross, R. J., Jr., 1951, Stratigraphy of the Garden City Formation in northeastern Utah, and its trilobite faunas: Peabody Museum of Natural History, Yale University, Bulletin 6, 161p. Established letter trilobite zones and described their component faunas.

Sweet, W. C., Ethington, R. L., and Barnes, C. R., 1971, North American Middle and Upper Ordovician conodont faunas: In Sweet, W. C., and Bergström, S. M., Symposium on conodont biostratigraphy: Geological Society of America Memoir 127, p. 163-93.

Faunas 1-5 reported in this paper were based on the conodonts of the Wah Wah through Crystal Peak.

Taylor, M. E., 1971, Biostratigraphy of the Upper Cambrian (Upper Franconian-Trempealeauan stages) in the central Great Basin, Nevada and Utah: Ph.D. dissertation, University of California-Berkeley, 427p., 19 pls. Documented upper Cambrian and lowermost Ordovician (Missisquoia) trilobites in North Peak Formation of western Utah.

Terrell, 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.

Traced 14 genera through sparsely fossiliferous lower 122m (400 feet) of Fillmore Formation through zones D and E, here subdivided into E-1 and

Yochelson, E. L., and Jones, C. R., 1968, Teiichispira, a new Early Ordovician gastropod genus: U.S. Geological Survey Professional Paper 613-B, 15p. Listed occurrence of this genus in Wah Wah Limestone of western Utah.

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. A 13-cm (5-inch) limestone bed in Zone H in Fillmore Formation yield-

ed 21 trilobite species assigned to 18 genera. Named 9 species and 1 new

species. Listed 30 contemporaneous conodont species.

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